2 Discovering Science Through Inquiry

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Main Ideas

Chapter 2 discusses the role of inquiry in creating scientifically literate students. A scientifically literate person, as defined by the NSES, understands scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. By using inquiry as a paradigm for teaching science, students will also see that science is not simply a body of facts. Instead, science is a lens through which to see the world. We also discuss the changing priorities in science education, including more discussion, interaction, collaboration, continual assessment, and of course a focus on inquiry. We also present the constructivist theory and its implications for teaching. Constructivism is the belief that knowledge is not passed on from the teacher to the student. Rather, it is constructed by an individual as he or she creates his or her own world view. As you can see, the Constructivist theory aligns well with the inquiry approach. The final section discusses the 6-E model of Engage, Explore, Explain, Elaborate, Evaluate, and E-learning, and how it can be used as a model to prepare for inquiry in your classroom.

Teaching Suggestions

1. We like to begin this chapter by bringing our own children and their friends into the classroom to do an activity which is observed by the methods students. Then, we discuss how children learn and what approaches to teaching and learning the college students may be familiar with.

2. The constructivist strategies for teaching of the text are good for comparing what has been observed in elementary science classroom to what the proponents of constructivism would like to see happen in the classroom. We often list what strategies students see in their practicum on the board and, then, challenge them to see which of these could be substituted with the strategies provided in the Constructivist Learning Model (CLM).

3. In order to promote a better view of the scientist and science in general, we often refer to the elementary students we teach as "scientists." Challenge the college students to present an argument as to if this practice conflicts with the constructivist approach.

4. Using the constructivist strategies as a basis for a lesson planning, invite students to rewrite a recent lesson plan using these strategies. Compare the old plans with the new ones.

Additional MyEducationLab Video Assignments

1. To find out more about the components of the 5E model that was used as the basis for the 6E model in this text go to the Video Examples section of the MyEducationLab for your course and select the video "Four Days of Science." Can you identify components of the 5E model for inquiry?

2. To find out more about active learning go to the Video Examples section of the MyEducationLab for your course and select the video "Active Learning." Would you agree that the activity is representative of active learning consistent with a constructivist approach to teaching?

3. To find out more about the zone of proximal development go to the Video Examples section of the MyEducationLab for your course and select the video "Zone of Proximal Development." Use examples in the video to describe the Zone of Proximal Development in your own words.

4. To find out more about cognitive development go to the Video Examples section of the MyEducationLab for your course and select the video "Cognitive Apprenticeship." Can you identify how Mr. McKnight may be assisting in the children's cognitive development?

5. To find out more about scaffolding go to the Video Examples section of the MyEducationLab for your course and select the video "Scaffolding." Provide a specific example of scaffolding from the video.

6. To find out more about questioning go to the Video Examples section of the MyEducationLab for your course and select the video "Questioning." What is the function of Mr. McKnight's questioning?

Additional Web/Classroom Discussions

1. Look back at Kim Bunton's fifth grade lesson in Chapter 1 and compare how Kim taught her lesson to how Pita taught the lesson she describes in her Focus on Inquiry.
   - Can you pick out where Pita is *engaging* the children and making the connection between their prior knowledge and the skills and concepts she will be introducing in the new lesson?
   - What science knowledge skills will Pita's children be *exploring* in the activity to help identify misconceptions and refine their own understandings?
   - What science process skills, such as observation and communication, will Pita's children develop as they explore?
   - What evidence shows how Pita transitions from the exploration activity to focusing the children's attention on *explaining* the concept?
   - What is done after the clarification of the concept to further *elaborate* on ideas, extend the children's conceptual understanding and skills, and generate new questions?

   In what way does Pita formally or informally *evaluate* the children's' understanding?

2. Read this Rio Puerco Management Committee Watershed Education passage.

This spring, Pita McDonald's fourth graders at Cuba Elementary continued to learn about the Rio Puerco watershed through weekly explorations of the school grounds. After studying the water cycle, erosion, piñon jays, and bird migration the previous semester, the students shifted their attention to discovering geology, soils, and different trees with Rio Puerco Watershed Initiative Coordinator Kavita Krishna.

It may be hard to believe that anyone could get excited about rocks and mud, but these bright students were eager to get their hands dirty. They quickly understood that the Earth's crust is made up many different kinds of rock, and that each type of rock has unique qualities. In the classroom, they compared two basketball-sized samples of pumice and obsidian (or "natural glass"), both of which form in volcanic eruptions. They had seen obsidian before and knew that it could be used to make razor-sharp arrowheads. While it was difficult to lift the obsidian, the students were delighted that they could easily lift the pumice over their heads. Weeks later, they still remembered that the pumice was so light because of the abundance of air holes.

Out on the Nature Trail and armed with workbooks, students sharpened their observation skills by taking a closer look at - and really touching - some other familiar rocks. They examined a large piece of petrified wood and learned that it had been formed when a tree was buried very quickly and turned into a fossil. Students also noticed how much sand surrounded an outcrop of sandstone, one of the most common rock types in the Rio Puerco watershed. After feeling how easy it was to crumble some of the sandstone, they recognized that the sand was being worn off of the rock bit by bit. Later, the class learned that rocks, like water, go through a cycle, but over a much longer period of time. Sandstone forms when a layer of sand is compacted and cemented over time. As wind and water beat away at the sandstone, it slowly breaks down into small pieces of sand again, and the cycle starts over.

These sediments, or broken down pieces of rock and mineral, can also become part of soil. With trowels and water in hand, Mrs. McDonald's class explored soil in front of the elementary school. Soil, they learned, is made up of minerals, water, air, and organic matter (both living and dead). They dug around in the dirt and observed it with their eyes, hands, noses (and sometimes mouths), and poured water over it to see what happened. Some areas became sticky when wet, which meant they had a lot of clay in them. The students also discovered that most soil in the watershed does not have much organic matter in it, which makes it harder for many plants to grow. The class made lists of things they found in the soil that were living, non-living, and once-living. Then they created their own soil snack by "weathering" graham crackers down to "sand," adding chocolate pudding mix to be the silt and clay, crumbling Oreo cookies for organic matter, and adding gummy worms for the creepy crawlers.

Returning to the Nature Trail, the fourth graders learned about three different types of trees by filling in the blanks in stories told by the tree's point of view. To find the answers, they studied the trees' needles, bark, berries and cones. They revisited the piñon pine, New Mexico's State Tree, and recognized the nice scent of the juniper tree. They also got up close to the ponderosa pine's orange bark and found that it smells like vanilla, not oranges.

Mrs. Montoya's fourth grade class joined Mrs. McDonald's class for their final outing in May - a service-learning field trip to the Rio Puerco restoration project on Hwy 550 north of La Ventana. Here they met the project coordinator, Michael Coleman from the New Mexico

Environment Department, and learned that years ago the river had been straightened to one side of the highway, which had caused erosion to happen much more quickly. Now that highway bridges had been built over the old stream channel, the straightened part had been blocked off and the river moved back into its natural, gentler channel. The classes worked hard at digging holes at the edge of the river bed and transplanted hundreds of willow poles to help protect the bare banks from fast water once the river started flowing. With big smiles on their faces, they also discovered that some of the best places to plant the willows - where the ground was moist - were also the best places to get caked in mud. In the afternoon, the students carried milk jugs of water down the river to water some older transplants. With a hard day's work under their belts and the hot afternoon sun beating down, the fourth graders continued downstream to rest in the shade of a huge, old cottonwood tree on the bank of the Rio Puerco.

A few words from these fourth graders, soon to be fifth graders, illustrate how much they learned while exploring the outdoors:

Kym: "I loved going and replanting willows.... I like the walks in the back of our school. We see a lot of other stuff like rock, soil, and plants.... We also learned about erosion and planting."

Danielle: "While I was working with Kavita I learned that erosion can be dangerous because it could overflow and you're in it and you might drown.... I liked the nature walks because we looked at rocks. We also looked at soil and we smelled it. We tasted it."

Elias D: "With Kavita I learned that rocks have a cycle like all other things. Kavita and Mrs. Mc took us on a field trip to the Rio Puerco to plant willows to slow down the erosion. We learned about making mud pie. We went in the back of the school and wrote and drew about rocks."

Tate: "We planted some plants at the Rio Puerco. It was fun.... We did that because we can stop the erosion in the Rio Puerco river."

Jacob: "We got to go on a field trip to the Rio Puerco. The willows had to get chopped down. The willows had to get replanted in a different place. Then after the planting, we...took a long hike up the road to where we were giving the water.... I liked working at the Rio Puerco."

Alycia: "When I was working with Kavita, I learned about the types of rocks there are in the world. We also learned a lot about soil, erosion, and plants.... The plants we looked at were trees. One of the trees we saw was piñon pine."

Jason: "We learned about what the people that were working on the Rio Puerco were doing. We wrote about the rocks and what particles are in the rocks. We looked at the different trees and wrote about the three different trees like piñon tree, pine needles, and a berry tree."

Joaquin: "We went on a field trip to the Rio Puerco and planted willows. It was funny. We got muddy and my shoes were muddy. The river was high. It was so wet. We looked at big, big trees. She told us what kind of trees they were."

Ashleigh: "Ms. Kavita showed us what type of rocks there [are] and told us where they were from.... So this year I learned a lot from Ms. Kavita. I know all of the trees from her.... And I know all about the plants and rocks and water cycle."

Myra: "Ms. Kavita showed us about how the plants grow and ... [where] they come from."

Shannon: "I learned about soil, erosion, plants, and [m]any types of rocks with Kavita.... We went on a hike through the erosion.... erosion is when the water takes the soil away to another place. I know that plants can grow in soft brown soil.... It was fun working with Miss Kavita."

Amber: "I learned that erosion can take soil away from a river, a lake, or a ditch. An erosion is water that takes soil away from its place. When a storm comes, the rain falls into the dry river, the water is a lot, strong, and heavy and fast, so it could take the dirt or soil away."

How does this passage support the notion of inquiry as a paradigm for teaching and learning in science?

3. Occasionally advances in technology or new research cause a paradigm shift and an accompanying “revolution” in the scientific community. Old ideas are discarded as a new theory emerges and becomes the dominant paradigm. An example is the presentation of the plate tectonics theory in 1956. The plate tectonics theory changed how scientists viewed the movement of continents and seafloor spreading. What is an example of another paradigm shift in science? How did it change scientists’ thoughts or actions?

4. One alternative term for the “scientific method” is *scientific process*. As one scientist explains “By scientific process I do not mean the famous four steps in the scientific method that are drilled into the heads of children from grade 3.” He goes on to describe the scientific process as follows “Instead I mean the real scientific skills of investigation, critical thinking, imagination, intuition, playfulness, and thinking on your feet and with your hands that are essential to success in scientific research.” (Bower, 2005) How does his description of the scientific process change your own mental view of a scientist? [Bower, James M. (2005). Scientists and science education reform: myths, methods, and madness. Washington, DC: National Academy of Science. Retrieved August 18, 2008, from http://www.nationalacademies.org/rise/backg2a.htm]

5. There can be many meanings for “inquiry.” One distinction is the difference between inquiry as a “means” and inquiry as an “end” as follows: “Inquiry as means” (or inquiry *in* science) refers to inquiry as an instructional approach intended to help students develop understandings of science content (i.e., content serves as an end or instructional outcome). “Inquiry as ends” (or inquiry *about* science) refers to inquiry as an instructional outcome: Students learn to do inquiry in the context of science content and develop epistemological understandings about [nature of science] and the development of scientific knowledge, as well as relevant inquiry skills (e.g., identifying problems, generating research questions, designing and conducting investigations, and formulating, communicating, and defending hypotheses, models, and explanations). (Abd-El-Khalick et. al., 2004, p. 398). Can you provide an example for inquiry as a “means” and inquiry as an “end?” [Abd-El-Khalick, Fouad, Boujaoude, Saouma, Duschl, Richard, Lederman, Norman G., Mamlok-Naaman, Rachel, Hofstein, Avi, Niaz, Mansoor, Treagust, David, & Tuan, Hsiao-Lin (2004). Inquiry in science education: international perspectives. *Science Education, 88* (3), 397-419. Retrieved August 18, 2008, from http://www3.interscience.wiley.com/cgi-bin/fulltext/108061364/PDFSTART]

6. Google "*Teaching science through inquiry*. ERIC/CSMEE Digest" (Haury, 1993/2003). The author makes the point that a constructivist, or active learning, approach to teaching science helps students understand and make meaning out of the natural world. What are some of the benefits of teaching through inquiry that he cites in the digest?

7. Google the book *How People Learn* (NRC, 2000b) from the National Academies Press. The authors summarize three important ideas about learning and teacher support as follows:
   - Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom. *Teachers must draw out and work with the preexisting understandings that their students bring with them*
   - To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application. *Teachers must teach some subject matter in depth, providing many examples in which the same concept is at work and providing a firm foundation of factual knowledge*.
   - A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them. *The teaching of metacognitive skills should be integrated into the curriculum in a variety of subject areas*.(p. 14-21)

   Summarize one of these ideas in your own words and provide a specific example related to Pita Martinez-McDonald's Focus on Inquiry.
   [http://books.nap.edu/openbook.php?record_id=9853&page=1]

8. Spontaneous concepts are the concepts acquired informally from everyday life experiences. Scientific concepts are those concepts represented by a systematically organized body of knowledge and are usually learned through formal instruction. In other words, a concept such as "loss of water" begins as a spontaneous concept in an informal social setting as children talk about things such as "why the water level is going down when no one is using it" or "why the water goes down more some days than others." Later, through time and repeated use, this spontaneous concept, and related spontaneous concepts, will become better organized into the student's cognitive structure. A more systematic "scientific concept" of "evaporation" forms and the child can better understand and apply this concept to make sense of his or her world (e.g., I need to add water to the fish tank periodically not because the fish are drinking it but because of evaporation). List other examples of related spontaneous concepts that could form into a scientific concept.

9. Vygotsky suggested that an individual is guided by their own mental processes as they participate in social activities. His theory was that mental functions first begin on a social plane (i.e. *cultural mediation*) and then move to an inner plane (i.e. *internalization*). In other words, internalization involves transforming social phenomena into psychological phenomena or, put another way, making meaning through both external and internal interactions (Vygotsky, 1981). Can you think of an example in elementary science where a

child would first learn a concept through social interaction and then internalize this concept? [Vygotsky, Lev S. (1981). The genesis of higher mental functions. In J. V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp. 144–188). Armonk, NY: Sharpe.]

10. Vygotsky's theory illustrates how a child can move from the ability to complete a task in a group to later being independently successful with that same task. For example a child able to complete a classification of leaves based on common properties with the assistance of a more knowledgeable classmate could later complete this classification task independently. Provide an example that you have seen when working with children.

11. The Partnership for 21st Century Skills identifies the following attributes of a 21st Century learning environment:
    - Creates learning practices, human support and physical environments that will support the teaching and learning of 21st century skill outcomes
    - Supports professional learning communities that enable educators to collaborate, share best practices and integrate 21st century skills into classroom practice
    - Enables students to learn in relevant, real world 21st century contexts (e.g., through project-based or other applied work)
    - Allows equitable access to quality learning tools, technologies and resources
    - Provides 21st century architectural and interior designs for group, team and individual learning.
    - Supports expanded community and international involvement in learning, both face-to-face and online

    Describe how these attributes support Vygotsky's theory. (See the "Overview-Skills Framework" item at the http://www.21stcenturyskills.org/ link or Google "Framework for 21st Century Learning" from the Partnership For 21st Century Skills).

12. Read following vignette and comment on how the children are engaged in collaborative learning.

Children's Learning, Dr. Ken Tobin, Presidential Professor, The Graduate Center of City University of New York

"Hold it! Hold it! Oh, no! Ana, you've got to hold it while I connect the roof on." Michael is agitated with Ana. They have been working on building a castle for 3 days now, and still the walls will not stay up. They planned a good castle, and the drawings looked very good, but the materials Ms. Roberts had given them to build with were not working.

Ana is feeling grumpy about this whole activity. It is not her fault that the walls will not stay up. Every time she holds them up, the pins come loose. Why can't they use glue anyway? "Castles are not made out of pins and straws!" she asserts.

Ms. Roberts is pleased with the activities. The students are busy, and they are doing science. Furthermore, the activities in which they are engaged involve manipulatives and an opportunity to exchange ideas orally. Further, they integrate drawing, writing, social studies, and literature. The idea of building castles arose from their studies of Germany. Importantly, they allow the students to engage in problem solving. Ms. Roberts perceives her role to be that of a facilitator: closely observing her students, learning from listening to them, and helping them meet their goal of building a castle.

Teachers like Ms. Roberts have long accepted that a hands-on approach is an appropriate way to teach science. The term hands-on/minds-on is a popular way to describe school science. Ms. Roberts's Grade 3 science lesson is typical of what can be observed in many elementary classrooms. The activity is consistent with a hands-on/minds-on metaphor and the teacher's role as facilitator. However, even though Ms. Roberts' students are involved in an extensive hands-on activity that promotes communication and problem solving, the development of scientific ideas is absent. Scientific knowledge does not reside in the materials the students use. Rather, scientific knowledge needs to be co-constructed in interactions in which students and teacher interact verbally by using a shared language during the activity.

For example, the realization that a structure can be made rigid through the use of triangular braces is a reasonable goal for the activity described. But in this case, it is unlikely that the students will construct that understanding. And even if they do include triangular braces in their structures, it is unlikely that they will associate that inclusion with increased rigidity of the structure. Manipulations of materials are a context for rich conversations in which those who know science can facilitate the learning of those who do not know. It is essential to student understanding that the teacher mediate the language of the child and the language of science. This does not imply a return to the days when teachers transmitted facts in lectures or when the principal learning resource was a textbook. But it does require students to talk science—in ways that connect their experiences in other subject areas and the relevant contexts to their lives outside school.

13. It is argued that society emphases "scientific" ways of knowing while ignoring other ways such as "intuition" and "embodied knowledge." What is meant by "scientific ways of knowing?"

14. As an extension to the activities on air, the teacher is sitting on a lunch table that has been flipped upside down and placed on top of a similar table. There are small garbage bags with the open end sticking out sandwiched between the two tables along the entire perimeter of the tables. The teacher provides the challenge to the children to lift her up just using air. Describe how this activity would help demonstrate that air does have volume and takes up space. (You can also Google "PBS Kids Airlift" for similar activities).

Questions for Chapter 2: Discovering Science Through Inquiry

Correct answer: c

1. Which of these is NOT a current emphasis in the teaching of science?

    a. Providing opportunities for scientific discussion and debate among students

    b. Continuously assessing student learning

    c. Supporting competition among students

    d. Understanding and responding to students' individual interests, strengths, experiences, and needs

Correct answer: b

2. A paradigm is:

    a. A systematic arrangement or sequence

    b. A current viewpoint that is widely accepted by the scientific community

    c. The manner in which a lesson is presented by an instructor

    d. The framework in which science lessons are created

Correct answer: d

3. What is the first step of developing inquiry in the classroom?

    a. Taking a survey of student interests

    b. Encouraging the students to discuss their ideas

    c. Having the students make observations

    d. Asking students open-ended questions

Correct answer: a

4. Which of the following is an example of a paradigm shift in science?

    a. The transition from a Ptolemaic solar system to a Copernican one

    b. The transition from a trial and error approach to following the scientific method

    c. The transition from the transitional methods of teaching to a more inductive approach

    d. The transition from teachers asking questions to students asking questions

Correct answer: b

5. What is an alternative term used for the scientific method that is considered to be more appealing?

    a. The scientific pattern

    b. The scientific process

    c. The thinking circle

    d. The thinking pattern

Correct answer: d

6. Which of the following is an example of scientific literacy?

    a. The ability to predict natural phenomena

    b. Being able to understand articles in popular press relating to the field of science

    c. The ability to express one's positions on scientific issues

    d. All of the above

Correct answer: a

7. What is the current paradigm for teaching and learning in science education?

    a. Constructivist theory

    b. Behaviorist theory

    c. Stimulus-response theory

    d. Subsumption theory

Correct answer: b

8. According to the Constructivist theory, it is believed that learning takes place in the context of:

    a. What topics the student is most interested in

    b. What knowledge the student already has

    c. What strengths the student possesses

    d. How the student learns best, whether it is visually, auditory, or kinesthetically

Correct answer: c

9. Why must teachers address students’ preexisting understandings?

    a. So that they can go home and tell their parents that they taught them wrong

    b. Because students may have misconceptions that are never addressed, causing them to learn the new material better and replace their old ideas

    c. Because students may have misconceptions that are never addressed, causing them to fail to grasp the new material because it does not fit with their preexisting notions

    d. So that the teacher can help the students see things from his or her point of view.

Correct answer: d

10. To fully understand an area of inquiry, a student must:

    a. Have factual knowledge

    b. Understand facts and ideas in a conceptual framework

    c. Organize knowledge in ways that facilitate retrieval and application

    d. All of the above

Correct answer: a

11. What is the name of the approach to learning that allows students to take control over their own learning and should be integrated in a variety of subject areas?

    a. Metacognitive

    b. Behaviorist

    c. Laissez-Faire

    d. Goal-setting

Correct answer: d

12. Which factors should be taken into account when designing science activities?

    a. Student interests

    b. Students' developmental level

    c. Resources available

    d. All of the above

Correct answer: d

13. Which of the following opportunities can be used to teach a science lesson?

    a. Everyday relevant topics, such as the class pet

    b. A field trip to an art museum

    c. A child's question about why you can see the moon when it's not night time yet

    d. All of the above

Correct answer: a

14. The inquiry approach results in:

    a. Active learning

    b. Subjunctive learning

    c. Procedural learning

    d. All of the above

Correct answer: c

15. Vygotsky based his theory of learning on:

    a. The developmental stages of children
    b. The pedagogical content knowledge of the teacher
    c. The role of culture and society
    d. The prior experiences of the teacher

Correct answer: c

16. What is the main difference between Piaget and Vygotsky's theories?

    a. The ages at which children are capable of abstract thinking
    b. The importance of disequilibrium in the learning process
    c. If learning leads to development or if development precedes learning
    d. The importance of metacognition

Correct answer: b

17. Vygotsky believed that psychological tools were important. Which of the following is an example of an internal psychological tool?

    a. Keeping notes in a notebook
    b. Creating a mnemonic rhyme to help us remember something
    c. Algebraic symbol systems
    d. Maps and diagrams

Correct answer: c

18. Anne is a fourth grade science teacher. She is wondering if she should incorporate group work in her science lessons. After reading a book on Vygotsky's theories, she realizes that:

    a. Group work often results in students getting off-task and not focusing on the lesson

    b. She should not use group work because most of the time, it results in one student doing all of the work

    c. Students are likely to perform at higher levels when placed in groups, as long as they are well monitored by an adult

    d. Group work is always a great idea because it allows students to share ideas and form their own conclusions, based on others' input

Correct answer: b

19. With group or teacher assistance, a child's instruction should always be __________ what is possible for the child on their own.

    a. Very ahead of

    b. Slightly ahead of

    c. Slightly below

    d. Very below

Correct answer: d

20. The teacher should provide an environment where learning in the zone of proximal development is maximized. In this way, the teacher acts as a _________ and provides just the right amount of support to accomplish the developmental goal.

    a. Antennae

    b. Comforter

    c. Brace

    d. Scaffold

3 Planning for Inquiry

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Main Ideas

Chapter 3 goes into further detail about how to actually plan in inquiry lesson. We recommend using the Wiggins and McTighe backward design model, which calls for teachers to first consider the desired results of the lesson. Next, the teacher determines what evidence will be acceptable. Lastly, the teacher plans the actual learning experiences and instruction. Working backwards allows teachers to plan activities with a learning goal in mind and then develop a plan in order to meet that goal. This of course works in synergy with the 6E model. We also discuss the fact that classroom inquiry is characterized by learners engaging in scientifically oriented questions. The amount of learner self-direction is in ratio to the level of teacher control.

Teaching Suggestions

1. Teachers must constantly self-assess their teaching practices. One way for student teachers to do this is to have them do a microteaching activity. During this microteaching, students (either in pairs or individually) will teach a lesson to their peers. The lesson should be inquiry-based, with the teacher asking probing questions throughout, rather than lecturing. By recording the microteachings and allowing students to watch themselves, they can identify their strengths and areas that they want to work on. Students should take note of how long they wait for a response after asking a question and if they are dominating discussions or doing an appropriate amount of questioning and facilitating.

2. Students should begin to familiarize themselves with the state standards as well as those for the NSES. Students should be writing their own lessons and identifying the national standards as well as the ones for your state.

3. As mentioned in the chapter, children's literature can be used to introduce or extend a science topic. As a college instructor, you may choose to incorporate several trade books and model how they could be used in an elementary lesson.

Additional MyEducationLab Video Assignments

1. To find out more about planning go to the Video Examples section of the MyEducationLab for your course and select the video "Planning." What are some indicators of good planning by Mr. McKnight?

2. To find out more about observing students and their own learning to think go to the Video Examples section of the MyEducationLab for your course and select the video "Learning to Think." What do you discern about Mr. McKnight's observations of his students?

3. To find out more about finding and organizing materials go to the Video Examples section of the MyEducationLab for your course and select the video "Finding and Organizing Materials." In this video we see Mr. McKnight organizing the class for the inquiry lesson. What is the relationship between planning and successfully organizing the class?

4. To find out more about desired results of the backwards planning method as well as the social learning of students go to the Video Examples section of the MyEducationLab for your course and select the video "Social Learning." What might the desired results be for the lesson shown in the video? How could social learning help achieve the desired results?

5. To find out more about big picture understandings and the idea of concept invention go to the Video Examples section of the MyEducationLab for your course and select the video "Concept Invention." What big picture understandings is Mr. McKnight trying to develop with his class? What potential concepts will they develop based on the activity?

Additional Web/Classroom Discussions

1. In their *Understanding by Design* text, Wiggins & McTighe provide six facets of understanding (2005, pp. 85-103). These include:
   - Facet 1: Explanation (For example providing complete and justifiable accounts, theories, models, or illustrations of various events, phenomena, facts, ideas, and data.)
   - Facet 2: Interpretation (For example relaying stories, historical accounts, translations, or other personally developed analogies or anecdotes that provide meaning.)
   - Facet 3: Application (For example adapting and using knowledge effectively in a variety of new and diverse contexts.)
   - Facet 4: Perspective (For example understanding situations and people through the ability to gain insight by critically seeing and hearing other points of view.)
   - Facet 5: Empathy (For example finding value in other's thoughts, feelings, and situations whether consistent to, or in opposition of, your own.)
   - Facet 6: Self-Knowledge (For example understanding your own strengths and weaknesses, ways of handling situations, prejudices, and ways of thinking about and interpreting the world.)

Understanding can have many meanings beyond knowing the facts. In his lesson, Matt wants students to understand how to "infer based on observation." In light of the six facets of understanding, what other understandings may result from Matt's lesson as presented in his vignette?

2. Review the No Child Left Behind information for your district. Do you feel that NCLB is making a difference in your district? Why or why not?

3. Discuss your own view on the use of the backwards design in planning a 6E inquiry lesson. Defend your support or opposition of backwards design with specific examples.

4. Referring to the Chapter Three *Focus on Inquiry*, in what other ways could Matt develop evidence that the students understood observations, inferences, and predictions?

5. Google the "American Association for the Advancement of Science *Benchmarks for Science Literacy*" ([AAAS], 1993). Read the *Scientific Inquiry* section of Chapter 1. Are the suggestions for scientific inquiry consistent with planning through backwards design and 6E models? Support your answer with two or three examples.

6. Go to the National Science Teachers Association (http://www.nsta.org/) website and search for the "Position Statement on Scientific Inquiry" (NSTA, 2004). How closely would your own science teaching align with use of scientific inquiry as suggested by the authors? What would you have to change in your approach to science teaching to be more consistent with the Position Statement on Scientific Inquiry?

7. Google the "National Academies Press" and search for the book "*Taking Science to School: Learning and Teaching Science in Grades K-8"* (NRC, 2007b) On pages 253-254, the authors state that "Of course, what children learn is not solely dictated by curriculum and standards "content," but also by ways in which their encounters with curriculum are structured—the things students typically do in science classrooms." Explain in your own words what this means.

8. Teachers that use the backward design model for planning science inquiry activities often find that there is way too much material in the designated curriculum guide or adopted textbook. Is that a problem or not? How would you address this situation in your own planning of significant learning experiences for your students?

9. Mr. Mayernik has his class participating in an activity to make a comeback can. Review the activity below and describe the student's engagement in terms of learner self-direction.

   A thin stripe of yellow tape in the school hallway marks the starting line for the test track. In a few minutes, colorful cans of many sizes will clink, clank, and thump their way down the long, narrow test course, with students whispering encouragement to their carefully constructed devices as the cans slow down, wiggle, and begins the trip back to the starting line. At no time is science terminology, textbook pages, or vocabulary words referred to as the children test, refine, and retest their "comeback cans."

   In my science class, the school year begins with a demonstration of "Herbie, the Wonder Can," a 3-pound coffee can that is rigged with a rubber band and a large fishing sinker inside. When Herbie is carefully rolled across the classroom, it magically slows, stops, and returns to its starting point. After students are shown how to construct a similar device, they are challenged to build their own comeback cans and test them against the best efforts of Herbie. The next day, cans of all sizes and construction litter the windowsill, ready to challenge Herbie in a test of endurance.

   Which can will roll the longest distance and return to the yellow stripe? After several cans traverse the track, students begin to realize that variations exist in their methods of construction. Some cans have thicker rubber bands, some thinner. Some devices are larger, some fatter, some longer. The masses inside are small, huge, and everywhere in between. Which of these variables are critical to can performance? What are the optimal can size, rubber band width, and mass? Students are encouraged to study the construction of the leading cans and to modify or refine their cans, as they like. Finally, after weeks of testing and retesting, trial and error, and elation and frustration, the top cans compete in the Comeback Can Derby. The five winning can-builders are awarded small trophies in honor of their efforts.

   This activity promotes divergent thinking. Although the comeback cans have a common construction, the task encourages a wide variety of responses. The winning cans have never been constructed in quite the same way. This activity allows students to explore, analyze, and adapt. It encourages children to attempt a novel approach (like a "Bigfoot" can, with Plexiglas "wheels" twice the diameter of other competitors'). The experience provides the "mental hooks" upon which learners will hang physics concepts in high school.

10. In the *Inquiry by Design* at the beginning of the chapter, Matt engages his students in the exploration by challenging them to "use the bubble solution and hula hoop produce a bubble that would be able to surround you." After ample time for exploration, the class begins explanation. Look at the examples of questions below and explain which would be appropriate to ask during the explanation stage of the 6E model during Matt's lesson.
    - Why was it difficult to form a body bubble?
    - What color was the bubble?
    - How many students were successful in forming a body bubble?
    - How can we measure a bubble?
    - How many separate measurements may be needed for more reliable results?
    - What will the bubble look like after we add more glycerin to the water?
    - Why would we want to add an additional 25 ml of glycerin to the bubble solution?
    - Will the measurement change as a result of adding more glycerin?

Do you think we can create a bubble that is high enough to surround the tallest child in the school?

11. As teachers complete the desired results and assessment evidence stages of Wiggins & McTighe backward design model (2005) and begin to plan inquiry activities, they often find that their lecture-based teaching repertoire limits their ability to effectively plan inquiry lessons that provide enduring understandings. What are some other approaches to inquiry teaching that can supplement lectures and help the children better achieve the big idea understandings that have enduring value and can be transferred to new situations? [Wiggins, Grant P., & McTighe, Jay. (2005). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.]

12. Here's an example of a misconception scenario. Suppose you ask a child what would happen if an astronaut "dropped" something like a pen on the moon. The child may reply that it would float away. You may then ask why the astronaut does not "float away." Students may answer that the astronaut's heavy boots weigh him down and keep him from floating away. Of course, the moon does have gravity, and this is what keeps the astronaut from floating away. The pen actually does fall toward the moon as it would on the earth. Because the moon has less mass, however, the pen falls with less force than here on the earth. In synopsis, everything on the moon is attracted to it; otherwise, the rocks and dust would also float away. What is an example of another common misconception?

13. Closed-ended activities, sometimes referred to as direct instruction, tend to be tightly focused and generally involve a greater amount of teacher direction. Open-ended activities, sometimes referred to as open discovery or problem-centered learning, are usually longer, branch out into many related questions, and are student directed. Look at the following examples and discuss whether they are primarily an open or closed activity. Include your reasons as to why you classified them as open or closed.
    - Activity 1: In Mrs. Aziz's class, children work on the "Mouth Map" activity from the book *Gobble Up Science* (Johmann & Rieth, 1996). Using sugar, salt, instant coffee granules, and lemon juice, they find groups of taste buds in the mouth: The tip of the tongue senses sweet, the back senses bitter, and salty and sour taste buds are predominately on the sides.
    - Activity 2: In Mr. Clemo's class, some children are learning about acids and bases with the "Red-Cabbage Indicator" activity found in the book *Science Experiments You Can Eat* (Cobb, 1994). They find that cabbage juice solution is an indicator and changes color, depending on whether the substance is an acid or a base.
    - Activity 3: In Mrs. Gonzalez's class, some children learn about variables through the "Popcorn Comparison" activity in *Fun With Foods: A Recipe for Math & Science* (Alfving et al., 1987). They are finding that the moisture content of popcorn kernels has an effect on the volume of popped popcorn produced.
    - Activity 4: Mrs. Hawkins places a few food items, some balloons, and various other items such as beakers and jars out on a table and challenges her students to blow up a balloon by using the food. This activity is based on the "blowing up a balloon with a banana" activity found in Icky, Squishy Science (Markle, 1996). Later, the students will discover some properties of food, including the presence of bacteria.

- Activity 5: In Mr. Pettis' class, he allows his students to discover their own ways to cure meat, based on suggestions from the books *More Science Experiments You Can Eat* (Cobb, 1979) and *Silly Science* (Levine & Johnstone, 1995). The students complete this activity based on questions originating with the reading of Stone Soup (Brown, 1997), Eating the Plates (Penner, 1991), Corn Is Maize (Aliki, 1976), and other stories. Their study of the foods eaten by Pilgrims and American Indians generated possible discovery activities that could promote further inquiry.
- Activity 5: Mr. Mitchell plans his lesson to start with *reading What Do You Do When Something Wants to Eat You?* (Jenkins, 1997) The students read about how certain fish, reptiles, amphibians, and other animals escape danger. Mr. Mitchell asks why the animals need to defend themselves in the examples provided in the book. The students respond in a variety of ways, and Mr. Mitchell allows them to ask about examples of animal defenses not found in this story. Soon, students are posing questions about why animals would want to eat one another. Mr. Mitchell continues the lesson by reading *Who Eats What?* (Lauber, 1995) Various food chains are provided in the book. The students give other possible examples when prompted by Mr. Mitchell about what food chains may have been a part of their dinners last night.

14. The science curriculum in America is often negatively described as "*a mile wide and an inch deep*." What does this mean to you in terms of planning your yearlong teaching goals for science? The science curriculum in America is often negatively described as "*a mile wide and an inch deep*." What does this mean to you in terms of planning your yearlong teaching goals for science?

Lesson Plan on the Planets

- Overview of the Lesson
    - This lesson centers on the names of the nine planets and their relationship to the sun.
    - The students will be asked to name the planets in order, give an approximation of their size, and be able to understand the concept of a satellite of a planet.

<u>Backwards Design Stage 1: Identify Desired Results</u>

- Science Themes
    - Systems – The solar system is a common example of a system. It is a group of planets and their satellites. It also includes solid, liquid, and gaseous material in an interrelated organization.
    - Models - The idea of a model is established as students create models of the solar system.
    - Consistency – The planets rotate in consistent patterns in the solar system.
    - Patterns of Change – Patterns of change are modeled as stars are formed and the visibility of planets changes throughout the year.
    - Evolution – There is a lot of verified data on the evolution of the solar system. The launching of new spacecraft to study the solar system and beyond brings relevancy to this topic.
    - Scale – Scale is established as the various sizes of the planets are compared.
- Benchmarks for Science Literacy

    By the end of fifth grade, students should know that

  - Planets change their positions against the background of stars.
  - Earth is one of several planets that orbit the sun, and the moon orbits Earth (AAAS, 1993, p. 63).
- National Science Education Standards

  As a result of their activities in Grades K-4, all students should develop an understanding of
  - Objects in the sky.
  - Changes in Earth and the sky (NRC, 1996, p. 130).
- Scientific Skills
  - Classification – Classification activities are promoted as students develop classification systems for the planets (by composition, temperature, and size).
  - Observation – The students will observe the night sky and record data.
  - Measurement – The students will measure and re-create a scale model of the solar system.
  - Inference/Prediction – The students will infer why the temperature of Venus is high, based on that planet's characteristics.
- Curricular Integrations
  - Measurement activities integrate mathematics into this lesson.
  - Art is incorporated into this lesson as students draw planet and star models.
  - Social Studies is integrated into this lesson as students discuss ancient theories of an Earth-centered solar system.
  - Reading is integrated into this lesson as students read The Magic School Bus Lost in the Solar System (Cole, 1990).<u>Backwards Design Stage 2: Determine Acceptable Evidence</u>
- Student Assessment
  - Design a mnemonic sentence to remember the order of planets (e.g., My Very Excellent Mother Just Served Us Nine Pizzas).
  - Describe in your journal what life would be like on Jupiter. How would it compare to life on the moon?
  - Write to NASA for more information on space exploration and present it to the class.

<u>Backwards Design Stage 3: Plan Learning Experiences and Instruction</u>

- Engage
  - Read *The magic school bus lost in the solar system* book.
- Explore
  - Introduce the vocabulary: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto, moon, satellite, orbit, asteroid, rotation, and revolution (Use definitions from end of the chapter and have students repeat the words.)
  - Read the chapter on the planets from the students' text. Discuss origins of the solar system.
  - Demonstrate the relative distances between planets by creating a model with students acting as the sun, planets, and satellites (see specific measurements in the text).
    - Materials: Large sheets of paper; crayons, markers, or paints.
  - Demonstrate the rotation of Earth and the moon and their revolution around the sun by using students to represent the sun, Earth, and the moon (see picture in supplemental materials).

- Explain
  - Closed-Ended Questions
    - What is the center of the solar system? Describe its characteristics.
    - What is the first planet from the sun? Describe its characteristics, (Repeat for the rest of the planets.)
    - What is the difference between the moon and a satellite? (Note: The moon is Earth's satellite. We call other "moons" by their proper name, "satellite.")
    - Define an orbit.
  - Open-Ended Questions
    - Which planets are colder? What is a possible cause for their low temperature?
    - Give some possible reasons for Venus being so hot. (Discuss greenhouse effects.)
- Elaborate (select form the following as appropriate)
  - Develop three planet classifications.
  - Redraw the scale model of the planets from the text, measuring exactly from the book.
  - Draw a picture of the night sky.
  - Find pictures of the winter and summer night sky from other books and magazines.
  - Take students into the planetarium and demonstrate the position of the stars and planets by using the portable star projector.
    - Materials: Inflatable planetarium (two large sheets of black painter's plastic with both sides taped together lengthwise to form a large dome). A box fan is taped to one end and turned on to inflate the dome.
    - Portable star projector.
  - Complete activities from: Lind, M., Knecht, P., Dodge, B., Williams, A., & Wiebe, A. (1994). *Out of this world*. Fresno, CA: AIMS Education Foundation.
  - Read one of the following:
    - Branley, F. M. (1987). *The planets in our solar system*. New York: Thomas Crowell.
    - Cole, J. (1990). *The magic school bus lost in the solar system*. New York: Scholastic.
    - Lauber, P. (1982). *Journey to the planets*. New York: Crown Publishers Inc.
    - Lauber P. (1990). *Seeing the Earth from space*. New York: Orchard Books.
- Evaluate
  - See Backwards Design Stage 2.
  - Optional Assessment: If you started today and traveled 1000 miles per hour to Jupiter, determine how old you would be when you reached your destination (see adaptation of AIMS activity from *Out of this world* (Lind et al., 1994, Fresno, CA: AIMS Educational Foundation).
- E-learning (to be infused throughout the lesson)
  - Look up the lesson vocabulary on the NASA website and Wikipedia.
  - Research the planets on NASA Internet sites.
  - Using the Internet, research what causes eclipses of the sun or moon.
  - Most people incorrectly believe that the distance from the northern or southern hemisphere of the earth from the sun causes the seasons. Use the web to research the real cause of the seasons.

- Use the Internet to research and discuss why the International Astronomical Union, the official body for naming astronomical objects, reclassified Pluto as a "dwarf planet," leaving only eight "classical planets" in the solar system.