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GETTING STARTED: A SET OF DISCUSSION
AND TEACHING MATERIALS FOR TEACHERS
AND TEACHER EDUCATORS

Kathleen J. Roth

with
Literacy in Science
and Social Studies Colleagues

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The Center for the Learning and Teaching of Elementary Subjects was awarded to Michigan State University in 1987 after a nationwide competition. Funded by the Office of Educational Research and Improvement, U.S. Department of Education, the Elementary Subjects Center is a major project housed in the Institute for Research on Teaching (IRT). The program focuses on conceptual understanding, higher order thinking, and problem solving in elementary school teaching of mathematics, science, social studies, literature, and the arts. Center researchers are identifying exemplary curriculum, instruction, and evaluation practices in the teaching of these school subjects; studying these practices to build new hypotheses about how the effectiveness of elementary schools can be improved; testing these hypotheses through school-based research; and making specific recommendations for the improvement of school policies, instructional materials, assessment procedures, and teaching practices. Research questions include, What content should be taught when teaching these subjects for understanding and use of knowledge? How do teachers concentrate their teaching to use their limited resources best? and In what ways is good teaching subject matter-specific?

The work is designed to unfold in three phases, beginning with literature review and interview studies designed to elicit and synthesize the points of view of various stakeholders (representatives of the underlying academic disciplines, intellectual leaders and organizations concerned with curriculum and instruction in school subjects, classroom teachers, state- and district-level policymakers) concerning ideal curriculum, instruction, and evaluation practices in these five content areas at the elementary level. Phase II involves interview and observation methods designed to describe current practice, and in particular, best practice as observed in the classrooms of teachers believed to be outstanding. Phase II also involves analysis of curricula (both widely used curriculum series and distinctive curricula developed with special emphasis on conceptual understanding and higher order applications), as another approach to gathering information about current practices. In Phase III, models of ideal practice will be developed, based on what has been learned and synthesized from the first two phases, and will be tested through classroom intervention studies.

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Abstract

This set of discussion and teaching materials are designed for use by teachers, prospective teachers, and teacher educators. The materials are multifaceted in nature, but all center around the case of planning, teaching, and learning in a beginning-of-the-year science unit designed to introduce and weave together two curriculum strands—a nature of science strand that introduces ways of thinking, acting, and inquiring in a science discourse community and a conceptual strand focused on adaptations.

The materials are designed for three purposes:

• First, they can be used to stimulate discussion among science teachers and prospective teachers (at any grade level) about the relationship between conceptual knowledge development (typically referred to in science curriculum materials as “content”) and the nature of scientific inquiry and discourse (typically referred to in science curriculum materials as “processes of science”). They challenge participants to think beyond “the scientific method” and “processes” in representing the nature of scientific inquiry. A set of discussion and analysis activities guides the reader in using the materials for this purpose.

• Second, the materials can be used to support teachers and prospective teachers (at any grade level) in developing an approach to science planning that will support conceptually focused teaching that is integrated with rich representations of ways of knowing and acting in a science discourse community. Materials accompanying the case description describe key features of the unit planning process used in this case.

• Third, the materials can be used by teachers and prospective teachers as a source of lesson ideas and activity plans. The lesson activities and accompanying commentary are described in sufficient detail to enable teachers to use them in the classroom. Comments to the teacher about each activity guide the teacher in understanding the purpose of the activity, the common student response patterns to the activity, potential pitfalls, and suggestions for how to use the lessons to create a science discourse community in the classroom.

The materials include the following:

• A research background paper describing the problems of science instruction that isolates science content and science processes and that represents science as “the scientific method”

• A case study description of a fifth-grade science unit in which the teachers introduced students to a study of the nature of science in tandem with their inquiry into adaptations and species diversity

• Discussion and analysis activities that guide the user in critically examining and discussing the various materials in this package

• Frameworks and instructional models to guide curriculum goals and unit planning

• Lesson activities and accompanying comments for the teacher about purposes of the activity, common student response patterns, suggestions for monitoring discussions, potential pitfalls, and meaningful links to other subject areas.
GUIDE TO USING THESE MATERIALS

Purposes of the Materials

These materials are multifaceted in nature and designed for multiple purposes. The research background materials, the case description of a science unit in action in a fifth-grade classroom, the teaching lesson materials and accompanying teachers' guide comments, the samples of student work, and the analysis activities are designed

• To stimulate discussion and learning among science educators--including inservice and preservice teachers--about the relationship between content (conceptual development) and processes (nature of science goals) in science and in science teaching and learning. They challenge users of the materials to think beyond "the scientific method" and beyond "processes" in representing the nature of scientific inquiry in science classrooms.

• To support planning in science that is focused on conceptual development in the context of scientific ways of thinking and acting in a discourse community. The materials can be used to support teachers and prospective teachers (at any grade level) in developing an approach to science planning that will support conceptually focused teaching that is integrated with rich representations of scientific ways of knowing and acting in a science discourse community. Thus, the materials provide support in developing an approach to planning that would enable a teacher to construct a unit on any topic and for any grade level that would integrate an explicit curriculum strand about the nature of science and scientific discourse into a year-long conceptually integrated curriculum strand.

• To assist teaching of science. Teaching lesson activities and accompanying guide comments are specific enough that teachers or preservice teachers can use the activities as presented here to teach a unit that introduces students to modes of discourse and action in a scientific community while also teaching concepts related to adaptations.
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Position Statement:
Developing Conceptual Understanding in a Scientific Discourse Community

**Problems with traditional approaches to science teaching.** Studies of the philosophy of science and studies of science teaching and learning provide convincing evidence that typical classroom science represents science in ways that exclude many students from understanding science and that give students distorted understandings of what it means to do and to understand science. Students in textbook-oriented classrooms, for example, typically learn that science knowledge is authoritarian, fixed, and unchanging and that science is about learning a foreign language composed of many complicated and hard-to-understand words. Students in hands-on classrooms often learn that science is about measuring, observing, graphing, and explaining, but they do not see the purpose of all this activity. Because they engage in these activities without undergoing significant changes in their thinking about the explanations of the phenomena they are studying, they find these science “processes” just as mysterious and foreign as the big words in the science textbooks.

**Thus:** We need new approaches to science teaching that will help all students develop meaningful understandings of science and make them feel comfortable in the “neighborhood” of science.

**Science as conceptually driven.** Philosophy of science, however, helps us understand that there is a much closer relationship between science concepts and science processes than our classroom representations of science usually portray. Science concepts both grow out of scientific processes and shape scientific processes. Choices about what observations to pay attention to and what experiments to do are decided by scientists who bring particular conceptual frameworks to bear on the phenomena of interest. In classrooms, we often communicate that science is divided into two discrete areas: a body of knowledge/content and a set of processes. Students spend their time in classrooms either learning the established content or engaging in scientific processes. But rarely do students participate in scientific processes in the ways that scientists participate in them: to solve genuine problems and to push their understanding of the phenomena being studied.

**Thus:** Students need to use scientific processes to develop well-integrated, meaningful conceptual understandings of phenomena in their real-world experience.

**And:** We need to avoid teaching science processes in isolation of conceptual development and teaching concepts in isolation of students' active participation in constructing content knowledge through the use of scientific processes.

**Science as socially constructed.** Studies in the philosophy of science paint a much richer and messier picture of what it means to do science than is communicated by “the scientific method.” The presentations of scientific method in science textbooks (neatly described in Chapter 1 and then usually not referred to explicitly again) communicate that science is done in purely objective and clearly laid-out steps. Rarely do these descriptions of scientific method help students consider the ways in which scientists interact, talk, collaborate, debate, argue, communicate in acting out multiple variations of scientific methods. In activity-oriented classrooms, students may do experiments all year long, but rarely are they taught how to talk, debate, argue and think about these experiments in ways that are characteristic of science discourse communities.

**Thus:** We need to portray science as a richer, messier, more human, more collaborative, more tentative endeavor. There needs to be a focus on scaffolding students' efforts to learn how to think, talk, and act in a science discourse community. Students need to learn how to use their interactions with others (in the class, in texts) to change and strengthen their ideas and explanations.

**Scientific literacy as providing access to science discourse communities.** The students who do well in science often come to the science classroom already knowing a lot about scientific modes of
discourse (use of evidence and logic, sources or proof, explanatory requirements, etc.). These students come from families where such reasoning is understood and promoted. Students who come from different kinds of cultural and home backgrounds do not bring this kind of discourse pattern with them to school. To provide all students access to the classroom scientific discourse community, we need to teach explicitly about science talk and norms of interaction.

**Thus:** We need to bring in the traditional outsiders to science by teaching students explicitly about the norms and values of interactions in scientific communities, including the science classroom community. We need to support all students in developing meaningful understandings in science class through careful scaffolding of their efforts to use what may be very new reasoning and discourse patterns.

**Learning is an evolutionary process that takes place across time.** Through many studies of students' learning in science, we have become convinced that genuine understanding in science cannot happen in a lesson or a unit. To support students in changing long-held patterns of thinking and discourse and in changing their experience-based ways of explaining phenomena in their everyday experience (how plants work, what makes day and night, how electricity works, how light helps us see), we need to be much more patient with students. This patience would include careful attention to students' thinking and ways of making sense as a daily part of science teaching. In addition, the science curriculum needs to be coherent and integrated across time. Conceptual themes need to be developed and revisited in different contexts across time, and explicit attention to what it means to know and act in science discourse communities needs to be a theme throughout the science curriculum (not just in Chapter 1).

**Thus:** The science curriculum needs to be integrated in two ways:

1. There needs to conceptual integration across time
2. Conceptual learning needs to be integrated with continual learning about the nature of science and modes of inquiry and discourse in science communities.

**Addressing these issues in an introductory science unit.** The materials in this packet are drawn from our efforts over the last three years to design an approach to creating the kind of science learning community that would address these urgent needs in science education. Thus, the unit is designed to link conceptual learning goals with students' participation in scientific processes, to represent science as a discourse community rather than just a "method" and to teach explicitly about the norms and rules of discourse in this community. The unit is designed to begin two important curriculum strands that are continually developed and woven together across the school year: a conceptual strand and a nature of science strand.
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Research Report 1: Beyond Processes²
What's Wrong With Process-Focused, Hands-On Science Instruction?

In the 1960s and 70s science educators were convinced that "hands-on" and process-focused approaches to science teaching would revolutionize science teaching, enabling students to develop much richer understandings of science concepts and the nature of science. While there are many who still see "hands-on" approaches as the salvation of science teaching, there is growing research evidence that our hopes were misguided. Just as content-focused science instruction communicated distorted messages about the nature of science to generations of science students--science has all the answers, science is not to be questioned, science is complicated and hard to understand, science has a special status--so process-focused science classrooms supported students in developing inappropriate understandings of the scientific endeavor. Just as content-focused, didactic approaches to teaching science turned off many students to science, so process-focused approaches confused and frustrated many students.

How can this be? What could possibly be wrong in classrooms where students are busily and enthusiastically engaged in carrying out experiments and examining nature firsthand? These students look happy and engaged, quite a contrast from the usual disengaged looks of students sitting through science lectures or copying down definitions of big words in bold print in their textbooks. Certainly, these approaches must make a difference in student learning. This is what we used to think as we watched students in activity-based science classrooms apparently actively involved in their learning. These classrooms seemed like wonderful learning settings for young scientists! How could the students not be learning important stuff?

Let's consider the learning of students in a Roth, Smith, and Anderson (1983) study, who were studying about plants' role as food producers using the activity-based, process-focused approach embedded in the Science Curriculum Improvement Study (SCIIS; Knott, Lawson, Karplus, Their, & Montgomery, 1978). Despite six weeks of experimenting, graphing data, and

²"Beyond Processes" is the title of a paper by Millar and Driver (1987) that helped me better organize and explain the concerns I had about process-focused science teaching.
discussing results of experiments with plants, students failed to develop meaningful understandings about the targeted concepts of the unit. They began and ended the unit asserting that plants get their food from the outside environment (water, soil, etc.), failing to integrate into their thinking the important idea that plants produce their energy-containing food internally. This lack of conceptual learning was distressing, but even more upsetting were the analyses of students' understandings about the nature of science. Despite their daily engagement in the scientific processes (prediction, observation, data gathering, data reduction, experimentation, inferencing, etc.), many of these students ended the unit frustrated with the constant measuring and recording of data. Although they found “doing” science fun, they grew tired of it and were just as confused about the purposes of all that measuring and graphing as students in the textbook-oriented classrooms (Roth, Anderson, & Smith, 1987) were tired and confused by an overwhelming content and vocabulary load in their study of light and seeing. As Rachel explained, “I don't know why we kept measuring those plants. I mean it was fun for awhile, but I already know that plants need light and now I know it again” (Roth, 1984, 1990).

What did Rachel learn about science processes and scientific thinking? She learned that it involves a lot of activity that does not help you make any better sense of things. She learned that science activities and processes are ends in themselves. It is important, for example, to make careful observations and to record them accurately not because such care helps you develop better understanding but because “that’s what you do in science.” Because Rachel did not develop better conceptual understanding, the processes of science seemed meaningless and not worth the effort. Driver (1983) critiques this doing of science in the absence of meaningful conceptual development, suggesting that the “I do and I understand” slogan might more appropriately be “I do and I am even more confused.” Duckworth (1990) and others have joined in the critique of “hands-on” science, asserting that what we need are “minds-on” approaches to science instruction.

Millar and Driver (1987) draw from philosophy of science to explain what’s wrong with process-focused science. They argue that scientists use conceptual knowledge and so-called science processes, or reasoning strategies, in such closely integrated ways that it is misleading to
try and describe (much less teach!) content and processes as separate entities. Expert scientists, they assert, do not hypothesize, observe, make inferences, or design experiments in the absence of conceptual frameworks. Their conceptual frameworks are not only influenced by their observations and inferences; their frameworks also drive and shape the hypotheses they make, the questions they raise, the things they pay attention to in their observations. What distinguishes their work as science are not these processes, which are equally applicable in history, economics, mathematics, the arts, or any other domain, but the particular knowledge that organizes how these processes are used. A scientist who observes well, for example, is not one who spends endless hours documenting and describing every possible detail that can be observed about a particular phenomenon. A good scientific observation, in contrast, focuses on key features in ways that will contribute new knowledge, increase the explanatory power of a particular conceptual framework, generate new understandings of relationships among concepts, or raise significant questions about accepted conceptual frameworks. The scientist who makes such critical observations does not just happen to see what others have not seen because of expert “observation skills.” To set up the conditions in which important observations are made, the scientist draws from existing conceptual knowledge, asks questions about important pieces of the framework, develops hypotheses, and designs experiments that will permit the critical and relevant observations to be made.

The importance of the observation is not how accurately the scientist can detail and describe all facets of the observed phenomenon but how the scientist focuses the observation and uses the observed phenomenon to develop a more powerful and complete explanation. Thus, skillful expert observation is intimately linked with both conceptual knowledge and with all of the other “processes” of science.

As Millar and Driver (1987) argue, each of the so-called scientific “processes” can be submitted to a similar critique. These processes are not meaningful in isolation, and they are not science in the absence of a scientific conceptual framework. So what’s wrong with hands-on science instruction? It too often represents science as process-focused and fails to teach students about the important role of concepts in thinking and doing science.
Beyond Processes

Using This Research Lens to Examine Instructional Tasks:

**Analysis Activity 1**

What excites a scientist are ideas and explanations: processes are simply a means to develop better and more satisfying ideas and explanations. Unfortunately, many of the process-focused curricula miss this conceptual heart of science—the conceptual connection. In Analysis Activity 1 are three examples of instructional activities that engage students (3rd-5th grade level) in using scientific processes. Examine these activities with the conceptual connection in mind. What powerful concepts do the activities support students in exploring and developing? What might students learn about scientific processes from these exercises? Will they learn that science processes are useful in solving important puzzles of our world? Will they develop new understandings and explanations of the world around them from using these processes? Will they see how these science processes can help them see the world in new and richer ways? Or will they learn that science processes can be used to answer trivial questions in a very systematic, complicated “scientific” way? Will they learn that science is about following a bunch of rules, procedures, and steps, or that science is about ideas and sense-making? Do these activities have the potential to help students appreciate, value, and understand the conceptual heart of science?
Activity 1: M&Ms

The Problem: In a bag of M & M's, which color is most frequently found?

Data Collection: Each group of students sorts a bag of M & Ms by color and counts how many of each color there are.

Data Organization: Students are supported in constructing bar graphs to show how many M&Ms of each color were found.

Data Interpretation: In a whole-class discussion, students compare the results of each group and look for patterns in the results. Conclusions are drawn, or if the data is not clear, plans for additional data collection are made.

Activity 2: Fingerprints

The Problem: How can fingerprinting help us see the texture in our fingers?

Introduction of idea of texture: Even though your fingers feel smooth, they have texture. High and low places on a surface give it texture. Special techniques are needed to help us see things we otherwise would not, such as the high and low places on our fingers.

Procedures: In small groups, each student makes a carbon print of each finger and thumb on one hand.

Observations: Students are asked to describe their fingerprints. They are asked to look for and describe patterns in their fingerprints.

Explanation: Students are told about three fingerprint patterns—whorl, arch, and loop.

Looking for Patterns: They are then asked to reexamine their fingerprints looking for these patterns.

Discussion: What are ways the carbon printing technique might be used to make records of textures that are hard to see?

Reflecting on the Activity:
What are the names of the three basic fingerprint patterns?
What do we call the “fingerprints” left behind by cars and bicycles?
What could you print with carbon printing besides fingerprints?
How could you make fingerprints besides carbon printing?
Why is it a good idea for young children to be fingerprinted?
Activity 3: Bean Seeds

The Problem: How does a growing bean seed get the food it needs to grow?

Exploration: Students examine bean seeds, taking them apart to see the embryo and cotyledon.

Hypothesizing: Individual writing followed by whole-group discussion is used to generate ideas about how a bean seed gets its food. Hypotheses are kept on a class chart.

Predicting: In small groups, students construct predictions and explain reasons for their predictions about what will happen to bean seeds placed in varying conditions:

- What do you predict will happen if we water the whole bean for a few days? Why?
- What do you predict will happen if we separate the embryo from the cotyledon and water the embryo? Why?
- What do you predict will happen if we water the cotyledon by itself? Why?
- What do you predict will happen if we water the embryo that is attached to one half of the cotyledon? Why?

Observing: Over the next several days, students measure, describe, and draw to track the growth of the bean seed parts.

Organizing data: The data from the different groups is compiled into a class chart or graph. Students compare results to predictions.

Developing explanations: What might explain the results? Students write their own explanations of the results. These ideas are used in a class discussion, with the teacher scaffolding children's thinking. Teacher emphasizes that a good explanation explains why and how; it does not just describe what happened.

Synthesis: Teacher will highlight the consensus explanation, which will probably be that the embryo gets its food from the cotyledon. However, the teacher will be on the lookout for alternative explanations and will support students in developing further experiments to test out competing explanations. For example, if students say that the cotyledon doesn't contain food, it just carries the water to the embryo (like a mouth and throat), the teacher could help students do a sugar or starch test on the bean cotyledon.
Research Report 2: Beyond “The Scientific Method”:
What's Misleading About Representing Science as “the Scientific Method”?

I will never forget the day that Lee Shulman, my professor in a doctoral course on
cognitive psychology at Michigan State University (now professor at Stanford University), circled
the word “the” in a paper where I mentioned “the scientific method.” “Come on, Kathy, do you
really believe this?” he wrote on my paper (or something to that effect). In retrospect I am
surprised that I had made it through a rigorous undergraduate major in biology without ever having
this idea challenged. Certainly, the literature on history and philosophy of science has documented
the over simplistic and misleading nature of our characterization of science as being guided by “the
scientific method.”

“The scientific method” as presented in almost every science textbook fails to portray
science in all its diversity, its humanness, and its richness. The method makes science look like a
completely rational, objective approach to thinking, and it sends the message that there is a clear
sequence of steps in scientific inquiry processes. Thus, it portrays a much neater version of
science than is encountered in the real world. But does that harm students in any way? What is so
bad about simplifying and organizing the essence of science in our representations for students?
Do they really need to know about all the messiness of doing and thinking and talking science?

Many educators argue forcefully that such a representation of science is educationally
harmful. Lemke (1990), for example, believes that the representation of “the scientific method”
being taught in schools today communicates to students that observations provide us with absolute
facts independent of human judgment and interpretation, that science is a perfect means to absolute,
objective truths. He worries about students leaving the schools who fail to understand the
interdependence of theory and observation, to be critical of absolute fact or proof in science, and to
recognize the ways in which alternative theories can coexist and be used for different purposes by
different people (p. 175). He argues that “science education cannot just be about learning science:
Its foundation must be learning about the nature of science as a human activity” (p. 175-emphasis
added).
Educators who are concerned about access to science by those who are typically outsiders (minorities, women) also view this representation of science as dangerous. First, it strips away all the humanity of science that might make science more appealing and accessible to many female students and students of color. As Brickhouse (in press) notes, "research on girls' interests in science indicates repeatedly that their interests are connected to their concerns for people and living things (Harlen, 1989; Smail, 1987)" (p. 11). She quotes a student who voices her alienation from science in the following way:

What's missing in science is a whole sort of human element. It doesn't seem to be infused with any morality. It doesn't even seem to be a world about people anymore (cited in Belenky, Clinch, Goldberger, & Tarule, 1986, p. 71).

Similarly, students who are more oriented to stories and narrative than to logical sequences and equations might believe from this representation that there is no place for them in science. They might believe that their less stepwise thinking would not be valued in science. In fact, as Medawar (1987) so eloquently states, science is all about creating "stories":

Like other exploratory processes, [the scientific method] can be resolved into a dialogue between fact and fancy, the actual and the possible; between what could be true and what is in fact the case. The purpose of scientific enquiry is not to compile an inventory of factual information, nor to build up a totalitarian world picture of Natural Laws in which every event that is not compulsory is forbidden. We should think of it rather as a logically articulate structure of justifiable beliefs about a Possible World--a story which we invent and criticize and modify as we go along, so that it ends by being, as nearly as we can make it, a story about real life. (p. 111).

Medawar here challenges what it means to be scientifically literate, challenging the belief that science is the accumulation of knowledge of acts about the natural world and challenging the belief that scientists work according to a rigorously defined, logical method. But most importantly here, it challenges the belief that scientific discourse is represented only by forms of writing and talk that are thoroughly objective and impersonal. As Warren, Rosebery, and Conant (1989) point out, Medawar's use of the term "story" to capture the purpose of scientific inquiry calls attention to the human, meaning-making character of science. Meaning is not "out there" in the science textbooks; it is constructed through human interactions. The scientific knowledge rests not external to the individual but rather within the discourse community, "within the corps of human beings with a common intellectual commitment" (King & Brownell, 1966, p. 68). Brickhouse and others argue
that many students might be drawn to a science in which the emphasis is on collective cognition and consensus building, rather than on the individual and competition among individuals. But this social constructivist view of science is invisible in "the scientific method" as described in textbooks.

There is also a strong argument that this representation of science does not make explicit the norms and values of scientific communities—their ways of thinking, talking, acting. By failing to make explicit how one goes about developing a good hypothesis and developing arguments in support of a theory, researchers argue that traditional science outsiders do not have access to the scientific community (Brickhouse, in press; Delpit, 1988; Lemke, 1990; Michaels & O'Connor, 1990; Warren, Rosebery, & Conant, 1989). These researchers recognize that knowing how to talk and think science goes beyond the steps listed in the scientific method and that these norms for scientific discourse can become roadblocks to students who do not come to school with the "cultural capital" of white, middle and upper class children—especially boys—in science. Therefore, they argue that representing science as "the scientific method" in Chapter 1 of a textbook does not provide access to the most essential aspects of the science discourse community. Instead, we need explicit teaching about how to think, act, and talk science as an important and ongoing aspect of science instruction.
Beyond "The Scientific Method"

Comparing Different Representations of What It Means to Know Science:

Analysis Activity 2

• Using the chart on the next page, compare the ways in which the doing of science is represented in the textbook description and in Roth's classrooms. In what ways does Roth's list of "Important Aspects of Scientists' Work" address some of the concerns raised by the researchers mentioned in this research report? What ideas do you have about ways that a list like this could be used as a part of ongoing instruction with the students?

• How does the list of characteristics of scientific understanding on p. 13 compare/contrast with the Holt Science description (Abruscato, Hassard, Fossaceca, & Peck, 1984) of the scientific method?
### Beyond "THE" Scientific Method: Norms of Discourse and Interactions in Scientific Communities

<table>
<thead>
<tr>
<th>The Scientific Method (Holt Science, Abruscato, Hassard, Fossaceca, &amp; Peck, 1984, p. 7)</th>
<th>Important Aspects of Scientists' Work (1990, Roth's 5th Grade)</th>
<th>Important Parts of Scientists' Work (1992, Roth's 5th Grade)</th>
</tr>
</thead>
</table>
| When scientists get involved in solving problems, they follow the steps you see outlined below:  
1. Ask questions  
2. Make observations  
3. Come up with ideas  
4. Test the idea or hypothesis  
5. Carry out an experiment  
6. Record results, make conclusions  
7. Answer question and then ask another question | - Discover and describe our natural world  
- Explain the whys and hows of our world  
- Ask and seek answers to questions  
- Solve problems, figure things out  
- Study  
- Observe carefully and keep notes  
- Talk to other scientists  
- Write about discoveries and findings  
- Read journals to find out what other scientists are learning | - Observing  
- Predicting  
- Asking questions and looking for answers  
- Looking for evidence  
- Comparing things  
- Estimating  
- Planning experiments  
- Doing research  
- Collaborating  
- Talking  
- Debating  
- Forming explanations--how? why?  
- Disagreeing and agreeing with each other, using evidence to support arguments  
- Forming hypotheses  
- Using technology (tools) to help answer questions  
- Reading  
- Writing  
- Creating and using models  
- Taking action (to protect earth, life, etc.)  
- Gathering and looking for data  
- Thinking  
- Working in communities; working together |
CHARACTERISTICS OF SCIENTIFIC UNDERSTANDING
Kathleen Roth and Charles W. Anderson

I. CONNECTEDNESS OF KNOWLEDGE

A. Connections among science concepts and theories
B. Connections of science concepts and theories to prior knowledge or “real world” knowledge

II. USEFULNESS OF SCIENTIFIC KNOWLEDGE in activities that scientists and scientifically literate persons engage in

A. Description of real-world systems or phenomena
B. Explanation of real-world systems or phenomena
C. Prediction of real-world systems or phenomena
D. Design of real-world systems or phenomena
E. Appreciation of wonders, beauties, complexities of natural world

III. WAYS OF THINKING, TALKING, AND ACTING IN A SCIENCE DISCOURSE COMMUNITY

A. Disposition to reflect on scientific knowledge by

1. Testing or justifying beliefs on empirical or theoretical grounds--looking for “best” sources of evidence
2. Criticizing arguments on theoretical or empirical grounds--having the disposition to evaluate arguments critically
3. Viewing knowledge as constantly changing, building, deepening over time--taking a historical and cultural perspective on the development of knowledge
4. Recognizing limits to knowledge--what is known, what is not known, what is knowable with current tools, techniques
5. Interacting with other people (through writing, discussion, argumentation) and valuing such interactions as an important part of the scientific community.

B. Disposition to construct new scientific knowledge by

1. Asking appropriate questions
2. Developing solutions to problems using personal knowledge and reasoning, other resources, or empirical investigations
3. Interacting with other people (through writing, discussion, argumentation) to develop new understandings; viewing knowledge as cooperatively constructed within a scientific community.
Beyond “The” Scientific Method

**Considering Different Models of Doing Science: Analysis Activity 3**

Consider the quotes from and about three women scientists who have made outstanding contributions to science: Rachel Carson, Lynn Margulis, and Barbara McClintock. Each of these women faced ostracism from the scientific community because of their nontraditional approaches to science. However, each succeeded in making contributions that became widely accepted in the scientific community. In what ways did these women go “beyond the scientific method?”

- Do you think their contributions include changing the norms and values in the scientific discourse community?

- In what ways could case studies from these women be used in the science classroom to help students understand both concepts in science and the nature of science?

- Compare/contrast their ways of knowing science to the description of the nature of science and scientific habits of mind in the AAAS (American Association for the Advancement of Science) Science for All Americans report (AAAS, 1989). See chapters 1 and 12 of this report.

**Rachel Carson**


In response to criticisms that her book, Silent Spring, was unscientific because of its emotion-laden writing style, Carson responded:

> The aim of science is to discover and illuminate truth and that, I take it, is the aim of literature, whether biography or history or fiction; it seems to me, then, that there can be no separate literature of science...if there is poetry in my book about the sea, it is not because I deliberately put it there, but because no one could write truthfully about the sea and leave out the poetry. (cited in Briggs, 1987).
Barbara McClintock


But the story of McClintock’s contributions to biology has another, less accessible, aspect. What is it in an individual scientist’s relationship to nature that facilitates the kind of seeing that eventually leads to productive discourse? What enabled McClintock to see further and deeper into the mysteries of genetics than her colleagues?

Her answer is simple. Over and over again, she tells us, one must have the time to look, the patience to “hear what the material has to say to you,” the openness to “let it come to you.” Above all, one must have “a feeling for the organism.”

One must understand “how it grows, understand its parts, understand when something is going wrong with it. [An organism] isn’t just a piece of plastic; it’s something that is constantly being affected by the environment, constantly showing attributes or disabilities in its growth. You have to be aware of all of that . . . You need to know those plants well enough so that if anything changes, . . . you can look at the plant and right away you know what this damage you see is from—something that scraped across it or something that bit it or something that the wind did.”

You need to have a feeling for every individual plant.

“No two plants are exactly alike. They’re all different, and as a consequence, you have to know that difference,” she explains. “I start with the seedling, and I don’t want to leave it. I don’t feel I really know the story if I don’t watch the plant all the way along. So I know every plant in the field. I know them intimately, and I find it a great pleasure to know them.” pp. 197-198

***************

That there are valid ways of knowing other than those conventionally espoused by science is a conviction of long standing for McClintock. It drives from a lifetime of experiences that science tells us little about, experiences that she herself could no more set aside than she could discard the anomalous pattern on a single kernel of corn. Perhaps it is this fidelity to her own experience that allows her to be more open than most other scientists about her unconventional beliefs. Correspondingly, she is open to unorthodox views in others, whether she agrees with them or not . . .

For years, she has maintained an interest in ways of learning other than those used in the West, and she made a particular effort to inform herself about the Tibetan Buddhists [and their ability to regulate body temperature and run for hours on end without sign of fatigue]: “I was so startled by their method of training and by its results that I figured we were limiting ourselves by using what we call the scientific method.”

But these interests were not popular. “I couldn’t tell other people at the time because it was against the ‘scientific method.’ . . . We just hadn’t touched on this kind of knowledge in our medical physiology, [and it is] very, very different from the knowledge we call the only way.”

What we label scientific knowledge is “lots of fun. You get lots of correlations, but you don’t get the truth. . . . Things are much more marvelous than the scientific method allows us to conceive.” pp. 200-201
Lynn Margulis


For almost 20 years, Margulis has been on the trail of one basic hunch--one might call it a vision--that has led her to a radical scenario of evolutionary processes. That hunch is to place symbiosis--the mutually advantageous association or union of two distinct organisms--at “the dead centre of plant and animal cell lineages.” p. 46

 Margulis is well aware that her proposal is heretical. She knows just how much it flies in the face of the traditional view of evolution as a result of competition between different life forms. . . . But Margulis is fearless as well as energetic. Although a devout believer in science, she takes special pleasure in defying established scientific dogma. pp. 20-21

 The responses to her effort were mixed. As one reviewer wrote, “It has to be a young scientist and a woman who dared to challenge the scientific establishment by writing such a book.” p. 48

 In her quest for support of her hypothesis, Margulis has sought evidence from many different, often non-communicating disciplines: bacteriology, cell biology, geology, molecular biology, and natural history. . . . But the effort to integrate so many disparate kinds of data has largely been solitary. Only in the past few years has her own synthetic perspective come to be professionally legitimized. p. 49

 But the fact is that Margulis is even less likely to be daunted by charges of scientific or philosophical heresy now than she was when she started out. Her intuitions have proved to be too productive, and her confidence in the logic of her vision itself has grown accordingly. . . . It could be argued that all scientific revolutions begin with a private vision of what the world looks like--a vision that acquires meaning only in time, as it gets publicly elaborated. . . . What is perhaps most unusual about Margulis is first, that the vision with which she began her career was so conscious (and indeed changed so little with elaborations), and secondly, that she trusted it so fully--not only privately, but publicly as well. Hers is a style of scientific inquiry unbounded by the walls of academic disciplines and marked more by daring than caution. Perhaps she was emboldened by her beginnings as a marginal woman scientist. But, whatever the case, the scientific world has profited from her deviance. p. 50
Case Study of Fifth Grade Teaching and Learning: What's So Difficult About Integrating Conceptual Development and Science Processes in the Classroom?

The research provides convincing evidence that both didactic, content-focused approaches to science teaching and process-focused approaches are problematic. These findings are addressed in multiple national calls for reform in science education through an appeal to more integrated, coherent science instruction that focuses on teaching for understanding. Duckworth (1990) and others have distinguished this call for reform from earlier calls for hands-on science: This new reform movement calls for “minds-on” science. As stated in the State of Michigan new science objectives, a key criterion of understanding is usefulness of the knowledge: Can students use their developing knowledge and skills to explain, predict, design the world around them? A logical solution to the dilemma is to integrate conceptual approaches and process approaches in science teaching.

Through our efforts in trying to enact and study such an integrated curriculum in fifth-grade classrooms, we have learned some important lessons about the kinds of support that young students need in making sense of both science concepts and the nature of science.

In our first efforts to integrate conceptual instruction with instruction about the nature of scientific inquiry, we tried to build on what was learned from some of the best attempts at creating activity-based approaches. We found that embedded in the SCIIS curriculum materials, for example, were some very powerful conceptual connections. It seemed to us that we simply needed to make these conceptual connections more visible to the students and more connected to their prior knowledge and experience. Thus the curriculum and instruction we developed made more explicit the conceptual development, leaving the ways of thinking that enabled students to develop these concepts an unnamed, invisible but everyday piece of the classroom experience. Through participation in inquiry and scientific discourse, students were expected to make inferences about the nature of talk, action and thinking in science. In retrospect, we recognized that we had made an assumption that students who were engaged in inquiry and rich discourse and who succeeded in using those processes to develop meaningful understandings of important and
widely applicable concepts would recognize, value, and be able to name the science processes that enabled them to develop these understandings. We were wrong.

When we interviewed students (names are pseudonyms) at the end of the school year, we were excited and impressed with the conceptual understandings they had developed. Not only were they successful in developing the core ideas emphasized in each unit of study, they also succeeded in integrating conceptual knowledge across the school year, in using that knowledge in novel situations, and in raising questions about that knowledge. Students of all so-called “ability” levels spoke comfortably and articulately about concepts like cells, energy, adaptations, structure, function, photosynthesis, cell respiration, ecosystems, food chains, et cetera.

But there was also bad news. Students were not very successful in describing the nature of scientific inquiry and discourse. Although we did not expect them to know the steps of the scientific method, we did expect that they would have assumed that some of the norms in our science classroom were also important norms in the scientific community.
Analysis Activity 4: Students' Descriptions of What It Means to Do, Think, and Talk Science

Examine the ways in which fifth graders--Nathan, Matt, Brenda, Nan, Michelle, Justin, Tiffany, Heidi--described science and scientific ways of knowing to the Interviewer (I) at the end of the school year.

• What do the student comments reveal about their understanding of the nature of scientific inquiry and discourse?

• Compare Brenda's responses with the other students. In her classroom (Roth's 1988-89 class), the focus of science instruction had been on conceptual development, and the values and norms of scientific discourse, while practiced in the classroom, were not explicitly taught. In what ways are her images of scientific ways of knowing and acting different from those of Nathan, Nan, and the others?

NOTE: It might be helpful to refer to the list of “Characteristics of Scientific Understanding” listed on p. 13 to support this analysis.

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Nathan

I: What else can you tell me about what scientists do?
Nathan: They have to research stuff.
I: OK, tell me how they research stuff?
N: They have to look at different scientists perspectives and see what they think, and then they try and see if they thought it was any different. And then they maybe could try and find that other scientist and talk about it, and see if he thought it was a good idea.
I: Tell about this, “They look at different scientists' perspectives”?
N: Well, if they were in a book and stuff they might read it, and get some ideas and they might say, “Well, I don't think this is right” and try and change their idea.
Nan
I: Do you think it would be easy or hard for scientists to study about humans who lived a million years ago?
Nan: It would be hard because they got to find a lot of evidence, and they got to find a lot of things. . . . because there is no proof. [To find out if early humans got married in churches] they’d have to go all around the world and try and find like if they find a church or something. They are not going to say that that is a church where early humans go to get married. They ain’t going to know.

Michelle
I: Why is it important to do science?
Michelle: You can find out different things and aren’t going with just one point of view like when we did the bean plant, we weren’t just looking at the book.
I: Why is it important not to go with just one point of view?
M: Cause you’d be getting your own ideas too, like when we were reading books on plants, we weren’t just going by that perspective, we were going by our perspectives, too, like doing different experiments with beans.

Justin
I: What does it mean to do a science job?
Justin: Scientists explore, are fascinated, they wonder, they don’t always have answers to questions.
I: What is science all about?
J: Science is a lot of learning and fascinating and wondering.

Tiffany
I: What kind so people become scientists?
Tiffany: Before we studied this, or after?
I: Both.
T: Before I thought it was men, because there’s this cartoon -- a mad scientist -- and he’s an old man and he has weird hair. And now I think it could probably be anybody. It could be a man or a woman or anybody, really.
I: Does this writing in your journal show anything about you as a scientist?
T: That I’ve used other people’s ideas to help change mine and make them better or make them right or sometimes just to improve them.
I: What things helped you understand in science?
T: Scientific arguments helped because you could change your ideas. People helped you see it different and then it might be better. Experiments help and experiments on our own helped, too. I got to do the experiments I wanted, so I could see, I could do an experiment on what questions I had. Like I did one to see where sugar was at cause at first I didn’t understand that the cotyledon made sugar so then when I did that one, I found out what it was, like the cotyledon was all sugar except the brown part.
**Heidi**

I: Have your ideas about scientists changed?

Heidi: Yes! When I first started science, I used all the stereotypes and now I've learned that they can do anything they want. They can ride a moped, wear grubby clothes. Some work in labs but most of 'em are studying things, finding out things, trying to figure out things.

I: Were there times in science class when you felt like a scientist?

H: When we did the bean experiments. We were finding the things out, we were the ones that were making the experiments. Some people would like stay in for recess and make up their own experiments.

I: What kinds of talking do scientists do?

H: They have arguments sometimes, they sometimes talk to each other at meetings about what they found out and how they got that information.

I: Can you say more about arguments?

H: Well, some people might believe in one thing and some might believe in the other, like if I said the seeds could grow in the dark, other people might say they can't grow in the dark cause they don't have any sunlight and that's part of food, so you'd do an experiment and find out. They can argue about which one they think is right and then they can try or find out which one is right.

I: Is it a good thing or a bad thing to have arguments in science?

H: I think it's a good thing cause then you learn more about what the other people think and if you're wrong you learn from yourself and sometimes you learn from the other people.

**Matt**

I: Do scientists travel around for other reasons?

Matt: Yeah, like for meetings with other scientists to share their perspectives and to like collaborate to mix what they have with some others to form some better evidence....

I: And what about the talking that they do?

M: They talk with other scientists to mix their ideas, collaborate to see if they can solve the problem. A lot of scientists don't just work by theirselves, they collaborate with other scientists and come up with better ideas.

**Tiffany and Nan**

Tiffany: Scientists do experiments to find answers to questions.

Nan: That's what we did!

T: They have discussions with other scientists about what they think and then they add to their ideas.

Nan: That's what we did!

T: Different scientists can do different experiences and add to their evidence.

Nan: We found evidence too just like scientists. Because we are scientists!
**Brenda**

I: What kinds of talking goes on in science class?
B: We have discussions like little arguments of what some people think one thing and other people think another thing. Like we did a paper [a worksheet that presented the ice-over-the-pond problem] and we saw it and some people thought that the fish would die if there was ice over the pond all winter and some people thought they wouldn't die and things like that.
I: What do you think about that?
B: If it didn't have any snow over it and the sunlight could get through to help make energy for the plants, yeah, it could live.
I: Is it a good thing or a bad thing or both to argue like that?
B: It's good to argue so both people can know and have an understanding for both things and know what both people think.

***

I: What is science all about? Why do people study science?
B: So they can learn about what's happening in the world. So we can study what's happening in the world so they can know what things to expect like if the rain forests are all cut down so they know what to expect, how things are working.

***

Q: What other things go on in class discussions?
B: Somebody saying the real answer and then trying to figure out things. When we were learning about photosynthesis or however you say it, people were trying to figure out how that really, how plants got their food and how its cotyledons or whatever got their food before they sprouted out.

B: You could be talking. You might talk about that you want us to do something in the log books, or you might help us, you might start a discussion going about something and talking and maybe tell us the answer so we can figure it out.

B: [It's important to ask questions] so you can know the answer to something and so you can know the answer to it or somebody can give you the answer.

B: [The Question Book] it's when you don't want to tell us the answer right now and she wants us to keep our guess and we go write it down in the Question Book so we can remember it, I guess if when we come back to it.

B: Sometimes I get frustrated because I want to know the answer right away and sometimes it's OK because I don't need to know the answer right away.

B: [About writing in science class] we write a lot. We write about things we are learning and like the little story of the cell and the atom or something. On tests we write the real answer and in the log book we can write what we think even if it's not right. [That helps in our learning] because so we will have what we think so we can learn how we, so that we can learn to make guesses instead of always having to find out the real answer.

I: Could it be that both people are right?
B: Yeah, in a way. That they both are right because they expressed their opinion and they probably made a good guess even though it's not right.
# CASE STUDY MATERIALS

Planning and Teaching An Introductory Unit in a Fifth-Grade Science Classroom

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| Teacher Planning Materials | p. 30 |
| Phase I: Lesson Activity Ideas for Introducing the Nature of Science Strand | p. 54 |
| Phase II: Lesson Activity Ideas for Introducing the Conceptual Strand | p. 90 |
| Phase III: Lesson Activity Ideas for Weaving Together the Nature of Science Strand and the Conceptual Strand | p. 117 |
| Phase IV: Lesson Activity Ideas for Reflecting on the Nature of Science Strand and the Conceptual Strand | p. 127 |
| Phase V: Lesson Activity Idea for Continuing the Weaving—Conceptual and Nature of Science Links to the Next Unit | p. 145 |
| Teacher Journal Entries | p. 149 |
| Student Writing Samples | p. 154 |
Planning and Teaching An Introductory Unit in a Fifth Grade Science Classroom: So What is the Alternative?

Overview of Goals and Instructional Phases of the Unit

Making the Nature of Science Strand Visible and Explicit

In our most recent teaching-research experiences, we have examined ways in which we can intertwine an explicit curriculum strand about the nature of scientific inquiry and discourse with the multiple conceptual strands that we are hoping students will be able to weave together across a school year. Drawing on the research of Delpit (1988), Warren, Rosebery, & Conant (1988), Michaels & O'Connor (1990), and Brown & Palincsar (1989), we have attempted to make the discourse norms and values of scientific communities as prominent and visible to students as the conceptual strand.

Weaving the Conceptual and Nature of Science Strands Together Continuously

And we have tried to make both strands visible throughout the entire school year—not just at the beginning of the year. Thus, students are consistently asked to reflect on the nature of their science learning and its relationship to learning within scientific communities outside of school. Thus, all curriculum and instruction decisions are made based on the dual goal of wanting students to develop integrated and useful conceptual understandings and to develop a rich appreciation of how particular kinds of inquiry and discourse enabled them to develop these powerful understandings.

In this report, we share glimpses of our attempts to weave together with our students important conceptual and nature of scientific inquiry and discourse strands in the science curriculum. We focus on a unit that we have taught in a variety of ways at the beginning of the school year to introduce fifth graders to these two curriculum strands. We highlight how this unit enabled us as teachers to go well beyond an obligatory presentation of “the” scientific method at the beginning of the school year.
Using the Case Study Materials

To help describe our goals and efforts, we include materials that we created while teaching and studying this unit with fifth graders. We invite teachers and teacher educators to use these materials in a variety of ways. At one level, they could be used almost as a teacher's guide for putting together a unit just like the one we taught. However, this is a very limited use of these materials. We believe the unit can serve a broader purpose as a starting place to enable other educators--at all educational levels--to create new models and units that focus simultaneously on teaching for understanding of concepts and teaching for understanding of the nature of scientific inquiry and discourse. We invite readers to create other models or to use our model in developing units with a different conceptual focus. We hope that our case materials will illustrate key issues to consider in teaching science in an integrated way and that they will stimulate thinking about alternative approaches.

The Planning Process: How We Got Started

Our planning for this unit started with our study of gaps in student understanding in our previous teaching using a conceptual change teaching model (see p. 33). In this model we focused on supporting students' conceptual development as they wrestled with problems like: What is food for plants? What happens to the air we breathe and the food we eat? Our teaching was built around the students' thinking and sense-making, with instructional decisions being tailored to the students' unfolding thinking, understanding, and confusions. At the end of a year with this kind of instruction we found that students had developed strong conceptual understandings. They had well-connected understandings of important concepts that they were able to use to explain a variety of real-world phenomena in their experience. However, the bad news was that they did not link the kinds of inquiry and discourse that had characterized their classroom study with the world of science outside of school. They viewed their own knowledge as tentative, changing, and uncertain, but they viewed scientists as being certain, authoritarian, and as having all the answers. While they described discussions in our classroom as arguments, they did not link this style of discourse with the scientific community outside our classroom.
We decided that to make the nature of scientific inquiry and discourse more visible to students that we would precede our usual units with a short unit that would introduce students to the norms and values of scientific discourse communities. But we did not want to just have a unit about scientific inquiry and discourse in the abstract. We wanted students to come to understand the nature of science through their own explorations and inquiries. Therefore, we picked a topic that we thought would provide a comfortable starting place for exploring some concepts that could be further developed throughout the year and for introducing important aspects of scientific work and discourse. The unit topic—adaptations—was also in the students' textbook. We see no magical importance in the particular topic we selected, and we hope that others will easily identify alternative topics that could be approached in this way in an introductory unit.

The Central Question: Beyond Answers

We have found a central problem or question for a unit to be an extremely useful tool in engaging students in an inquiry and in keeping instruction focused on the usefulness of knowledge in solving this particular problem. As we brainstormed possible central questions for a unit that would address adaptations and the nature of scientific inquiry and discourse, we struggled to find a question that would be conducive to teaching both curriculum strands. Over time, we have come to understand the importance of devising a central question that does not have a definitive answer. The first year, it was by luck that our question was one that we never answered as a class (in fact, we only got more uncertain about our answer to the question as the unit proceeded): Are there more different species of plants and animals in the desert or in Michigan? In retrospect, however, we see multiple benefits of starting the year with a question that we cannot answer by the end of the unit:

1. It enables us to engage honestly in inquiry with the students.
2. Students feel their ideas contribute to the collaborative inquiry; the problem enables them to feel safe in this science discourse community.
3. Students learn that the discourse in this classroom is focused on genuine sense making rather than on guessing the answer that the teacher has in her head.
4. The lack of an answer at the end of the unit models important aspects of the nature of scientific inquiry—the tentativeness of knowledge, the messiness of inquiry, the need for multiple approaches and sources of evidence (as well as patience) in scientific inquiry, the limits of scientific knowledge.
Phase I: Introducing the Nature of Science Strand

In this phase the students' ideas and attitudes toward science are elicited and respected. Through a study of stereotypes of scientists, students are challenged and supported in confronting their images of science and scientists. Science is not neatly defined for students or described as a series of steps in a scientific method. Rather, students come to construct their own definition of the essential aspects of scientists' work through their exploration of different models of scientists at work. The models provide insights into multiple ways of coming to know in science. During this phase of the unit, the teacher works to create a safe learning environment by being supportive of students' various feelings about science. Interactive journal writing with students is particularly important in this phase of instruction; we take special time and care in responding to students' journal entries at the beginning of the unit.

Phase II: Introducing and Weaving in the Conceptual Strand

After an introduction to the nature of science through a study of stereotypes and cases of scientists at work, students are introduced to the central question or problem for the unit: Are there more different species of plants and animals in the desert or in Michigan? Students' ideas about the central question are elicited and explored, and they are encouraged to draw from and use evidence and knowledge from their personal experiences to develop their explanation. Students are then engaged in planning and/or carrying out strategies to gather data regarding the central question. Students are more likely to invest in the problem and its solution if they view the question as meaningful and important. Thus, we are constantly struggling to make the central question seem both genuine and important. We are not so sure that our central question does an excellent job of meeting those two criteria. However, we are pleased that our question is linked to some important concepts (structure, function, adaptation, species, diversity) and that it is an accessible and potentially interesting question for our students (even if it is not exactly the kind of question that scientists explore). In this phase of the unit, new concepts are introduced and used in trying to address the central question. Students are continually reminded of the central question and our overall goal of addressing this question.
Phase III: Weaving Together the Two Strands

In this phase we begin to help students weave together the two curriculum strands; by the end of this phase of the unit students should understand that they are engaged in some ways of thinking, talking, and acting that are characteristically labelled as science. In this phase of instruction we look for activities and resources (like the Creatures of the Namib National Geographic video) that will help students continue to develop both their understanding of science concepts and their knowledge of ways of being in a science discourse community. We consider scientists who are exploring questions related to our own. The teacher's talk about talk is essential in this phase, making invisible thinking processes more visible.

Phase IV: Reflecting on the Two Strands

In this phase of instruction, students revisit their initial predictions and explanations about the central question. They reflect on the quality of the data and evidence they have gathered to develop their explanations. Debates regarding various positions on the question are carefully discussed in a scientific argument format. The teacher carefully monitors the “arguments” and engages students in reflecting on ways in which their discussions are similar and different from discussions in scientific communities. Activities that engage students in reflecting on their learning and identifying connections across the two strands support students' integration of knowledge.

Phase V: Linking to the Next Conceptual Unit

In this phase the students are helped to bridge from one unit of study to the next. The bridge should help them see both the conceptual connections between the two units and the nature of science connections. Just as scientists' questions grow out of previous studies, so the central question or problem for the next unit of study should address questions that arose during the first unit of study. In our case, we moved to an exploration of what happens to the water that cacti and other plants take in and store: What is food for plants? Is this water food for the plants? If not, what does the water do for the plant? Why is water so important to plants, anyway?

We like to let students help shape the next questions of study but are also sensitive to our curricular goals of helping them develop across the year some connected understandings of
powerful concepts. If we let students pick the questions of study, they may not pick questions that they can explore in ways that will lead to powerful ideas. Thus, the year may end with students who have engaged in a lot of scientific activity but who have not undergone significant conceptual change. Our compromise is to increasingly let student voice play a role in shaping the questions to be explored as the year progresses.
Teacher Planning Materials:

Models Guiding the Planning Process  
Unit Planning Materials:  
   The Adaptations/Nature of Science Unit

p. 31
p. 38
Models Guiding the Planning Process:

Analysis Activity: Instructional Models that Go Beyond Processes and Beyond The Scientific Method p. 32
Constructing and Weaving the Strands Together:
  A Visual Representation of Our Goals p. 33
A Conceptual Change Model of Science Instruction p. 34
A Conceptual Change Science Learning Community p. 35
A Learning Setting vs. a Work Setting p. 36
Characteristics of Scientific Understanding p. 37
Analysis Activity

Instructional Models that Go Beyond Processes and Beyond The Scientific Method

Examine the instructional models on the next four pages.

• What do these instructional models reveal about the ways in which conceptual teaching and "process" teaching are intertwined?

• What do these models reveal about the aspects of scientific knowing that are being emphasized? How is this different than the tradition steps in "the scientific method"?

• For further elaboration of these models, read "Science Education: It's Not Enough to 'Do' or to 'Relate' (Roth, 1989-90) or "The Role of Writing in Creating a Science Learning Community" (Roth, 1992).
Nature of Science/
Inquiry in a Scientific Community

Adaptations:
Are there more different species in the desert or in Michigan? Why?

Food for Plants:
What is food for plants?
A CONCEPTUAL CHANGE MODEL OF SCIENCE INSTRUCTION

ESTABLISHING A PROBLEM

*Eliciting Students' Ideas About a Natural Phenomenon

Students should see that other students have different ways of explaining the same phenomenon.

*Challenging Students' Ideas to Create Conceptual Conflict, Dissatisfaction

Engage students in thinking through whether there is evidence for their ideas and whether their ideas really make sense. For example, have students make predictions and then read or do a laboratory activity to find out if their predictions are correct or not. Encourage students to debate among themselves.

*Contrasting Students' Naïve Explanations and Scientific Explanations

Explain and/or introduce new concepts in ways that are likely to make sense from the students' perspectives. Use a variety of different representations to explain new ideas (models, role playing, explanations, charts, diagrams, etc.). Compare/contrast students' ideas with scientific explanations.

UNDERSTANDING AND USING SCIENTIFIC CONCEPTS

Students need numerous opportunities to use new concepts to explain real world situations. A variety of activities and questions that engage students in using scientific concepts and in refining their understandings of these concepts will help students see the wide usefulness of the concepts. At first, students' misconceptions will persist as they answer these questions. The teacher, therefore, must play the role of "cognitive coach" (Collins, Brown, and Newman, 1987), helping students develop better strategies for comprehending concepts and explaining phenomena by:

a. modeling appropriate strategies
b. coaching students as they try to use the strategies
c. scaffolding the students' efforts to use the strategies
d. gradually fading the amount of teacher direction and guidance in constructing explanations for these questions.
A Conceptual Change Science Learning Community

Establish a Problem
* Elicit
* Challenge
* Contrast

Create Opportunities for Students to Use Concepts to Explain Real World Situations
* Model
* Coach
* Fade

learning is celebrated in a caring environment
personally meaningful learning as a goal

valuing & respecting others' ideas

use of evidence & shared expertise

inquiry, asking questions

trust, respect

collaboration

personal involvement in meaningful & authentic problems

public sharing and revision of ideas

ownership, commitment, shared responsibility
## A Learning Setting vs. a Work Setting:  
Creating a Conceptual Change Learning Community

<table>
<thead>
<tr>
<th>A CONCEPTUAL CHANGE SCIENCE LEARNING COMMUNITY</th>
<th>A WORK-ORIENTED CLASSROOM SETTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Sense making and learning as the goal</td>
<td>*Getting the work done as the goal; getting facts learned or activities and projects completed</td>
</tr>
<tr>
<td>*Personal, emotional involvement in meaningful and authentic problem situations</td>
<td>*Depersonalized, unemotional relationship with work, getting the products made</td>
</tr>
<tr>
<td>*Ownership and commitment by each person; responsibility shared</td>
<td>*Teacher as executive in charge of everything</td>
</tr>
<tr>
<td>*Active inquiry and question asking are valued and encouraged</td>
<td>*Getting the right answer is valued and encouraged</td>
</tr>
<tr>
<td>*Expertise comes from everyone, is shared; learning is a collaborative process</td>
<td>*Expertise comes from the teacher and learning is a private activity</td>
</tr>
<tr>
<td>*Everyone’s ideas are valued and respected as useful in the learning process; diversity is celebrated in a caring environment</td>
<td>*Workers need to keep quiet and busy; diversity is a problem for quality control and efficiency</td>
</tr>
<tr>
<td>*Good learners listen to each other</td>
<td>*Good workers listen to the teacher</td>
</tr>
<tr>
<td>*Public sharing and revising (working out) of ideas</td>
<td>*Only complete, polished final products are shared</td>
</tr>
<tr>
<td>*Evidence, not authority, is used to construct new knowledge and judge merits of ideas</td>
<td>*Knowledge comes wrapped in neat packages that are delivered from teacher or text to student; all packages are to be appreciated and not questioned</td>
</tr>
<tr>
<td>*Each learner starts and finishes in a unique place; learning as a process of conceptual change</td>
<td>*All workers create the same product or else are failures; learning as a &quot;you have it or you don’t&quot; phenomena</td>
</tr>
</tbody>
</table>

**NOTE:** The metaphor of a learning vs. a work setting for thinking about classrooms was adapted from Hermine H. Marshall (1990) in "Beyond the Workplace Metaphor: The Classroom as a Learning Setting" in *Theory Into Practice*, 29, 94-101.
CHARACTERISTICS OF SCIENTIFIC UNDERSTANDING
Kathleen Roth and Charles W. Anderson

I. CONNECTEDNESS OF KNOWLEDGE
   A. Connections among science concepts and theories
   B. Connections of science concepts and theories to prior knowledge or “real world” knowledge

II. USEFULNESS OF SCIENTIFIC KNOWLEDGE in activities that scientists and scientifically literate persons engage in
   A. Description of real-world systems or phenomena
   B. Explanation of real-world systems or phenomena
   C. Prediction of real-world systems or phenomena
   D. Design of real-world systems or phenomena
   E. Appreciation of wonders, beauties, complexities of natural world

III. WAYS OF THINKING, TALKING, AND ACTING IN A SCIENCE DISCOURSE COMMUNITY
   A. Disposition to reflect on scientific knowledge by
      1. Testing or justifying beliefs on empirical or theoretical grounds--looking for “best” sources of evidence
      2. Criticizing arguments on theoretical or empirical grounds--having the disposition to evaluate arguments critically
      3. Viewing knowledge as constantly changing, building, deepening over time--taking a historical and cultural perspective on the development of knowledge
      4. Recognizing limits to knowledge--what is known, what is not known, what is knowable with current tools, techniques
      5. Interacting with other people (through writing, discussion, argumentation) and valuing such interactions as an important part of the scientific community.
   B. Disposition to construct new scientific knowledge by
      1. Asking appropriate questions
      2. Developing solutions to problems using personal knowledge and reasoning, other resources, or empirical investigations
      3. Interacting with other people (through writing, discussion, argumentation) to develop new understandings; viewing knowledge as cooperatively constructed within a scientific community.
Unit Planning Materials:
The Adaptations/Nature of Science Unit

Central Questions and Concepts p. 38
Unit Overview: Conceptual and Activity Flow p. 42
Unit Calendar: Daily Lesson Activities and Concepts p. 45
(1990 version of the unit)
INTRODUCTORY SCIENCE UNIT:
STARTING THE INQUIRY and DISCOURSE STRAND
WOVEN WITH
A CONCEPTUAL STRAND ON ADAPTATIONS AND DIVERSITY

CENTRAL QUESTIONS:

1990 Version of the Unit:

• Are there more different species of organisms living in the desert or here in Michigan?

• Why don't we have all species of plants and animals living in Michigan?

1992 Version of the Unit (integrated with social studies focus on Native American cultural diversity from before 1492 to today and into the future):

• How have the plant and animal species of the grasslands, the desert, and the Pacific Ocean changed since 1492? How might they change in the next 500 years?

• Are there more different kinds of species in the grasslands, the desert, or the Pacific Ocean?

• Does it matter whether or not there are a lot of different kinds of plant and animal species living on earth (biodiversity)?
1990 UNIT CONCEPTS

1990 Version of the Unit:

Nature of Science and Discourse Strand

scientist
stereotype
research
writing
scientific discussions
scientific argument
evidence

Conceptual Strand

organism
structure
function
adaptation
species
(Introduce diversity, ecosystem, extinction, geologic time)
1992 UNIT CONCEPTS

1992 Version of the Unit (when integrated more closely with “1492” theme in social studies):

<table>
<thead>
<tr>
<th>Science</th>
<th>Social Studies</th>
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</thead>
<tbody>
<tr>
<td><strong>Nature of Science Strand</strong></td>
<td><strong>Nature of History and Social Science Strand</strong></td>
</tr>
<tr>
<td>science</td>
<td>historian</td>
</tr>
<tr>
<td>stereotype</td>
<td>stereotype</td>
</tr>
<tr>
<td>explanation</td>
<td>interpretation</td>
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<tr>
<td>prediction</td>
<td>perspective</td>
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<tr>
<td>hypothesis</td>
<td>evidence</td>
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<tr>
<td>observation</td>
<td>artifacts</td>
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<td>evidence</td>
<td>writing</td>
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<tr>
<td>data</td>
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<tr>
<td>scientific discussion/argument</td>
<td></td>
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<tr>
<td>writing</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Conceptual Strand</th>
<th>Conceptual Strand</th>
</tr>
</thead>
<tbody>
<tr>
<td>organism</td>
<td>diversity</td>
</tr>
<tr>
<td>structure</td>
<td>culture</td>
</tr>
<tr>
<td>function</td>
<td>race, racism</td>
</tr>
<tr>
<td>adaptation</td>
<td>discrimination</td>
</tr>
<tr>
<td>species</td>
<td>social conflict</td>
</tr>
<tr>
<td>biodiversity</td>
<td>discovery</td>
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<tr>
<td>ecosystems</td>
<td>exploitation</td>
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<tr>
<td>interdependence</td>
<td>power</td>
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<tr>
<td>extinction</td>
<td>interdependence</td>
</tr>
<tr>
<td>endangered species</td>
<td>changes in cultures over time</td>
</tr>
<tr>
<td>changes in structures and organisms over time</td>
<td></td>
</tr>
</tbody>
</table>


Unit Overview
Conceptual and Activity Flow
1990-91 Version of the Unit

I. Introducing the Nature of Scientific Inquiry Strand -
Eliciting and challenging students' stereotypes of scientists

A. Draw a picture of a scientist and describe the scientist at work
B. Interview a scientist
C. Look at pictures of scientists at work
D. Construct a list of stereotypes of scientists and start a list of “Important Parts of Almost All Scientists' Work”
E. Consider a particular nontraditional scientist. In what ways does this scientist challenge your stereotype of a scientist? Possible scientists to consider:
   1. Dorothy Hodgkin: Look at painting of her writing at a desk--Do you think she is a scientist? Introduce role of women, older people, writing
   2. Rachel Carson--The Sense of Wonder, writer and scientist. Introduce role of writing, wonder, beauty, and social action in science
   3. Rosalind Franklin and DNA--ideas of competition, discrimination and cooperation, collaboration in science (with Watson and Crick)
   4. George Washington Carver--Why so few Black scientists? What does it take to become a scientist?
   5. Dr. Roth (your teacher)--everyday people as scientists
   6. Native American scientists
II. Introducing and Weaving in the Conceptual Strand--

Learning about Nature of Scientific Inquiry and Discourse by Becoming Scientists:

**Central Question:** Are there more different kinds of species on the desert or in Michigan?

A. Brainstorm all different plants and animals you can think of that live on desert and in Michigan. Make a prediction about the central question.

B. Construct class chart that will be used to document our findings about both desert and Michigan organisms. Put brainstormed ideas on the chart (using yellow stickies that students add to the chart):

<table>
<thead>
<tr>
<th>DESERT ORGANISMS</th>
<th>MICHIGAN ORGANISMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants</td>
<td>Plants</td>
</tr>
<tr>
<td>Animals</td>
<td>Animals</td>
</tr>
</tbody>
</table>

C. Examine chameleon and Venus flytrap as interesting organisms: What structures does each have? Would you predict that these structures would enable the organism to adapt to a desert environment? to a Michigan environment? Use this discussion to introduce and start using the terms: structure, function, adaptation

D. Work in groups with resources to find out about animals that are well adapted for desert life. Report to class about your findings using the terms structure, function, adaptation. Put findings on class chart.

E. Work in groups with resources to find out about certain interesting plants that are well adapted for desert life. Report to class about your findings using the terms structure, function, adaptation. Put findings on class chart.

F. Have a race through resources to find as many names of different desert species (plants or animals) as possible. Add to class chart.
III. Weaving Together the Nature of Science and Conceptual Strands

A. Observe 3-4 different species of plants.

1. Describe the structures of the plants. What are their functions?

2. Which plant do you predict would be adapted for hot, dry desert conditions? Why?

3. How could you plan and carry out an experiment with the plants that would provide evidence that your predictions are correct or not?

B. Watch and discuss the National Geographic video, "Creatures of the Namib Desert" with a dual focus:

1. Focus on diversity of organisms and the structures that enable them to adapt to this environment. Why does the one beetle live nowhere else on earth? Why couldn't it live on a U.S. desert? Students keep a list in journals of organisms mentioned. Add organisms to class chart.

2. Focus on challenging stereotypes of scientists and constructing list of important parts of scientists' work. Imagine what it would be like to be a scientist on the desert like Jane Seeley. What does she like about her work? What do you think she does during a typical day? What would like about being a scientist like Jane Seeley? What wouldn't you like? Do you think her work is important? Why or why not? How is Jane Seeley different from the scientist you drew on the first page of your science journal?
IV. Weaving Together the Nature of Science Strand and the Conceptual Strand

Reflections and Question Raising--Revisit our central question with discussion and concept mapping activity keeping a dual focus:

A. Conceptual focus: Does anyone want to change their prediction? Can we answer our central question? Why might there be more different kinds of species in Michigan or in the desert? Why are there more total numbers of plants and animals in Michigan than in the desert?

B. Nature of Scientific Inquiry and Discourse Focus: What questions still remain unanswered? Reflect on ways we have been like scientists in gathering information to try to answer our question.

C. Combined Focus: Construct a “word picture” or concept map that shows how the different concepts (from both strands) can be connected together in meaningful ways.

V. Continuing the Weaving--Conceptual and Inquiry Links to Next Unit

A. Conceptual Focus: We have seen how important water is for plants. But why do plants need water? How do they use it? How do plants work? Is water their food? How do they get food--especially those plants on the desert? If water is their food, how do they get enough of it on the desert? What structures do plants have (internal as well as external) that enable them to adapt to the desert environment?

B. Nature of Scientific Inquiry: How can we examine in scientific ways our hypotheses about how plants get their food and why they need water?
<table>
<thead>
<tr>
<th>DATE</th>
<th>DAY</th>
<th>Topic/Concepts</th>
<th>Lesson Activities</th>
<th>Concepts [*newly introduced]</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/10/90</td>
<td>1</td>
<td>DAY 1</td>
<td>Draw a picture of a scientist at work. Write about this scientist. Discuss stereotypes of scientists.</td>
<td>*stereotype</td>
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<tr>
<td></td>
<td></td>
<td>PHASE I: Nature of Science Strand</td>
<td></td>
<td>*scientist</td>
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<tr>
<td>9/11/90</td>
<td>2</td>
<td>DAY 2</td>
<td>Discuss stereotypes of boys and girls Create class list of our stereotypes of scientists What really makes someone a scientist? Look at photo of a scientist in a lab Is this person a scientist? Can you tell by looking? Small groups: Look at pictures of humans engaged in variety of activities. Do you think this person is a scientist? Why or why not?</td>
<td>stereotype</td>
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<td>PHASE I: Nature of Science Strand</td>
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<td>scientist</td>
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<td>9/12/90</td>
<td>3</td>
<td>DAY 3</td>
<td>In journals, list 3 stereotypes of scientists Review class list about stereotypes of scientists and create class list about important features of scientists work Share and discuss pictures of humans at work: Are these people scientists? Watch video of interview with an entomologist. What important parts of scientists' work can we add to our list?</td>
<td>*writing</td>
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<td>Phase I: Nature of Science Strand</td>
<td></td>
<td>*reading</td>
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<td>*experimenting stereotypes</td>
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<td>scientists</td>
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<td>9/13/90</td>
<td>4</td>
<td>DAY 4</td>
<td>Watch video of interview with an entomologist again. What else does this scientist do besides experimenting? Look at print of a painting of an older woman working at her desk. Write to the person who lent us the print describing reasons you think this person is/is not a scientist and describing your reactions to the painting. Consider your audience. NOTE: The painting is of Nobel Prize chemist Dorothy Mary Hodgkin.</td>
<td>*talking,</td>
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<td>Phase I: Nature of Science Strand</td>
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<td>*discussing scientists</td>
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<td>writing</td>
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<tr>
<td>Date</td>
<td>Day</td>
<td>Activity</td>
<td>Notes</td>
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<td>9/17/90</td>
<td>DAY 5</td>
<td>Reflect on and add to class lists of stereotypes vs. important features of scientists' work. Tape copies of list in journals for future ref.</td>
<td>Important parts of scientists' work stereotypes scientists</td>
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<td>Read some students' letters about the painting. Reflect on ways in which students used stereotypes or important features of scientists' work in writing the letters.</td>
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<td></td>
<td>Teacher tells class a little about Dorothy Mary Hodgkin, the woman in the painting.</td>
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<td>Teacher dresses up as stereotyped scientist. Students interview her to find out if she is a scientist.</td>
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<td>Students write in journals about ways in which they are/are not like scientists.</td>
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<td>9/18/90</td>
<td>DAY 6</td>
<td>Share and reflect on journal writing about ways in which students see themselves as scientists.</td>
<td>Organism species diversity scientist</td>
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<td>Introduce terms &quot;organism&quot; and &quot;species.&quot; What organisms can we name at our school?</td>
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<td>Groups: List as many organisms as you can that live in Michigan. Do the same thing for the desert.</td>
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<td>Create a class chart of brainstormed lists of organisms.</td>
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<td>Discuss central problem: Are there more different species of organisms living in Michigan or in the desert?</td>
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<tr>
<td>9/19/90</td>
<td>DAY 7</td>
<td>Establishing the problem: Are there more different species in Michigan or the desert? Why?</td>
<td>Adaptation structure function organism species</td>
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<td>Look at brainstormed lists of desert and Michigan organisms and discuss predictions about number of species in desert vs. Michigan.</td>
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<td>Write individual predictions and reasons in journal.</td>
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<td>Define words &quot;adaptation&quot;, &quot;structure&quot; and &quot;function&quot; Use these ideas in exploring why there are no cacti living in the wild in Michigan</td>
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<td>Brainstorm ways we could do research to answer our question.</td>
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<tr>
<td>Date</td>
<td>Day</td>
<td>Subject</td>
<td>Activities</td>
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<tr>
<td>9/20/90</td>
<td>DAY 8</td>
<td>Phase II: Weaving in</td>
<td>Researching the problem: Chameleon adaptations</td>
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<tr>
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<td></td>
<td>the Conceptual Strand</td>
<td>Review terms: adaptation, organism, structure, function.</td>
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<td>Show pictures and discuss adaptations of chameleon.</td>
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<td>Fill out research chart together as a class about adaptations of a chameleon to desert environment.</td>
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<td>Read to class about desert fish.</td>
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<td>Reflective journal writing: Write a letter to Dr. Roth telling her how things are going for you in science so far this year.</td>
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<tr>
<td>9/24/90</td>
<td>DAY 9</td>
<td>Phase II: Weaving in</td>
<td>Research on desert animal adaptations</td>
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<td>the Conceptual Strand</td>
<td>Review and use terms: organisms, structure, function.</td>
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<td>Together as a class read about chameleons and study pictures of them. Describe ways they are adapted for desert life and write these down on individual &quot;research charts.&quot;</td>
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<td>In groups students begin research about desert animals (library), recording data about adaptations on individual research charts.</td>
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<td>Reflective journal writing: Write about an interesting desert animal adaptation you discovered or about something you are wondering about.</td>
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<tr>
<td>9/25/90</td>
<td>DAY 10</td>
<td>Phase II: Weaving in</td>
<td>Sharing research about desert animal adaptations</td>
<td></td>
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<tr>
<td></td>
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<td>the Conceptual Strand</td>
<td>A student from each group teaches the class, using the overhead to fill in information about desert animal adaptations on the class research chart.</td>
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<td>Groups use books to look for as many different names of desert animals as possible. These findings are added to class chart about desert species.</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Day</td>
<td>Activity Details</td>
<td>Key Themes</td>
<td></td>
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</tbody>
</table>
| 9/26/90 | DAY 11| Research on desert plant adaptations  
Quick write in journals: Use terms (adaptation, structure, function, desert, species) in a sentence in a way that shows how they are related to each other.  
Discuss our images of deserts as barren, with no plants, and our predictions that Michigan would have a lot more plant species than the desert.  
Groups do desert plant research, writing findings on research chart.  
5-minute challenge: How many different plants can you find in our resource books that live on the desert? Add these to class list of desert plant species.                                                                                       | organism structure function adaptation species research                                                                                               |
| 9/27/90 | DAY 12| Sharing research: Desert plant adaptations  
Students teach about their plant adaptation findings, writing findings on class overhead transparency chart  
Begin laboratory on plant adaptations (looking at different types of plants and predicting whether each plant is well adapted for desert life)                                                                                                     | organism structure function adaptation species research                                                                                               |
| 9/28/90 | DAY 13| Plant Lab: Desert plant adaptations  
Discuss and reflect on behavior in laboratory work.  
Write in journals about helpful things to do in groups during laboratory work.  
In groups students explore a variety of plants, hypothesizing about their likely success in living in a desert environment. Students write down their predictions and reasons.                                           | organism structure function adaptation species research                                                                                               |
<table>
<thead>
<tr>
<th>Date</th>
<th>DAY 14</th>
<th>Activity</th>
<th>Date</th>
<th>DAY 15</th>
<th>Activity</th>
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<tbody>
<tr>
<td>10/2/90</td>
<td>Research</td>
<td>Research on desert plant adaptations—Nature of scientific inquiry</td>
<td>10/3/90</td>
<td>Research</td>
<td>Research on desert plant adaptations/Nature of scientific inquiry</td>
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<td>Review structure, function, organism using index quiz cards with students taking turns as teacher.</td>
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<td>Students propose ideas of experiments that could test out our predictions about which plants are best adapted to the desert.</td>
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<td>Read from Pringle book about functions of spines on cacti.</td>
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<td>Teacher scaffolds students' efforts in critiquing these experiment proposals.</td>
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<td>Show book of desert flowers - over 100 kinds mentioned in the book.</td>
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<td>Students revisit central problem: Have you changed your prediction?</td>
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<td>Student-led demonstration: Cutting open a thick leaf to see if lots of water stored inside.</td>
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<td>Students watch video of Namib desert, keeping track of new organisms mentioned and keeping track of desert scientists and important features of their work.</td>
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<td>Discuss demonstration: Does this prove it will survive well in the desert?</td>
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<td>In journals, write down questions you're wondering about the plants you observed. How could you do an experiment to find out if these plants are well adapted to the desert or not?</td>
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- diversity
- evidence
- organism
- structure
- function
- adaptation
- species
- experiment
- fair test
- scientist
- prediction
- research
- scientist
- important parts of scientists' work
<table>
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<tr>
<th>Date</th>
<th>Activity</th>
<th>Notes</th>
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<tbody>
<tr>
<td>10/4/90</td>
<td>Research on Namib Desert organisms and scientists</td>
<td>Patience scientist important parts of scientists' work stereotype experiment research prediction discussion writing evidence diversity organism structure function adaptation species</td>
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<td>Students explain to visitor what we have been exploring in our science class.</td>
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<td>Reflect on desert organisms and scientists that have appeared so far in the Namib Desert video</td>
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<td>Watch next portion of Namib Desert video, keeping a list of organisms and scientists.</td>
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<td>10/8/90</td>
<td>Research on Namib Desert organisms and scientists</td>
<td>Patience scientist important parts of scientists' work stereotype experiment research prediction discussion writing evidence diversity organism structure function adaptation species</td>
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<td>Fast write in journals—what adaptations means to you and/or question you have.</td>
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<td>Keep writing continually until time called.</td>
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<td>Create class concept map about adaptations.</td>
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<td>Finish Namib Desert video, keeping lists of organisms and scientists.</td>
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<td>Journals: What would it like to be a desert scientist like Mary Seeley?</td>
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<td>10/9/90</td>
<td>DAY 18</td>
<td>Phase III Weaving Together the Nature of Science and Conceptual Strands</td>
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<td>10/10/90</td>
<td>DAY 19</td>
<td>Phase IV Reflecting on the Nature of Science and Conceptual Strands</td>
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<td>10/11/90</td>
<td>DAY 20 Phase IV Reflecting on the Nature of Science and Conceptual Strands</td>
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<td>Synthesis and reflection activities</td>
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<td>Finish and review tests.</td>
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<td>Create class list: Stereotypes vs. the Real Thing</td>
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<td></td>
<td>Create class project to share our findings with others. Begin work on project</td>
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PHASE I: LESSON ACTIVITY IDEAS FOR
INTRODUCING THE NATURE OF SCIENTIFIC INQUIRY STRAND
PHASE I: LESSON ACTIVITY IDEAS FOR
INTRODUCING THE NATURE OF SCIENTIFIC INQUIRY STRAND

GOALS FOR THIS PHASE OF THE UNIT

• Eliciting and challenging students' stereotypes of scientists
• Explaining to students about stereotypes and important parts of scientists' work
• Giving students opportunities to use ideas of stereotypes and important parts of scientists' work

IDEAS ABOUT TIME LENGTH AND SELECTION OF ACTIVITIES FOR THIS PHASE OF THE UNIT

We have taught this section of the unit several different ways now. In one version, we explored these ideas about scientists and the nature of science at length before going into the conceptual curriculum strand. For example, we spent a long time one year introducing students to different scientists (either in person or in books) and talking about the nature of science through these biographies and autobiographies.

Comparing that approach with our experiences in other years, we now lean towards keeping this section of the unit fairly brief with a focus on eliciting and challenging students' stereotypes and introducing a few ideas about the important and central aspects of scientists' work. It seems more natural, integrated, and engaging for students introduce these ideas briefly and the move promptly into the context of acting as scientists in studying some interesting conceptual issue. Ideas introduced about the nature of scientists' work seem more powerfully reinforced in the context of these conceptually focused, problem-oriented studies than through the biographical approach.

We present here a variety of activities that we have used. We suggest that careful selections be made to keep this section of the unit limited to approximately 4-5 lessons.
Ia. SCIENTISTS AT WORK

What do you think of when you think of a scientist at work? Draw a picture in your journal of a scientist at work.

Describe your scientist by answering the following questions:

1. What is your scientist doing? This scientist is ........

2. Do you think this scientist's work is important? Why or why not?
   I think this scientist's work is/is not important because ........

3. What is this scientist like as a person?

4. Do you think you would like this scientist? Tell why or why not.

5. What feelings do you have about science and scientists?
Ia. Scientists at Work
Teacher's Guide

Purpose
The purpose of this activity is to elicit students' stereotypes of scientists and to engage their curiosity about what scientists are really like. Thus, the activity is a kind of pretest focusing on ideas from the nature of science curriculum strand.

Introducing the Activity
Do not tell the students that this is a pretest or that you are trying to find out about their stereotypes of scientists. (They may respond by trying to alter their pictures to fit what they think is the "right" answer.) Simply tell students:

"Since this is a science journal, I thought it would be a good idea if we had the first page of our science journal (or log book) be a picture of a scientist at work. Draw a picture of a scientist at work and then describe your scientist by answering these questions."

Be careful not use pronouns like "he" or "she" when giving the directions. It will be interesting for you and the class to see how many students think to draw a female scientist without being given that hint.

We have found the follow-up questions help us understand a lot more about students' thinking than we can get from the pictures alone.

Student Response Patterns:

• Students typically draw men.
• Their scientists often are shown in a laboratory working with chemicals and beakers or (less frequently) outside digging fossils.
• They (often boys) love to put explosions and exciting events (like volcanoes) in their pictures.
• Scientists are often pictured with wild hair and crazed expressions, with students describing them as "mad" scientists.
• Scientists are almost always shown working alone.
• Scientists are almost never shown writing, reading, or talking, although they often have a lot of books in their laboratories.
• The students are more fanciful in their pictures than in their written descriptions and often attribute their pictures to images from movies and TV shows. They often seem to have some sense that these images are not true of "real" scientists, but they do not have much of an image of "real" scientists.
• Students usually think scientists' work is important because they cure illnesses and discover "things." They are not usually very clear about what things they might discover, but they can sometimes be very specific about diseases that scientists are studying how to cure.
• The questions sometimes elicit a student’s attitude toward science in school ("I would not like to meet this scientist because I hate science and am not good at science").
• In our experience with this activity, we have never had a student who had a scientist in the family. We wonder what students who come from scientist families might draw and write!
Ib. HOW WOULD A SCIENTIST DESCRIBE THE DOING OF SCIENCE?

Suppose you could interview a scientist and ask:

*Is science and doing science about experimenting?*

What do you think the scientist would say? What if you asked:

*Is science and doing science about observing?*

Talk with your partner or your group about each of the descriptions in the chart. Decide whether each description tells about science and the doing of science. Put **YES** if you think a word or phrase describes the doing of science. Put **NO** if you think the word or phrase does not describe science. Put a ? if you are not sure. In the "REASONS" column write down the reasons you had for your choice.
**Ib. HOW WOULD A SCIENTIST DESCRIBE THE DOING OF SCIENCE?**

<table>
<thead>
<tr>
<th>IS SCIENCE AND DOING</th>
<th>YES, NO, OR?</th>
<th>OUR REASONS</th>
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<tbody>
<tr>
<td>experimenting</td>
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<td>observing</td>
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<td>evidence</td>
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<td>traveling</td>
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<td>collecting data, information</td>
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<td>problems</td>
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<td>understanding</td>
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<td>caring, concern</td>
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<td>controversy, debates</td>
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<td>courage</td>
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<td>the senses</td>
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<td>giving speeches</td>
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<td>large things</td>
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<td>small things</td>
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<td>fights, attacks, being rejected</td>
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<td>nature</td>
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<td>arguing</td>
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<th>love</th>
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<td>thinking</td>
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<td>struggling</td>
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<td>knowledge</td>
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<td>asking questions</td>
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<td>patience</td>
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<td>imagination</td>
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<td>being confused</td>
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<td>explaining</td>
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<td>describing</td>
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<td>protecting</td>
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</table>
Ib. How Would a Scientist Describe the Doing of Science?  
Teacher's Guide

**Purpose**
This is another activity that elicits students' conceptions and stereotypes about the nature of science. The activity is also a first step in challenging these stereotypes; students have to discuss these ideas with classmates who may have different perspectives. This may cause some students to start wondering: Which of these words really do describe scientists? Are my ideas accurate? Is Sally right that scientists are sometimes confused? I thought scientists always had things figured out.

**Introducing the Activity**
Since this may one of the first group activities that students do in your science classroom, you will need to give them guidance concerning how to discuss ideas in the small groups. Start with the whole group and make reference to the kinds of discussions that scientists have, perhaps using an explanation something like the following:

“In our class, we are often going to discuss ideas just like scientists do. In scientific discussions, people often have very different ideas and explanations. Instead of getting upset when someone has a different idea, they get excited about different ideas and listen very carefully to them. Scientists know that they can develop better explanations and understandings of the world around them if they can benefit from other scientists' ideas. Scientists may often disagree with other scientists, but they try to understand very clearly the other scientist's idea or perspective. It is considered a helpful thing to do—not a mean or nasty thing to do—to challenge another person's idea by giving good reasons or evidence to support a different idea. But scientists challenge ideas in the spirit of everyone learning, not in a mean spirit of making fun of another person.”

“In our discussion today, I want you to try to discuss like scientists do. Listen very hard to other people's ideas and their reasons to see if you agree or disagree with them. If you agree but have a different reason, you can help the discussion by saying, 'I agree with Bob because....' If you disagree, you could say something like 'I have a different idea than Janelle. I was thinking that scientists are confused sometimes because like scientists are confused about why people get cancer.'”

“Let's practice this kind of discussion together with a few items on the list. And then I want you to try this in your small groups.”

**Developing a Science Discourse Community**
Instead of giving any of your own opinions, focus on highlighting and supporting the students in having a scientific discussion. For example, you could repeat a student's comment and then ask the class for others to either support or challenge that student's idea. When students offer a reason for their perspective or offer an alternative perspective, congratulate them for acting as helpful scientists. Encourage students to use the ? pointing out to them that scientists are often unsure and that it is a good thing in science to admit uncertainty.

**Possible Student Response Patterns:**

• Scientists do all these things because they are human beings. [Student does not distinguish which of these activities are important parts of scientists' work.]

• Science is primarily about doing experiments—observing, predicting. [Student limits scientific activity to processes emphasized in descriptions of the scientific method.]
**Variations of the Activity**

This is a very long list. Depending on the time available and your students, you may select a shorter list of ideas for students to work with. Be sure to include some ideas that will challenge students' stereotypes of scientists (go beyond “the” scientific method types of verbs).
Ic. THE STORY OF RACHEL CARSON: 
THE SENSE OF WONDER

Read or listen to The Story of Rachel Carson. This is a biography about a scientist and a writer who used her knowledge of science and writing to protect the environment. Through her writing she helped people (both scientists and people who were not scientists) care and wonder about nature.

RACHEL CARSON AS A SCIENTIST

Controversy and Debate in Science. Rachel Carson writes very powerfully about her love of nature and children. Does her writing make it sound like she faced any difficulties in her life as a scientist?

Read about the controversies and difficulties Rachel Carson faced in her life.

How do you think Rachel Carson felt about these attacks?
Do you think it was important that she wrote her books even when they were not popular with everyone?

Look back at your chart about words and phrases that describe science and the doing of science. With your partner or group, pick the 5 words or phrases that you think best describe the way Rachel Carson did science. For each word or phrase you choose, write down your reason for choosing it. Your reason might tell a story from Rachel Carson’s life.
RACHEL CARSON'S WRITING

Many scientists write papers and books that are for other scientists to read. They are very detailed reports about their studies, their experiments, their findings. It is difficult sometimes for nonscientists to read these reports. But Rachel Carson wrote for many different audiences. She tried to take her knowledge of science and write about it in ways that all people could understand and enjoy. Listen to the way she explained her view of science:

If I had influence with the good fairy who is supposed to preside over the christening of all children, I should ask that her gift to each child in the world be a sense of wonder so indestructible that it would last throughout life.

One book she wrote was for parents of young children. This book was a story about her adventures with nature that she shared with her young nephew who she had adopted after his parents died. His name was Roger, and Rachel Carson wanted him and other children of all ages to always wonder about the beauties and mysteries and unanswered questions in nature. So she wrote the book, The Sense of Wonder.

Listen to the way she wrote to parents and encouraged them to wonder about nature with their children.

(pp. 8-10, 49-52, 54-55, 81)

Wonder about the photos in the book (pp. 52-53?). Ask yourself the questions Rachel Carson asked:

What if I had never seen this before?
What if I knew I would never see it again?
Ic. Rachel Carson--Teacher's Guide

Purpose
This exploration of Rachel Carson and the subsequent activities focusing on "wondering" are designed to challenge students' stereotypes of scientists by presenting a woman scientist who used her knowledge of science in multiple ways--as a parent educating a child, as a social activist concerned about protecting nature, as an artist intrigued with nature's beauties, and as an experimenter studying about interactions in the natural world. We are always looking for differing models of scientists, hoping that students will find at least one kind of scientist that they can identify with. Many young people are more comfortable with Rachel Carson's nature-focused kind of science than with laboratory science that seems disconnected from the world.

When used in conjunction with the follow-up "wondering" activities, this lesson can serve as introduction to a long-term project in which students choose a wondering project of their own.

Variations of the Activity
Getting to know Rachel Carson could be appropriately linked to conceptual development if she were introduced during a unit of study about ecosystems and interactions among living things. For each unit of study, we are always on the lookout for interesting and different kinds of scientists who the students might find engaging.

Potential Problems with the Activity
Students may become tired of being read to if it is extended for too long. Pick interesting segments from Rachel Carson's story. Highlight the controversies that Rachel Carson faced, with some scientists challenging her credentials as a scientist. Students find this aspect of the story most interesting. They also like thinking about Roger and how he must have felt losing his parents (This is not a central purpose of the lesson and takes the discussion outside the bounds of science, but could be a valuable side excursion for other purposes).

Using this Activity in Conjunction With a Writers' Workshop
This activity can be very effectively linked to writing instruction. By sharing Rachel Carson's different writing styles, you might stimulate students to consider writing in a variety of ways about their own experiences with nature. If they do such writing in writers' workshop, it will provide you with additional knowledge about the students that may be very valuable in planning and teaching science.

Student Response Patterns:
• Students may find it hard to understand why Rachel Carson was criticized. They immediately come to her defense and empathize with how she must have felt when she was attacked and criticized.
• Young students are quick to adopt a stance as lovers and protectors of the earth and nature. They find it more difficult to develop scientific explanations to support their positions. Rachel Carson was much more than a lover of nature; she used science to advance her love of nature.
• Although many scientists questioned Rachel Carson's credentials as a scientist, students typically do not. They often think that anyone who has anything to do with nature is a scientist. It might help to emphasize both Rachel Carson's formal scientific approaches to nature study and her informal approaches to nature study. The scientific community at that time (still?) was not used to recognizing informal nature study as science.
Id. RACHEL CARSON AS A SOCIAL SCIENTIST
AND AN ACTIVE CITIZEN

Rachel Carson was not just a scientist and a writer. In many ways she was also a social scientist—a person who tries to understand people and how they interact. She tried to use her knowledge about science to help groups of people, including people in the national government, care about nature. She put her knowledge of science into action to try to change laws to protect the environment. She was a responsible and conscientious citizen who wanted to change laws to protect the earth. She worried about a world of the future in which there were “silent springs” because all the birds had died.

• Have her actions changed our lives today?
• Do you have to be a scientist to change things like Rachel Carson did?
• How can scientists and nonscientists work together to make changes?
• Is it important for nonscientists to understand science?

Be on the lookout for other scientists who are active as citizens in changing the world to make things better for all of us.
Ie. WONDERING ABOUT THE WORLD AROUND US

Think back to your experiences this past summer or over this past weekend. What are some things you noticed in the world around you? What did you wonder about these things? Imagine you are looking closely at these things right now. What are some questions you could ask about this picture in your mind?

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<tr>
<th>THINGS I NOTICED.....</th>
<th>I WONDERED.....</th>
<th>MY QUESTIONS ABOUT THIS PICTURE IN MY MIND</th>
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If. A PERSONAL WONDERING PROJECT

Start thinking about something you would like to keep wondering about and figuring out about. This would be your personal science study for a while. Maybe you want to watch birds closely or study insects with a magnifying glass. Maybe you want to wonder about cloud patterns or storms. Maybe you want to watch how babies and young toddlers learn. Pick something that you would like to watch and notice more closely for awhile.

IN YOUR JOURNAL:

Write down in your journal your idea of something you want to watch and wonder about as your personal science study. Tell why this idea is interesting to you and how you plan to watch and wonder about it.

If you are not sure about an idea yet, write down why you are not sure yet. Write down ways that you will try to get ideas or decide on an idea.
Ig. STEREOTYPES OF SCIENTISTS

When we all share one view of a group of people, that is called a stereotype. What are some views of scientists that many of us included in our pictures?

Keep your ideas about stereotypes of scientists in a list. Put the list in a special place in your journal. You will need to refer to this list often this year in science.

Where do we get these views or images of scientists from?

A Question to Ponder:

What do you think a real scientist would say about our stereotypes of scientists?
Ih. EXPLORING THE WORD "STEREOTYPE"

When we all share one view of a group of people, like scientists, we call that a stereotype. We say that all members of the group share a certain behavior or characteristic when that is not really true. For example, many people think that boys like football and girls like ballet. Those are stereotypes, because it is not true that all girls like ballet or that all boys like football.

Stereotypes can often be hurtful to people. Sometimes people use stereotypes to make fun of people. Girls who like to play football might be teased and called tomboys. Boys who like ballet may be teased and called sissies.

A stereotype can also discourage people. Some people hold the stereotype that girls cannot be football players or scientists and that boys should not be interested in cooking and sewing. Let's explore ways in which stereotypes might make us angry or upset or discouraged. Girls who love football or science are discouraged from pursuing their interests. Boys who love to cook and sew things are discouraged from developing their interests and skills.

Let's explore some of our stereotypes and think about ways that these stereotypes can be hurtful.
1. What is our stereotype of "girls"? (What is the view of girls that most people share?)

2. What is our stereotype of "boys"? (What is the view of boys that most people share?)

3. What is our stereotype of adults? (What is the view of adults that most people share?)

5. What is our stereotype of children? (What is the view of children that most people share?)

6. Are there any ways in which these stereotypes of boys and girls, of adults and children, seem wrong to you? Do any of those stereotypes make you angry?

7. Write in your journal about a time when you (or someone you know) felt upset or angry because of being stereotyped as a girl or a boy or a child.
8. Look back at the picture you drew of a scientist. Do you think a woman scientist would be upset with your stereotype of a scientist? Why or why not?

9. How could we find out whether our view of scientists is accurate?
II. ROLE PLAYING: STEREOTYPES CAN BE HURTFUL

With your group, plan a skit to show how stereotypes of women might have been hurtful to Rachel Carson. Act out and discuss your skit with your class.

With your group, plan a skit to show how stereotypes can be hurtful in our school and in our community. You can consider stereotypes of girls and boys, women and men, of handicapped people, of minority people, of homeless people, of unemployed people, of politicians, of lawyers, of hunters, of “yuppies,” of “burnouts,” of any group of people in our school or community. Perform your skit for the class.

Talk with your classmates about ways in which the skits revealed different stereotypes and how they can be hurtful.
Ii. Role Playing: Stereotypes Can Be Hurtful
Teacher's Guide

Purpose

This activity gives students the opportunity to use and apply the concept of stereotype. The skits can provide the teacher with feedback about how students are making sense of this concept.

Potential Pitfalls of this Activity

• Because this discussion is not limited to stereotypes of scientists, students might get sidetracked into issues that distract from the science study.

• Students may want to get carried away and create elaborate props that will take time to prepare. We have had most success in limiting the preparation time for this activity to approximately 10-15 minutes. We have allowed students to create props that they can have ready in that time frame.

• Students need to be prepared for this activity so they do not treat it trivially. We have had success when we first modeled the activity by constructing and acting out a skit of our own—we found this especially effective when we acted out a personal experience from our lives when we were hurt because of stereotypes.

Potential Links with Social Studies

We used this activity in conjunction with students' study of diversity, stereotypes, discrimination, racism, sexism, etc. in social studies. Thus, the lesson was an integration of science and social studies. In discussing the skits as they were performed, we challenged students to use concepts from social studies (such as diversity, discrimination, prejudice, racism) and science (such as stereotypes, scientists) to describe what they had seen.

Student Response Patterns:

We have had students act out stereotypes of girls as not being good at math and boys as know-its-alls in math, stereotypes that handicapped people cannot hear and cannot participate in sports, stereotypes that girls cannot play football and that short people cannot play basketball, stereotypes that Hispanics all have big families, stereotypes that women cannot apply for jobs in science.
Ij. CHALLENGING OUR STEREOTYPES OF SCIENTISTS:
WHAT ARE THE IMPORTANT PARTS OF SCIENTISTS' WORK?

We have talked about our stereotypes of scientists. List here three ways stereotypes of scientists—three descriptions that might be true for some scientists but are not accurate for all scientists. List your 3 stereotypes of scientists:

1. 
2. 
3. 

Look at the picture that your teacher shows you. Is this person a scientist? How can you tell? Write down your thoughts in your journal.

WITH YOUR GROUP:

_____ TALK ABOUT:

What do you think are the really important features of scientists' work? Don't think about what they wear, or where they work, or what they look like. Think about what all scientists are really trying to do in their work.

_____ WRITE ABOUT:

As a group, pick three of the most important ideas you had about the important features of scientists' work. These should be ideas that would be true for all scientists, not just some scientists. Write your three ideas down in your journal.

_____ PICK A SPEAKER:

Have a person ready to report your ideas to the class.
WITH YOUR CLASS:

Talk about the ideas each group came up with.

Choose 3 or 4 of the ideas that the class agrees are important features of all scientists' work.

Copy and save your class list of important parts of all scientists' work on the inside front cover of your journal. We want this list to be in a place where it can be quickly found, because we will refer to it often. As we become scientists in our classroom and as we learn more about other scientists, think about important parts of all scientists' work that we can add to this list!
Ij. Challenging Our Stereotypes
Teacher's Guide

Purpose
This list of important parts of scientists' work is a first step in making explicit to students important ideas about the nature of science. The list will continue to be developed across the unit, and it should become a frequent reference across the year for reflections on how we are developing (individually and as a group) as scientists in our science learning community.

Developing the Science Discourse Community
Use this occasion to once again describe and emphasize the kinds of discussions that scientists strive for. In introducing students to both the small-group and whole-class discussions, remind them to strive to have scientific discussions:

“In your groups be sure to go around and let each person suggest one or more ideas about important parts of scientists’ work. Listen carefully to each person, just like scientists try to do. Think about whether or not you agree with the reason given to support the idea. If you agree, state your reasons for agreeing. If you disagree, state your disagreement politely and give a reason. You could say, 'I disagree because . . . ,' or 'I was thinking about that a little bit differently...’ or 'What do you think of this idea. . . . ' Like a good scientist, you should be willing to change your mind if good reasons or evidence is given.”

During the discussions, continue to reflect on students' efforts to discuss ideas in scientific ways. Toward the end of the discussion period, you might encourage students to reflect on how they are doing in these efforts (either in writing in their journals or in a discussion).

Student Response Patterns:

• It is easier for students to identify stereotypes of scientists than it is to identify important aspects of all (or most) scientists' work.
• In their groups students may come up with many ideas that they think are important for all scientists but are actually stereotypes. For example, many students think that all scientists work in a laboratory.

Sample Student Responses:
The chart on the next page shows the ideas that were constructed by one class.
IMPORTANT FEATURES OF SCIENTISTS’ WORK

• Discover and describe our natural world
• Explain the why's and how's of our world
• Ask and seek answers to questions
• Solve problems, figure things out
• Study
• Observe carefully and keep notes
• Talk to other scientists
• Write about discoveries and findings
• Read journals to find out what other scientists are learning

STEREOTYPES OF SCIENTISTS

• Wear white lab coats
• Use tools like microscopes, test tubes, beakers
• Are always experimenting
• Wear glasses
• Are men
• Have wild hair
• Are mad, crazy
• Like to be alone
• Work in a laboratory
• Work with poisons, explosives, and chemicals
• Have beards
• Make monsters
• Are not old
Ik. ARE THESE PEOPLE SCIENTISTS?

WITH YOUR GROUP:
LOOK AT the pictures that your teacher gives you.

TALK ABOUT: Is each person in these pictures a scientist?
How can you tell?

DECIDE: Which pictures are scientists and which are not?

CHOOSE ONE SPEAKER FOR EACH PICTURE: The speaker will tell the class why you think this person is or is not a scientist.

WITH YOUR CLASS:
Can you recognize a person as a scientist by looking at him or her? Why or why not?

What could you do to find out if a person is a scientist or not?
Purpose
This activity gives students an opportunity to use the ideas they have been considering about stereotypes of scientists and important parts of scientists' work. As they analyze the pictures, the teacher can assess the depth of students' understanding of these ideas and points of confusion at this point in time.

Developing the Science Discourse Community
During this discussion, we found it necessary to provide quite structured support. We viewed this lesson as an important occasion to reinforce explicitly those aspects of scientists' work that are at the core of science. As students examined the pictures, we encouraged them to refer back to our class list of "Important Aspects of Scientists' Work." We had them look for evidence of engagement in different kinds of scientific activities. At the end of the lesson, we emphasized the idea that you cannot tell simply by looking at someone whether or not that person is a scientist.

Potential Pitfalls and Variations
In our most recent teaching of this unit, we chose not to use this activity because we wanted to emphasize an important aspect of scientific inquiry that we had failed to include in our first versions of the unit: the importance of ideas and vocabulary in describing and explaining our natural world. We thought we had other activities that let us get at that aspect of "scientific knowing" better than the pictures.

However, recently we had a new idea about to use the pictures to get at the conceptual nature of knowing in science. Students could be asked to imagine what the people in the picture would be saying and talking about if they were scientists. What might they be saying or talking about that would not be very scientific?

Student Response Patterns:
• Many students were tempted to make judgments based on just one part of scientists' work. Thus, if they saw someone writing, they would say it is a scientist because she is writing, rather than saying it might be a scientist because scientists do write.
• It was difficult for students to imagine that a person sitting in a meeting in a business suit was a scientist. Someone standing in front of a group lecturing in a business suit was more likely to be identified as a scientist giving a speech about his work (scientist as authority).
• It was difficult for some students to imagine that people engaged in "ordinary" activities (reading, flying in a plane, driving a car, holding a baby) might be scientists.
• On the other hand, some students easily argued that any of the pictures could be scientists because scientists do things other than their work (they have personal lives).
• Students tended to quickly identify any people in white lab coats or people working out-of-doors (especially in dramatic settings that included things like volcanoes or glaciers) as scientists.
II. INTERVIEWING A SCIENTIST

One way to change our stereotypes of scientists and to find out what scientists are really like is to talk to scientists. What questions could you ask a scientist to find out what their work is really like?

______. Talk over your ideas with your partner or your group.

______. Write down in your journal questions you would like to ask the visiting scientist that will help you figure out what the really important parts of scientists' work are.

Watch or conduct an interview with a scientist. Be thinking about ideas to add to your class list of

IMPORTANT FEATURES OF SCIENTISTS' WORK.
II. Interviewing a Scientist
Teacher's Guide

Purpose
The purpose of this interview is to support students in developing their understandings of the essential aspects of scientific work and to challenge stereotypes of scientists by providing different models of ways of being a scientist.

Picking a Scientist
We try to pick a scientist who will challenge the students' stereotypes, and we specifically ask the scientist not to come in dressed in a lab coat. We have had women scientists and scientists who work primarily in the field rather than the laboratory. We encouraged our scientists to bring in examples of their writing (lab notebooks, poster presentations used at conferences, journals) and programs from meetings they attend to highlight the speaking, reading, communicating aspects of their work.

Developing the Science Discourse Community
To help students think about the nature of scientific discourse communities, we made sure that the scientist provided rich examples of the kinds of talk and writing that go on in the scientific community. We talked to the scientists ahead of time to make sure that this would be a focus of their conversation with the students.

It was important to scaffold the follow-up discussion of the interview to highlight “important aspects of this scientist's work” and ways in which this scientist challenges the stereotype of scientists. We had students keep their journals open to the class list of “Important Parts of Scientists' Work” during the discussion.

Student Response Patterns
• We encouraged students' questions that enabled the scientist to seem more human (Are you married? Do you have kids? Do you do other things besides work?).
• Students' questions often are limited to their stereotypes of scientists: What kinds of experiments do you do? Have you ever dissected anything? We had to help students think about questions that might challenge these stereotypes: What is a typical day like for you? How much time do you spend doing an experiment vs. talking with other scientists?

Possible Variations
This activity could be used at any time during this unit or other units to continue to challenge students' stereotypes of scientists. One year we videotaped a teacher-conducted interview with a scientist and brought the videotape in to the class. Another year we had the students develop the interview questions and conduct the interview. The advantage of the teacher-conducted interview on videotape was that it gave more focus to the interview and the discussion about the interview. The teacher made sure that the questions revealed aspects of scientists' work that are typically invisible to students (the nature of their collaboration and discourse, in particular). The videotape also had the advantage of allowing us to revisit it in our analysis of important aspects of scientists' work.

Another possibility is to invite several scientists in to be interviewed across the year, or to have students in small groups go out and visit and interview scientists in their workplaces. The scientists could be chosen based on the ways in which their work relates to the particular concepts and topics being explored in science class. Videotapes of these interviews could then be shared and discussed in class.
Im. IS THIS WOMAN A SCIENTIST?

Look at the painting of the woman. Think about whether or not this woman is a scientist. Choose **three** of the sentence starters below and write in your journals about this painting:

1. I think this woman could be a scientist at work because . . .
   
   (give at least 3 reasons)

2. I do not think this woman is a scientist because . . .
   
   (give at least 3 reasons)

3. One question I would like to ask this woman to find out if she is a scientist is . . .

4. One thing I really like (or dislike) about this painting is . . .

**OPTIONAL:** Write to the artist about your reactions to the painting.
Im. Is This Woman a Scientist?
Teacher's Guide

Purpose
This analysis of a painting of the Nobel Prize winning chemist, Dorothy Crowfoot Hodgkin, as she is shown busily writing at her desk in a home office, provides an opportunity for students to use the ideas they have been developing about essential aspects of scientists' work vs. stereotypes of scientists. It highlights the role of writing in science. The scientist is shown with four hands in motion to capture the active nature of her thinking and writing.

Student Responses
• She might be a scientist but right now she is at home working on her taxes.
• She is not a scientist because she is old. Scientists are not old.
• She is a scientist because she has a model of something in front of her (not because of her writing).
• Students' reactions often focus on the illusion of four arms that the artist has used to represent Hodgkin's active mind. Through discussion, some students might raise this interpretation, but more typically students are just baffled and fascinated by this aspect of the painting.

Using this painting
We typically do not tell the students who this scientist is until the next lesson. We then do something like Acitivity In, helping students get to know Dorothy Crowfoot Hodgkin. Then we come back to the painting and consider how this painting represents a scientist. We contrast it with our drawings of scientists at the beginning of the year. Usually students are more insightful about the “four arms” in the painting after they have gotten to know Hodgkin a little more.
In. GETTING TO KNOW A SCIENTIST:
DOROTHY CROWFOOT HODGKIN

Does this headline taken from a 1964 newspaper tell us something about the stereotypes of scientists? How do you think Dorothy Hodgkin felt to be described as a "British wife?"

NOBEL PRIZE FOR BRITISH WIFE

Read excerpts from Chapter 6 in A Passion for Science (Wolpert & Richards, 1988).

• What is Dorothy Crowfoot Hodgkin like as a person? What was her family like?
• What does she feel passionate about?
• What does she mean when she says she "thinks with her hands"? Does it ever help you understand things better if you "think with your hands"?
• Was it ever difficult for her being a woman scientist?
• When you look at the painting of Dorothy Hodgkin now that you know something about her life, do you look at the painting in new ways? What do you think now about her "four hands"?
• What do you think Dorothy Hodgkin would say is one of the most important features of scientists' work?
• What questions would you like to ask Dorothy Hodgkin?
Io. USING THE IDEA OF STEREOTYPES:
ADDITIONAL ACTIVITY IDEAS

FIELD TRIP OR CLASS VISITORS: Visit with a scientist and look closely for ways in which this scientist is different from our stereotype of a scientist.

CONDUCT A SURVEY STUDY: Write a survey to find out how accurate our stereotypes of scientists are. Send the survey to local scientists.

STUDY THE NEWS: Study TV news and newspaper and magazine articles. Find examples of scientists at work who are not at all like our stereotypes of scientists.

CREATE A SCHOOL SURVEY: Display pictures of both scientists and nonscientists at work. Have some of your scientists look like our stereotype of scientists. Have some of your scientists look very different from the stereotype of a scientist. Invite classes in the school to guess which ones they think are scientists. The person who makes the most correct guesses could win a prize. You could announce the winner and your explanations of why so many people guessed wrong over the PA system one morning, at a school assembly, or in an article in a school newsletter.

WRITE A STORY FOR CHILDREN (with pictures) about the life of Dorothy Crowfoot Hodgkin.
Ip. WAYS I AM LIKE A SCIENTIST

Write in your journal about ways in which you are like a scientist. This could be a story about a time when you really felt like you were a scientist.
Purpuse
This activity can be a wonderful assessment device. As students tell their stories about a time when they felt like a scientist, they reveal which aspects of science are most essential and important to them. Lingering stereotypes of scientists are also easily identified in this activity.

Potential Pitfalls
If you just give the assignment without any prewriting work, students tend to write only brief statements that do not help us assess their learning (“I am like a scientist when I explore the woods in the park.”) We have found that we get much richer and revealing stories from students if we model a story of our own first. A story I used with one class is provided on the next page.

Variations: Connections to Parent Conferences and to Writers' Workshop
We have found that students will get much more invested in this activity if we treat it as a genuine writing activity that has an outside audience. We have approached the writing activity from a writers' workshop perspective, supporting students in drafting and rewriting for a particular audience: their parents and teachers at the parent conference time. We encourage students to use the story as a chance to share how they have grown as scientists.

Student Response Patterns
• Some students continue to represent science as "doing experiments." Their responses reveal a focus on science processes and doing and little or no emphasis on the purposes of all this doing: ideas, explanations, concepts.
• Students who mix into their stories about experiments something about the kinds of understandings they develop from such experiments are capturing a richer picture of "doing science."
• Some students will talk about times they do writing. Look for evidence that they are thinking about purposes of writing that are appropriate in scientific inquiry. If they talk about feeling like a scientist when they write, examine closely what kinds of writing they are considering to be "scientific" and why.
• Look for the opportunity to share with the class examples of student responses that capture the richness of a science discourse community (e.g., "I felt like a scientist when I debated with John about whether or not there were such things as UFOs.")
Teacher Journal Entry: Ways I've Been Like a Scientist

11/10/90 My Story about Ways I've Been a Scientist (used as a model for students in writing their own stories)

In the desert adaptations unit I think we all were scientists (not just like scientists!) as we tried to figure out whether there were more different kinds of plants and animals in the desert or in Michigan. I liked this because we were trying to discover something that I don't think anybody has the answer to. It wasn't just something answered in a textbook. We studied the problem by asking questions like, “Do any flowers live on the desert? Do trees live on the desert?” We were scientists when we asked these questions. We then studied to get answers to our questions. We read in books. We also observed some plants that were adapted for desert life. We watched a video to find out more about desert organisms. We did a lot of writing in our science journals about our ideas and our findings. We started to solve the problem and change our predictions. At first most people thought there were many more kinds of organisms in Michigan, but now I think people are not sure. I bet if we had a discussion about it in class today, we would have a good scientific debate. People would have good evidence to support their hypotheses. I really feel like a scientist because I am still wondering about this question and how we could get better evidence to answer it!
Phase II: LESSON ACTIVITY IDEAS FOR
INTRODUCING THE CONCEPTUAL CURRICULUM STRAND AND WEAVING
IT INTO THE NATURE OF SCIENCE STRAND:

ADAPTATIONS AND BIODIVERSITY
Phase II: LESSON ACTIVITY IDEAS FOR
INTRODUCING THE CONCEPTUAL CURRICULUM STRAND AND WEAVING IT INTO THE NATURE OF SCIENCE STRAND:

ADAPTATIONS AND BIODIVERSITY

Goals For This Phase Of The Unit
• Elicit students' ideas and predictions about the central question: Do you think there are more different kinds (species) of plants and animals in the desert or in Michigan?
• Introduce (explain) concepts of adaptation, structure, function, species, (and biodiversity, extinction if possible)
• Engage students in collecting information about plant and animal species and their adaptations in the desert

Ideas About Time Length And Selection Of Activities For This Phase Of The Unit
This is the heart of the unit and where we found the students the most engaged. We found it advantageous to get students into this inquiry process quickly and to use this inquiry as a context for reinforcing and expanding students' understandings about the nature of scientific inquiry and discourse through explicit discussion of those themes throughout the study of species diversity on the desert.

Choose activities that seem both conceptually engaging and important and provide natural and potentially powerful opportunities to reinforce and extend ideas about the nature of scientific inquiry. In addition, we advocate choosing activities that introduce central concepts and that enable students to use those concepts as they strive to understand them.

Importance of Activities that Introduce Concepts--Is This the Same Old Thing of “Telling”? This phase of the unit involves introducing some scientific terms (adaptations, structure, function, species, diversity, extinction) and providing opportunities for students to practice using those terms as a way to come to understand them and as a way to develop a meaningful response to the central question of the unit. At times we wonder if we are just falling back on traditional “telling” kinds of instruction when we give explanations of words and then construct activities that engage students in using these ideas. Are we simply having kids memorize words and definitions? Are we just lecturing?

Through our study of this question we have developed two kinds of answers to this question. First, we have discovered that teaching children about ideas and words that scientists value can be a powerful way of helping them figure out the importance of the “conceptual connection” in science. On our most recent list of “Important Parts of Scientists' Work,” we now include “use words and language in special ways” and “like to play around with ideas to understand the world around them.” We like these additions to our list and feel they help communicate a much richer picture of science than our earlier lists.

Secondly, we see a clear distinction between lecturing and memorizing vocabulary words in traditional didactic instruction and introducing key terms that will be useful in solving problems in our approach. We believe that students can develop much richer explanations about the central question because they can draw on powerful concepts like adaptation, structure, and function. These are also terms that will be useful to them in explaining how plants make their own food, how life on earth has changed over time, how food and oxygen get to our body cells, how organisms interact in ecosystems, et cetera.
Using A Genuine Problem: A Question with No Predetermined Answer

We do not think our central question is necessarily the most ideal one. One thing we do not like about it is that it is not really the kind of question a scientist would ask; it does not have a "why" or a "how" embedded in it. However, we were very pleased with this question because it was one that we did not have an answer for. The question enabled us to introduce and use important science concepts like adaptations, species, biodiversity, structure, function, and so forth. But we did not expect to end the unit with clear answer to the question. We felt that this aspect of the central question was of particular importance for this first unit in the year for four reasons:

1. The question enabled us to engage honestly in inquiry with the students.
2. Students felt their ideas could contribute to the collaborative inquiry; the problem enabled them to feel safe in this science discourse community.
3. Students learned that the discourse in this classroom was focused on genuine sense making rather than on guessing the answer that the teacher has in her head.
4. The lack of an answer at the end of the unit modelled important aspects of the nature of scientific inquiry--the tenativeness of knowledge, the messiness of inquiry, the need for multiple approaches and patience in scientific inquiry.
IIa. BEING SCIENTISTS: ARE THERE MORE DIFFERENT SPECIES OF ORGANISMS LIVING IN THE DESERT OR HERE IN MICHIGAN?

Today we are going to start becoming scientists ourselves. As we become scientists, we will get to know better what it means to be scientists. It will help us develop better understandings of what is really important in science.

SCIENCE AS QUESTIONS. Scientists are always asking questions and trying to find evidence that will help them answer their questions about the world around them. Scientists never feel like they have completely answered a question. As soon as they get some answers, they start thinking of new questions! In our study of science this year, we will focus on trying to answer important questions about the world around us. As we look for answers, we will ask many new questions. Some of our questions we will be able to answer...but never completely. Every answer should lead to new questions! Some of our questions we may not be able to answer, but we can begin to collect evidence and data that will help us answer the question. Some of our questions would take much longer than one year of study to answer, but we can get the research process started. Maybe next year's fifth graders will pick up where we left off, or maybe some of us can continue to explore these questions in sixth grade. Maybe we can pass along some of our findings to scientists who spend their lives studying these questions.

Like good scientists, we will keep track of our questions--even those that we will not have time this year to study. We will write down good questions that would be worth studying in the Question Notebook. When you enter a question in the Question Notebook, be sure to write down your name and the date. Just like scientists, we will have to decide which questions we want to explore carefully. We will have to consider which questions we can study in meaningful ways given the time and materials available to us. Of course, scientists also pick questions to study that seem interesting and important to them. We will have to make similar choices.

To get us started in scientific inquiry, we will explore a question that last year's fifth graders studied but could never answer. As far as they were able to discover, no one knows for
sure the answer to this question. Maybe we can develop a better answer to the question this year!

Here is the question:

*Are there more different species (kinds) of plants and animals living in the desert or here in Michigan?*

Last year's students got wondering about what would happen to plant and animal life in Michigan if the atmosphere warmed up because of all the pollution. Many scientists are predicting that this is going to happen. Would plant and animal species in Michigan die off? Would oak trees and black squirrels become extinct? Would Michigan become like a desert? If Michigan did become like a desert, what plant and animal species would live here?
INTRODUCING A FEW NEW WORDS:

Scientists often use special words in order to be very precise in their descriptions. Two words we need to understand in answering our question are species and organism.

An organism refers to any living thing. In this classroom, we have about 25-30 human organisms. Are there other kinds of organisms in this classroom? in our schoolyard?

A species refers to a group of living things (organisms) that share very similar characteristics. A male and a female of a species can have babies that grow up to have similar characteristics to the parents.

NOTE: Our question is asking about how many different kinds, or species, of plants and animals live in the desert and in Michigan. It is not asking about how many total number of organisms there are.
WHAT DO WE KNOW ALREADY? One way scientists begin to study a problem or a question is to think about what they already know. We will start our study of plant and animal species here in Michigan compared to the desert by finding out what we already know about this question.

WITH YOUR GROUP:
LIST as many plant and animal species that you can think of that live in Michigan. Each group needs two recorders: One person write down the list on the group worksheet. Another person will write each species name on a yellow stickie.

LIST as many plant and animal species that you can think of that live in the desert. One person write the list on the group worksheet. One person write each species name on a yellow stickie.

WHEN TIME IS CALLED, count the number of different species you named in each of the four categories (plants in Michigan, plants in the desert, animals in Michigan, animals in the desert).

AS A CLASS:
CONSTRUCT A CLASS CHART. When it is your turn, place the yellow stickies on the class chart. Count up how many different species in each category were named by the class as a whole.

PUT QUESTION MARKS next to species that you are not certain about. Are you sure you could find evidence to show that each of the species you listed really does live in the desert or in Michigan? The question marks will indicate which ones we need to find out more about.
DISCUSS: What are your ideas, or hypotheses, about why it was harder to name desert organisms than Michigan organisms?

Why don't we have all the desert species living here in Michigan? Why don't all the Michigan species live in the desert?

How sure are you that there really are more different kinds of species living in Michigan than in the desert?

Do you have ideas about how we could find out an answer to this question?

WRITE IN YOUR JOURNALS. Some scientists study how many different kinds of organisms live in an area. If you could thoroughly study Michigan and the desert, do you think you would find more different species (kinds) of organisms in Michigan or on the desert? Explain the reasons for your prediction.

We will revisit your predictions later as we collect more information about desert and Michigan plant and animal species.
**ORGANISMS FOUND IN**
**MICHIGAN AND THE DESERT**

**Names:**

<table>
<thead>
<tr>
<th>MICHIGAN</th>
<th>DESERT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants</td>
<td>Animals</td>
</tr>
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<td></td>
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IIa. Being Scientists:
Are There More Different Species Of Organisms
Living In The Desert Or Here In Michigan?
Teacher's Guide

Purpose
This activity is designed to engage the students in the central question of the unit and to elicit their ideas about that question. Through brainstorming their ideas we try to get students interested and involved in the question.

Student Response Patterns
• Students usually predict that there are more different species in Michigan than in the desert, although in the follow-up discussion some students usually suggest that maybe we think there are more species in Michigan because we know Michigan better than we know the desert.
• Students can usually name many more animals than plants and many more species in their native area (Michigan, in our case) than in the desert.
• Students sometimes focus on naming groups of plants (weeds, flowers) rather than specific species. They are more likely to give species names with animals.
• Students have trouble understanding the central question's focus on "more different species". They tend to turn the question into a question about how many total organisms live in Michigan or the desert." From this perspective, they at first have a hard time thinking that the question is a valid one: "Of course, there are more plants and animals in Michigan--look at how empty the desert is!" We try to work with them on understanding the question but also do not worry about the confusion too much at this point in the unit.
• Our students never raised a question that we thought was important: What do mean by "the desert"? Are we talking about all deserts in the world or just U.S. deserts? During the unit we had students explore the locations of deserts throughout the world, and we added to our class chart species that live in any desert in the world.

Variations--A Class Chart
We have found it very helpful to create a large class chart like the individual chart included in this activity. After students work individually and in groups to brainstorm plant and animal species, we have them write their group's responses on small post-its which they place on the class chart. We continue to add to the class chart throughout the unit. This provides a focus for our discussion of the question about plant and animal species diversity in the desert and in Michigan.

Creating a Science Discourse Community
In discussing the various predictions about the central question, it will be important to teach students certain norms and values in science discussions. We have taught students to include a reason with their prediction, to show respect for others' ideas by responding to them, to speak directly to a person who asserted an idea when responding to them, and to use phrases like the following when challenging or supporting an idea:
• I have another reason to support Jeremy's idea.
• I was wondering what evidence you have to support that idea, Jane.
• Jennifer's evidence made me think of another idea.
• I am confused by your idea, Jennifer. Are you saying that....?
• I think that. (or My hypothesis is)...because....
• I disagree with your hypothesis, Amber, because....
• I want to change my idea because....
• I have a question about Morgan's hypothesis.
Variations: The Question Notebook

To show our valuing of good questions, we introduce a Class Question Notebook where students can record a question they pose that the class thinks is important and worth keeping track of. The student with the question writes the question in the notebook, dates it, and signs his/her name. This list of questions is later revisited as we get further into the inquiry.
IIb. ADAPTATIONS

Why don't we have cacti living here in our yards in Michigan? Why aren't there palm trees swaying in the breeze in downtown Holt or Lansing or Flint or Detroit? Why don't we have Gila monsters living in the woods here in Michigan? Why do rabbits survive very well both in Michigan and in the desert? Scientists have studied these questions and found out that plants and animals have special body parts (or structures) and special ways of living (behaviors) that enable them to survive in certain kinds of environments. These structures and behaviors that have enabled the plant or animal species to survive in a particular kind of environment are called adaptations.

Let's explore what we mean by structures, behaviors, and adaptations by studying carefully an organism that lives in the desert as well as in many other kinds of environments. We say this animal, the chameleon, has adaptations that enable it to survive in many different kinds of environments.

What are some things that an organism needs to stay alive?

Look at the pictures of the chameleon. What structures (body parts) do you observe? How do you think these structures enable the chameleon to get the things it needs to stay alive?

**FILL OUT THE CHART** with information about the structures that enable the chameleon to adapt to a desert environment. Tomorrow you will explore other desert animals in the same way—looking for evidence of structures that enable the organism to adapt to a desert environment.

*Reflecting on your learning.* Circle words in the paragraph you just read that are new to you. Put question marks next to the ones that you still do not really understand.
## IIc. ADAPTATIONS TO DESERT ENVIRONMENT: Chameleons

<table>
<thead>
<tr>
<th>Name of organism</th>
<th>Structure that helps it adapt</th>
<th>Function of that structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chameleon</td>
<td>tongue-long and sticky</td>
<td>to catch flies for food</td>
</tr>
</tbody>
</table>
INFORMATION ABOUT CHAMELEONS

Structures and Functions:

Tongue--51/2 " long; can stretch 11/2 times its length; sticky saliva, rough surfaces; takes 1/16 of a second to zap it out and back
Toes--claws, adhesive pads
Skin--change colors
Eyes--can move independently so chameleon can be looking in two directions at once
Horns--protection
Tail-balance, wrap around limbs

Behaviors:

Moves slowly--would lose a race with a turtle
Ability to puff itself up--frighten off enemies
Hissing sound--to frighten off enemies

There are 80 species of chameleons. They are adapted to mountains, rain forests, dry regions like deserts. They live in trees in Africa, Madagascar, India, the Middle East, Spain. They range from 11/2 inches--3 feet long. They have been around for tens of millions of years and are dinosaur-like in many ways.

To illustrate ability of the chameleon's tongue. Place a candy kiss about 8 inches from the mouth of a student. If you were a chameleon you could stick your tongue out and get the candy kiss without moving any closer. Why would that be an extremely helpful adaptation?

References: The Remarkable Chameleon by Lilo Hess

Chameleons: Dragons in the Trees by James Martin
IIb and IIc. Adaptations and Chameleons
Teacher's Guide

**Purpose**
This activity introduces students to some concepts that they will use throughout their exploration of the central question: adaptations, structures, behaviors. The lesson reflection emphasizes that it is encouraged in this discourse community to have questions and confusions. The chameleon was chosen as an entry point because it has many interesting structures and behaviors that will be engaging for the students. We use the chameleon as a point of focus to help the students become comfortable with the ideas of structure, function, adaptation that they will later use in investigating the central question.

**Potential Pitfalls**
It is more important to get students trying to use the words “adaptations” and “structures” than it is to require them to memorize definitions of these words.

**Student Response Patterns**
• Adaptations is a very difficult word for students to understand. This lesson is just an introduction to the concept. Students will not really understand it until they have had multiple opportunities to use the idea in different contexts across the unit.
• The word “organism” is easily confused with the word “organ” (or “orgasm” sometimes!).

**Creating a Science Discourse Community**
Because our focus here is to develop a shared understanding of certain concepts and terms, we use this activity as a place to explicitly talk about the nature of talk and words in scientific communities. We emphasize the ways in which scientists try to be very clear about their meanings and uses of words and ideas. Through the reflection at the end of the activity, we also teach that scientists value confusion and questions and understanding. Good scientists, we say, are willing to share their confusions because they recognize that it might help the whole group develop clearer and better understandings if their questions and confusions are shared. Phrases we teach students to use include.

• I am confused about the word.....
• I don't get what you mean when you say.....
• That doesn't really make sense to me....

**Variations--Observing Chameleons**
One possible variation here is to bring a small anole or chameleon to the classroom. Having students watch the organism in action can be a powerful motivational tool, although we have found that books with photographs of chameleons in action often illustrate the structures and functions more dramatically than watching a small anole.
IIId. USING THE IDEAS:

ORGANISM, STRUCTURE, FUNCTION, ADAPTATION

JOURNAL ENTRY:

1. What adaptation of the chameleon was most interesting to you? Why?
2. What is something you are wondering about chameleons?

USING THE TERMS IN A SENTENCE:

Each person take a turn filling in this sentence in a different way:

A ___(organism)______ has a ___(structure)____ which helps it to ___(function)____.

Fast Write:

Pick three of these words (or more, if you can) that go together somehow:

structure function adaptation species diversity organism

Use the words in a sentence to show how they go together.
II. Using the Ideas:
Organism, Structure, Function, Adaptation
Teacher's Guide

Purpose
The purpose of this activity is to support students in using these new concepts of adaptations, structure, function, and organism so that they will be able to use them more independently in their exploration of the central question: Are there more different species of organisms in Michigan or in the desert? This activity encourages students to practice using the terms and to see the connections among them.

Developing the Science Discourse Community
Again, we emphasize the reasons why we need to understand and use appropriately certain terms in our inquiry. We link this to ways in which scientists communicate and describe the world around them. We try to motivate students to want to learn these terms so that they can communicate their findings about the central problem to people outside our classroom—including scientists.

The question, “What is something you are wondering about chameleons?” is a very important one to us. We use questions like this throughout the unit and the year to communicate to students that such wonderings are essential aspects of knowing science. We then look for ways to support students in pursuing their questions and wonderments. Sometimes we can provide an answer to a question; other times we encourage students to define ways in which they could explore their question through reading or other kinds of investigation.

Potential Pitfalls
We worry a lot that this lesson will teach students that science is about memorizing big words for no apparent reason. But on the other hand, we want students to be able to use these ideas in their research about species diversity in Michigan and the desert. Therefore, we use this activity only briefly and emphasize why we are doing it. We tell the students explicitly that they are going to need to use and understand these ideas to be able to explore our focus problem effectively. We also challenge them to learn to use these concepts so that we can later communicate our findings about our inquiry with an outside audience of scientists.
IIe. DESERT ANIMAL RESEARCH

PART I.
Each group will choose one desert animal and find out about the many different structures/adaptations that animal has.

FILL IN your findings on the class chart.

PREPARE TO TEACH the class about your desert animal and its adaptations.

* camel
* roadrunner
* kangaroo rat
* spadefoot toad
* jack rabbit
* tortoise
* trap-door spider
* sidewinder snake

PART II:
Each group will be given time to explore multiple resource books about the deserts. Try to find as many different animal species that live on the desert as possible. Have a group recorder write one animal species name on each yellow stickie.
AS A CLASS:

Figure out how many different animals species you have identified. Add these species to the class chart.

JOURNAL WRITING:

What do you think now about our question: Are there more different species of plants and animals on the desert or in Michigan? Explain the reasons for your prediction.

Have you changed your prediction? Why or why not?
## Ile. ADAPTATIONS TO DESERT ENVIRONMENT: Animals

<table>
<thead>
<tr>
<th>Name of organism</th>
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<td>to catch flies for food</td>
</tr>
</tbody>
</table>
II. DESERT PLANT RESEARCH

Introduction

What is your image of a desert? When you close your eyes and imagine a desert, does it have plants and trees? Or is it mostly empty and sandy? Do we think of deserts as having very many plant species?

Read "How Plants Survive in the Desert." What is another word for "different methods to survive"?

PART I:

Each group will study one plant that is adapted to desert life. Find out about as many adaptations as you can for your plant.

*mesquite tree
*barrel cactus
*saguaro cactus
*Bi vine
*brittlebush
*ocotillo
*desert marigold

FILL IN THE CHART.

PREPARE TO TEACH the class about your plant and its adaptations.
PART II:

5-minute research challenge: In 5 minutes identify as many different plant species names as you can. Use the resource books available in the classroom.

One person should be recorder, writing each plant species name on a yellow stickie.

AS A CLASS:

Figure out how many different desert plant species you have identified. Add the new species to the class chart.

JOURNAL WRITING:

Were you surprised about how many different species of plants live on the desert? Explain why you were (or were not) surprised.
III.f. ADAPTATIONS TO DESERT ENVIRONMENT: Plants

<table>
<thead>
<tr>
<th>Name of organism</th>
<th>Structure that helps it adapt</th>
<th>Function of that structure</th>
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Purpose
This is a data gathering phase to help students develop their thinking about the central question: Are there more different kinds of animals and plants in the desert or in Michigan? This research is also a context in which students can use and develop their understandings of key concepts (structure, function, adaptation, organism, species, diversity).

Potential Pitfalls
If students lose sight of the central question, this library research activity can become meaningless and boring to students. We challenge students to find out about species that they did not know about before and to find interesting adaptations that enable these species to live in desert regions. As the research proceeds, we continually compile our data using the post-its on the class chart. As the chart starts filling up with findings, students start to get more excited about the research. We also return to the central question often, asking whether students want to change their predictions and hypotheses.

Students can also get distracted from the central question by texts that are too difficult for them to read. Or they may have trouble finding the sections in the texts that address their questions. Therefore, we carefully select a set of texts, marking with post-its places in the texts that will be accessible to our students. Sometimes we guide students to photographs and the captions beneath them. Sometimes we write on the post-it: “Read this paragraph about the mesquite tree!” We do not want this activity to become focused on learning how to find information in texts, so we heavily scaffold the process so that students’ reading and talk can focus on the different plant and animal species and their adaptations.

Some Good Reference Sources for Fifth Grade Students
Desert Life by Barbara Taylor
Animals Where They Live by J. Feltwell
A Night and Day in the Desert by J.O. Dewey

Developing the Science Discourse Community
As students are working in small groups, we monitor their work closely--talking with them about their findings, scaffolding their reading of the texts.

We frequently hold whole group discussions as a place to compile our data. In these discussions individual students report out about the species they have discovered, describing interesting adaptations and questions they have about the species.

A key activity in whole group discussion is revisiting the central question. Somewhere in this process, we introduce students to the idea of scientific discussions, debates or arguments. We characterize the nature of these arguments and talk about why scientists value them. As we revisit and reconsider the central question in light of emerging data, we encourage students to develop, elaborate and change their hypotheses and their explanations. We keep track of the changes in our predictions and reasons on a class chart, often identifying a hypothesis with a student name (Janette’s hypothesis). We also encourage students to explore what kinds of evidence would convince them that a particular hypothesis was true (or not). In addition, we encourage students to think of alternative ways of getting support for our emerging ideas.

It is in these “scientific arguments” that interest and excitement really seems to start taking off.
**Student Response Patterns**

- Usually students start considering a change in their predictions somewhere in this research process. They start getting excited about all the different species that are adapted for life in the desert, and they are amazed at all the species that they had never heard of before.
- Students will often change to a prediction that there are more different species in the desert but more total organisms in Michigan. This is an exciting change because it reflects an understanding of the idea of "species" and of the central question.
- Students often suggest that a way to study our question would be to travel to the desert. This provides a good lead-in the National Geographic video about the Namib Desert.
- Occasionally a student will challenge the idea that a visit to the desert would clear everything up: How would we know that we had found every single species? We try to highlight such questions and challenge students to pursue them.
- Students do not usually question whether there are species in Michigan that they do not know about. We never address this in our unit, but it could be an interesting direction to pursue.

**Variations**

It might be interesting to engage students in doing similar research to discover Michigan species they never knew about. One way to do this might be to explore endangered species in Michigan (which are usually species that students have never heard of).
Phase III:

LESSON ACTIVITY IDEAS FOR WEAVING TOGETHER
THE NATURE OF SCIENCE STRAND
AND THE CONCEPTUAL STRAND
GOALS FOR THIS PHASE OF THE UNIT
• Opportunities for students to use ideas about adaptation, structure, function, and species diversity to reconsider the predictions we made about the central question.
• Challenge students to reexamine their predictions in light of research findings about plant and animal species that are adapted for desert life.
• Use ideas about stereotypes of scientists and the important parts of scientists’ work to reflect on our own work as scientists and on the work of other scientists we encounter during our inquiry.

IDEAS ABOUT TIME LENGTH AND SELECTION OF ACTIVITIES FOR THIS PHASE OF THE UNIT

This is the phase of the unit where we want students to start acting in the scientific ways that we considered in Phase I. We want them to use evidence to reason about their predictions, to be willing to reconsider and change their ideas in light of new evidence (not teacher or text authority), to engage in scientific debate and argument, to challenge each other’s ideas and raise questions in the spirit of collaborative inquiry and understanding, to recognize the limits of our data to provide a definitive answer to our question. We support them in acting as scientists as they consider the desert vs. Michigan question. Reflections on the inquiry process are linked our earlier exploration of stereotypes and important aspects of scientists' work: In what ways are we acting, thinking, and talking like good scientists?

Activities should support the development of a science discourse community. We look for ways to engage students in many of the essential characteristics of scientific understanding—observing, hypothesizing, reasoning from evidence, debating and reconsidering explanations of phenomena, raising questions, proposing further avenues of investigation. We want these activities to support students in developing the habits of mind captured on our list of Characteristics of Scientific Understanding—habits that include genuine sense-making, willingness to puzzle through problems and not accept easy answers, willingness to persist with a problem, to raise questions and to share confusions.

Typically we have not spent a lot of time trying to come to consensus about the answer to our central question. Instead, we are satisfied if we can engage students in some good scientific arguments and help them understand the incompleteness of our answer to the question.
IIIa. OBSERVING, COMPARING, AND PREDICTING: WHICH PLANTS ARE BEST ADAPTED TO DESERT LIFE?

Today we will study carefully several different plants and consider which of these plants we think would be well adapted for desert life. To make good predictions, we need to think about all that we have learned about different kinds of desert plant species and their adaptations for desert life. We will also need to observe our plants very carefully. So we need to think about what we know about desert plants and we need to observe and study the plants very carefully.

**To Do In Small Groups:**

1. First, take about 15 minutes to observe your three plants carefully. Describe your observations of each plant in your science journal. Be sure that all group members get a chance to observe carefully each of the plants.

2. Make a chart like this in your science journal:

<table>
<thead>
<tr>
<th>Plant</th>
<th>Structures</th>
<th>Functions</th>
</tr>
</thead>
</table>

   On the chart, list all the structures that each plant has. For each structure, describe the function(s) you think it has. You can make your own name for any structures that you do not know the name for.

3. In what ways are the structures of the three plants alike? (Do they all have leaves? Do they all have roots? What structures are alike on all three plants?)

4. In what ways are the structures of the three plants different?

5. Predict which of these three plants you think would be best adapted to a dry, desert climate. Explain why you picked this plant. Use ideas from your research on desert plants to support your prediction.
6. Predict which of these three plants you think would be least adapted to a dry, desert climate. Explain why you picked this plant. Use ideas from your research on desert plants to support your prediction.

7. What questions do you have about these plants and how they are adapted to different climates?
IIIb. PLANNING AN INQUIRY:
WHICH PLANTS ARE BEST ADAPTED TO DESERT LIFE?

With your group, figure out an experiment that would give you good evidence to help you decide which plant in our classroom would be best adapted to the desert. Your group should discuss different ideas and come up with one idea that you think is best—which idea is likely to provide the most convincing evidence?

In the whole group discussion, consider which experiment you think will provide the best evidence to answer the question.
IIIa. Observing, Comparing, and Predicting:  
Which Plants are Best Adapted to Desert Life?  
and  
IIIb. Planning an Inquiry: Which Plants are Best Adapted to Desert Life?  
Teacher's Guide

Purpose
These two activities have important conceptual and nature of science purposes. Conceptually, they provide opportunities for students to use ideas they have been developing through their library research (about adaptations of desert plant and animal species) to make some predictions about plants that are commonly sold in plant stores in Michigan. Where do these plants come from—are they adapted for desert life? Regarding the nature of science strand, this activity involves students in reflecting on their developing understandings to make predictions and in constructing ideas for modes of inquiry to check out their predictions. The discourse surrounding these activities should provide a rich context for helping students explore first hand ways of thinking, talking, and acting in a scientific community.

Tips for Selecting Plants
We went to Frank's Nursery and chose a variety of small plants. We tried not to pick obvious cacti. Instead, we picked desert plants such as aloe plants that students might be less familiar with. For each group, we had at least one desert-adapted plant and one plant that was not adapted for desert life. For some groups, the third plant was a needle-bearing plant which we thought might provoke interesting conversation about whether “thick leaves” meant that the plant was always well adapted to desert life. The third plant for other groups varied but included species such as African violets.

Potential Pitfalls
Students get very excited about the plants and immediately want to claim individual plants for themselves. Before they work with the plants, students needs to participate in a discussion about how the plants will be handled and shared in the groups. This discussion can be linked to norms of interaction in scientific communities. Try not to allow students to grab a plant “for their own” during the small group work. Perhaps students could get one plant at a time to observe and share as a group; then return that plant and get a second one. The first time we did this activity, each student grabbed a plant and then proceeded to work individually rather than in a group.

An advantage of these activities is the excitement generated by working directly with plants. A drawback, however, is that it is not clear exactly how the work with these plants can help students address the central question: Are there more different species in Michigan or in the desert? It is an excellent set of activities to support students’ developing understandings of adaptations and to link that understanding to developing ideas about ways of knowing in science. But it does not directly support students in solving the problem about species diversity in the desert vs. Michigan.

One way we tied this back to our inquiry about the desert vs. Michigan is to ask students: Do we have an answer yet to our question about the diversity of species in the desert vs. Michigan? What are other ways we might explore this question?

Student Response Pattern
• Students usually reveal a satisfactory understanding of “structures” and “functions” in responding appropriately and with relative ease to questions 2, 3, and 4. They tend to be most facile with the idea of “structures.”

• Students tend to make their predictions based on observations of thickness of leaves and stems. They have difficulty noticing that the shape of leaves is very different among the three plants (for example, differences in surface area).
• Students' reasons for their predictions often do not draw from the research that they have done about other desert plants. We have learned to encourage and support students to make reference to the plants they researched in constructing their predictions.

• One of the most interesting and revealing parts of this activity is the plans for experiments that students construct. These plans typically do not reveal a knowledge of the idea of controlled experiments or even the notion of a “fair test.” Common ideas include:
  - Cut the leaf open and see how much water it has
  - Put the plant in a hot, dry place and see if it lives
  - Call Franks and ask them where they got it from

**Developing a Science Discourse Community**

This activity typically leads to at least two whole class discussions that are excellent contexts in which to support students in learning how to talk, think, and act in a scientific community:

1. **Talking about the predictions and reasons for them.** During this discussion, you can continue to teach students to engage in scientific argument using key phrases and questions. Students can be encouraged to talk to each other, not just the teacher as they consider, challenge, and support each other’s predictions.

2. **Planning experiments to test out our predictions.** This discussion can be used to challenge students to consider the idea of a fair test: the need for replication, the need to consider multiple variables, the explanatory power of certain kinds of evidence over others: Just because the plant has water in it, does that mean it is adapted to the desert? Just because one plant died in a desert-like environment, does that mean all plants in this species would die in a desert environment? We ask students to consider the kinds of evidence likely to be generated by each proposed experiment and to evaluate the usefulness of such evidence.

**Variations**

Many of the experimental ideas that students generate could be carried out in the classroom. You could support students in carrying out these experiments either as a class activity or as an outside-class activity carried out by a small group of students.
1. Do we know yet whether more different kinds of species live on the desert or in Michigan?

2. Have you changed your prediction? Why or why not?

3. What kinds of evidence have we gathered to try to answer our question?

Scientists often cannot prove something with absolute certainty. They try to get the best evidence they can. They try different ways of getting evidence so that they have lots of different kinds of evidence to support their hypotheses. Then they put together all the evidence they can find from different sources, and they try to develop an argument to support their view. Sometimes they are pretty certain their argument is correct; other times they know that their argument is not very certain. They keep looking for new sources of evidence.

Let's evaluate the evidence we have gathered to support our hypotheses about whether there are more different species in Michigan or in the desert.

4. What evidence do we have to support the prediction that the desert has more species?

5. What evidence do we have to support the prediction that Michigan has more species?

6. What are other sources of evidence that we could get to support (or challenge) our hypotheses?

7. How certain are you of your hypothesis? Why?
Creatures of the Namib

You have done some thinking about different ways we could get more evidence about desert and Michigan plant and animal species. Some of you idea may involve actually going to the desert and studying the plants and animals there. Unfortunately, the school district cannot afford to send this group of scientists to the desert! But there are many scientists working on the desert trying to understand the plants and animals there and how they are adapted to desert life. We are going to visit with some of those scientists through a video produced by the National Geographic Society.

As we are watching this video about life on the Namib Desert in Africa, let's keep two lists. You can keep one list in your journals. This will be a list of all the plant and animal species that are living on the Namib desert. I am sure we will discover some new species with some interesting adaptations to desert life. The second list we will keep on our class chart. This will be a list of all the scientists who work on the Namib Desert. As we watch them at work, we can think about ways in which they are very different from the stereotypes of scientists. Watching them at work, we can learn some new things about the most important parts of scientists' work.

In your journal keep a list in two columns like this:

<table>
<thead>
<tr>
<th>Namib Desert Organisms</th>
<th>Ways Adapted to Desert</th>
</tr>
</thead>
</table>

On the class chart we will keep track of:

<table>
<thead>
<tr>
<th>Namib Desert Scientists</th>
<th>Work They Do</th>
<th>What they Learn</th>
</tr>
</thead>
</table>

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IIIc. National Geographic Video: Creatures of the Namib
Teacher's Guide

Purpose
This video is a wonderful way for students to "visit" a desert and to engage in scientific research along with a group of scientists on the Namib Desert in Africa. We particularly liked this video because it helped us develop and pull together our two curriculum strands--the conceptual strand about diversity and adaptations and the nature of science strand. Students can develop new images of scientists at work at the same time that they are gathering information about desert plant and animal species and their adaptations to help us consider our central question.

Potential Pitfalls
Without structure and guidance, this can turn into a pleasant video-watching experience that does not help students develop their thinking. The students are intrigued with this video despite its hour-long length.

To support rich discussions of the material in the videotape, we developed a pattern of stopping the video at several points to discuss and synthesize findings about our two focus questions: What plant and animal species live on the Namib, and how are they adapted for life there? What kinds of work do scientists on the Namib do, and how does that challenge our stereotypes of scientists?

We also encouraged students to keep lists of organisms that are mentioned as the video is playing. During our stop points, we had them write and talk about the adaptations of these organisms.

Developing a Science Discourse Community
The opening discussion is an important context in which to work on norms and values of scientific discourse, including: the role of evidence as authority, the importance of multiple sources of evidence all pointing to the same conclusion, the tentativeness and uncertainty of scientists' knowledge, scientists' openness to revising their ideas--to change, scientists' willingness to acknowledge the limits of their knowledge.

To encourage discussion that is questioning in nature (versus passive reception of information), we stimulate discussion about the video by asking students questions like: If you could talk to Mary Seeley (or other scientists in the video), what questions would you like to ask her? How do you think scientists learned about that behavior or adaptation?

Student Response Pattern
• Students generally are enthusiastic about the many interesting species and their adaptations.
• The scientists in this film are memorable to the students--they are fascinated by the scientist who rides around the desert on a three-wheeler motorbike chasing lizards and by Mary Seeley's patience in counting and numbering bugs that she releases into the desert and later tries to find again. These scientists provide strong alternative models to the laboratory scientist mixing chemicals.
• Students do not typically think they would like to be this kind of scientist, because they see desert life as unpleasant.

Variations
Some of the scenes in the film may give the impression that scientists work alone. To bring alive the kinds of discourse that probably go on inside the desert research center, you could have students role play the different scientists portrayed in the film as they gather together to talk about their work.
Phase IV:
LESSON ACTIVITY IDEAS FOR REFLECTING ON THE
THE NATURE OF SCIENCE STRAND
AND THE CONCEPTUAL STRAND
Phase IV:
LESSON ACTIVITIES FOR REFLECTING ON THE
THE NATURE OF SCIENCE STRAND
AND THE CONCEPTUAL STRAND

GOALS FOR THIS PHASE OF THE UNIT

• Provide multiple opportunities for students to reflect on their learning about the nature of scientific inquiry and discourse and about the concepts of adaptation, species diversity, structure, function.
• Assess student learning about both curriculum strands

IDEAS ABOUT TIME LENGTH AND SELECTION OF ACTIVITIES FOR THIS PHASE OF THE UNIT

This phase of the unit is not just about “testing” students. Therefore, we encourage the use of multiple activities that will both promote students’ reflection on their learning and reveal their understandings and misunderstandings. Activities should be selected that will provide multiple windows into students’ thinking: How are they making sense of these ideas at this point in time? What are the multiple ways students are understanding these ideas? What are significant misunderstandings that are developing or persisting? We spent approximately 4 lessons on this phase and wish we could have done more to allow students to finish up on their bulletin board idea.

BEYOND RIGHT ANSWERS

In the activities we used, we focused on tasks that would be open-ended enough to genuinely tap into students’ thinking and reveal their multiple ways of thinking. We stayed away from multiple choice items or items that simply asked students to define words. We worked with students to share their thinking, not to give us the answers that they thought we wanted (the right answers). In this regard, the lack of a “right” answer to the central question of the unit was very helpful. It helped to make students feel comfortable in admitting their uncertainties, the incompleteness of their understandings, their confusions. Teacher modeling of these qualities also was helpful.
IVa. MY THINKING TODAY ABOUT ADAPTATIONS

We have been talking about lots of different desert plants and animals and their many interesting adaptations that enable them to survive on the desert. Today think about the word, “adaptations” for a few minutes. Then write in your journals as much as you can think of about this word and your understanding of it. Use the following list of questions to help you get ideas:

• What does the word mean to you?
• What is difficult or easy about understanding adaptations?
• What examples of adaptations can you give?
• Do you like studying about plant and animal adaptations?
• Do you feel like a scientist when you study about adaptations?

*The important thing in this writing is to put down everything that comes to your mind when you think of “adaptations.” Don’t worry about whether you are right or wrong.

Listen to the ideas from your classmates. Do they give you some new ideas about things you might write about adaptations? Do they help you understand some of the questions or confusions you had about adaptations? Look over the list of questions again. Write some more in your journals about adaptations. Do you want to change any of your ideas, or add to your ideas?
IVa. My Thinking Today About Adaptations
Teacher's Guide

Purpose
This reflection activity should both reveal students' understandings and confusions and also help
them clarify and synthesize their work with the concept of adaptations. The stimulus questions for
the writing are designed to tap student thinking about both the concept of adaptations and about
students' thinking about the nature of science and scientific inquiry.

Potential Pitfalls
Students are used to giving short definitions when asked about the meaning of a word. This task
may be very new to them, and they may be confused and hesitant at first. As students start
writing, you might share examples of things people are coming up with to stimulate students'
thinking. We also sometimes present this as a "non-stop" writing activity, where they must keep
writing constantly even if the only thing they can think of to say is, "I can't think about any more
things I know about adaptations."

Developing the Science Discourse Community
We tell the students that the focus should be on sharing your thinking clearly and being willing to
revise your thinking—not on right answers or definitions that sound good but are not personally
meaningful. Good scientists, we tell them, do not hide behind big words—they reveal their
thinking and their confusions. Good scientists ask hard questions of their peers to try to clarify
their understanding.

Student Response Pattern
• At this point students usually can give examples of adaptations, but not a very good definition.
• Students' efforts at giving a definition frequently reveal the idea that animals (and sometimes
plants) can adapt to the environment, that they can change to accommodate changing weather
conditions (the camel grows a hump to survive on the desert; the cactus grows spines to protect
its water supply from being attacked by animals). We try to address this problem by asking
students if the cactus plant or the camel could change its structures and behaviors to adapt to
conditions in the arctic or in the tropical rainforest. However, we have not really gone into the
idea of natural selection as an explanation for how adaptations came to be. We have been
surprised that students do not ask the question: How come these different plants and animals
have these adaptations? We would be excited if they would ask such questions—it would reflect
their understanding of the nature of science strand!
IVb. Reflecting on Our Central Question:
Are There More Different Species of Plants and Animals
in the Desert or in Michigan?

Let's think today about the problem we have been trying to solve: Are there more different species of plants and animals in the desert or in Michigan?

**Reviewing Your Journals**
Let's start by looking back through our science journals and remembering the kinds of evidence we have gathered to try to answer our question. As you look through your journal, think about whether your answer to this question has changed? Are you now more certain of the answer to the question? Or are you now less certain of the answer to the question?

**Writing About Your Current Ideas**
After looking through your journal, write in your journal about your current thinking about our question:

- Has your answer to our question changed since the first day we made our predictions? If yes, how has it changed?

- What evidence that we gathered has been important in your thinking?

  [You might start your writing by saying “The evidence that made me change my mind was.....” OR “The reason I have not changed my mind is because of the evidence that.....”]

**A Scientific Argument about the Question**
Listen to the ideas shared by your classmates. Ask them questions and share your ideas to try to convince them of your answer. Have a good scientific argument!

**Revisiting Your Ideas**
After participating in the scientific argument, read your last journal entry again.

Based on evidence from the scientific argument, do you want to revise your thinking in any ways? Write in your journal about any additions or changes you want to make to your thinking.
Purpose
The purpose of this activity is for students to use ideas they have developed about desert species and their adaptations to revisit and reconsider the central question of the unit. This task provides opportunities for students to revise their thinking using scientifically appropriate ways of thinking, talking, and acting.

Student Response Pattern
At this point in the unit, many students are ready to say that they have changed their thinking. The most common response is that now they think there are just as many different species in the desert as in Michigan. They tend to be pretty certain of this new prediction. Through this activity, you can support students in seeing that it is alright for them to be more tentative, less certain in their assertions.

Developing the Science Discourse Community
This is another opportunity for a scientific argument, and students should be reminded of the kinds of statements and questions that will contribute in a positive way to the argument. Look for places in the lesson or at the end of the lesson to reflect with students on ways in which they have had a good scientific argument.
IVc. CONCEPT MAPPING AND INTERVIEWING

The words on the following page are words we have been using in science class.

• Are there other words that we have been using in science class that you think are important to add to the list? Add your words in the blank boxes on the chart.

• With a partner, cut each word out from the chart. On the large piece of poster paper, arrange your words in a way that makes sense to you. Create a word picture that tells a story about what we have been learning in science class. After you and your partner agree on an arrangement, glue the pieces down.

• Explain your word picture to each other. Listen for ways in which you each tell the story a little differently.

• Be ready to explain your word picture to a teacher.
<table>
<thead>
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<th>scientists</th>
<th>function</th>
<th>writing</th>
</tr>
</thead>
<tbody>
<tr>
<td>structure</td>
<td>research</td>
<td>species</td>
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<tr>
<td>adaptation</td>
<td>argument</td>
<td>thinking</td>
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<tr>
<td>organism</td>
<td>animals</td>
<td>laboratory</td>
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<tr>
<td>desert</td>
<td>Michigan</td>
<td>tongue</td>
</tr>
<tr>
<td>chameleon</td>
<td>wild hair</td>
<td>store water</td>
</tr>
<tr>
<td>cactus</td>
<td>eyeballs</td>
<td>men</td>
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<tr>
<td>women</td>
<td>journals</td>
<td>gecko lizard</td>
</tr>
<tr>
<td>stems</td>
<td>sidewinder snake</td>
<td>Jane Seeley</td>
</tr>
<tr>
<td>talking</td>
<td>why</td>
<td>diversity</td>
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<tr>
<td>change</td>
<td>evidence</td>
<td></td>
</tr>
</tbody>
</table>
IVc. Concept Mapping and Interviewing
Teacher's Guide

**Purpose**
This activity provides an excellent opportunity for students to see how the ideas about adaptations, species diversity, and the nature of scientific inquiry and discourse are connected.

**Potential Pitfalls**
Since this is the first time that many students will have encountered a concept mapping type of activity, you should not expect their word pictures to conform to a particular set of rules for how concept maps should be constructed. It is better to leave it up to the students to decide how to organize their stories. Through your questioning you can help them think about other ways they could have represented their ideas:

- Are there any ways in which the ideas in this group are related to ideas in this group?
- Can you explain why you have these two words together? How are they similar? different?
- Explain what you mean by this word. Does this word, “adaptation” have anything to do with this group of words about “structures”?

**Student Response Patterns**
- Some students will simply classify the words into categories (e.g., organisms, structures).
- Some students will explain their word pictures in vague ways, with insufficient elaboration to reveal their thinking and understanding (e.g., “adaptations has to do with plants and animals”).

**Variations**
Let the students construct the list of words to use. This will reveal which ideas and concepts were most salient to them. It would be interesting to see if they include ideas from both the conceptual strand and the nature of science strand.
IVd. HOW CAN WE COMMUNICATE WHAT WE HAVE LEARNED?

How can we communicate what we have learned to others? In your groups today, I would like you to develop a proposal for an activity we could do to teach others in the school about what we have learned so far in science.

When your group agrees on a good idea, write that idea down in your journal.

Be ready to listen to other students' ideas about how we can communicate our learning to others in the school. We will vote on one idea that we want to carry out.
IVd. How Can We Communicate What We Have Learned?
Teacher's Guide

Purpose
This activity has the dual purpose of revealing student learning (what aspects of the study were most salient and important to them) and supporting students in reflecting and synthesizing their learning.

Potential Pitfalls
This can become a very time-consuming process that does not support the kind of learning that is worth the sacrifice of instructional time. It can easily turn into a chance for the teacher to look good to colleagues and parents through public representations of the students' work. In our case, we ended up not following through on the students' bulletin board idea, because we felt there were other more valuable uses of students' time. We felt badly, however, that we had engaged students in generating the ideas and then did not follow through on them.

Student Response Pattern
Our students came up with the idea of creating a bulletin board that would be covered with pictures they would draw of different kinds of scientists at work (including many that challenge the typical stereotype). The bulletin board would pose a question to passers-by: Which of these are pictures of scientists at work? Fill out a ballot and enter it in our contest!

The ballot would have a list of the pictures (a,b,c,d,e,etc.) with a place to mark “yes” or “no” beside each picture.

The students would collect the data from the school and then report the findings and the “right” answers over the loudspeaker system.
IVe. ADAPTATIONS UNIT TEST
1. Look at the list of science words on the label sheet. Think about how you might change the way you had your words grouped yesterday. Put the words on this piece of paper in groups in a way that makes sense. Be ready to tell a teacher about your groups. Be thinking about how different groups connect together in some ways.
2. Tell whether each of the following is an organism, a structure, or a function.

________________________ lizard ________________________ chewing food
________________________ feet __________________________ teeth
________________________ grass _________________________ running
________________________ cat ___________________________ eyes

3. Name two structures of a cactus plant that help it adapt to the hot, dry desert.

a. ________________________  b. ________________________

In sentences, tell the functions of the two cactus structures you named.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

4. Name an interesting animal that is well adapted to desert life. ________________________

Describe in a sentence how this animal is adapted to the desert.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

5. Any structure or behavior that helps an organism stay alive in its environment is called: (circle the answer)

  a. a structure        b. a function        c. an organism         d. an adaptation

6. The Roth family was on a car trip out west. In the middle of the desert, their cat (Marble) hopped out of the car and ran away. Do you think a cat is well adapted to desert life?

   ________

Explain your answer. _______________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

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7. Open your journal and look at your drawing of a scientist.

List two stereotypes of a scientist that your picture showed.

Why do we call these stereotypes?

DRAW A PICTURE OF A VERY DIFFERENT KIND OF SCIENTIST THAN THE ONE YOU DREW BEFORE:
IVe. Adaptations Unit Test
Teacher's Guide

Purpose
There are two major purposes of the test -- to reveal student learning and understanding in a way that will help parents and teachers see the students' learning and to provide a chance for students to reflect and synthesize their learning.

Potential Pitfalls
If too much emphasis is put on "the test" and "the grade" and "right answers," this activity will work against the kinds of thinking and openness that we are trying to establish in this science discourse community. We did not grade the papers with a letter grade. Instead, we wrote comments and had students revisit the test and revise their answers.

The particular test we used has some important problems in that there are several right/wrong answers (see numbers 2 and 5). We now think we could have assessed understandings of these terms through more open-ended, explanation type questions.

Variations
Here are two test items that we think might focus students' attention and reflections on the central question of the unit:

1. How many species of plants and animals do you predict are adapted to desert life? about 25? about 50? 100? about 1000? more?
   Explain your evidence for your prediction.

2. Do you think there is a scientist somewhere in the world who knows the answer to our question: Are there more different kinds of species in Michigan or in the desert? Explain why you think "yes" or "no."

We like these items because they have the potential to reveal both students' understandings of concepts and students' understandings of the nature of scientific inquiry and discourse.

Another variation we have found useful in other units of study is to give a nearly identical test as a pretest and a posttest. Then students can look at the two tests side by side and reflect on the growth in their learning.
IVf. STORY OF A TIME I REALLY FELT LIKE A SCIENTIST
IN SCIENCE CLASS

Think back over our experiences in science class so far this year. Think of a time that you really felt like a scientist. Then tell a story about the time that you really felt like a scientist in science class. Write your story so that someone outside our class could understand what you are talking about.
Purpose
This activity can be a wonderful assessment device. As students tell their stories about a time when they felt like a scientist, they reveal those aspects of science are most essential and important to them. Lingering stereotypes of scientists are also easily identified in this activity.

Potential Pitfalls
If you just give the assignment without any prewriting work, students tend to write only brief statements that do not help us assess their learning (“I am like a scientist when I explore the woods in the park.”) We have found that we get much richer and revealing stories from students if we model a story of our own first. A story I used with one class is provided on the next page.

Variations: Connections to Parent Conferences and to Writers' Workshop
We have found that students will get much more invested in this activity if we treat it as a genuine writing activity that has an outside audience. We have approached the writing activity from a writers' workshop perspective, supporting students in drafting and rewriting for a particular audience: their parents and teachers at the parent conference time. We encourage students to use the story as a chance to share how they have grown as scientists.

Student Response Patterns
• Some students continue to represent science as “doing experiments.” Their responses reveal a focus on science processes and doing and little or no emphasis on the purposes of all this doing: ideas, explanations, concepts.
• Students who mix into their stories about experiments something about the kinds of understandings they develop from such experiments are capturing a richer picture of “doing science.”
• Some students will talk about times they do writing. Look for evidence that they are thinking about purposes of writing that are appropriate in scientific inquiry. If they talk about feeling like a scientist when they write, examine closely what kinds of writing they are considering to be “scientific” and why.
• Look for the opportunity to share with the class examples of student responses that capture the richness of a science discourse community (e.g., “I felt like a scientist when I debated with John about whether or not there were such things as UFOs.”)
Phase V:

LESSON ACTIVITY IDEA FOR CONTINUING THE WEAVING--
CONCEPTUAL AND NATURE OF SCIENCE LINKS TO THE NEXT UNIT
Phase V:

LESSON ACTIVITY IDEA FOR CONTINUING THE WEAVING--
CONCEPTUAL AND NATURE OF SCIENCE LINKS TO THE NEXT UNIT

GOALS FOR THIS PHASE OF INSTRUCTION

• Engage students in constructing their own remaining questions that might be worth exploring further, especially regarding desert plants
• Engage students in a new conceptual question that is linked to the one they just examined: How do plants use the water they take in? Is water their food? What is food for plants? Do all plants have the same kind of food, or do different species have different kinds of food?
• Brainstorm and challenge each others' hypotheses/evidence about the new central question.
• Construct ideas of ways we could investigate this question in a scientific way.

IDEAS ABOUT TIME LENGTH AND SELECTION OF ACTIVITIES FOR THIS PHASE OF THE UNIT

This phase of the unit does not need to be long--it may be addressed in one lesson (or part of a lesson) that serves as a bridge from the first unit to the next. The important thing is to help students see a link and a continuity between the first unit of study and the next. Just as scientists' experiments and inquiries grow out of earlier studies, students should see how the next problem of study grows out of and is related to the first problem. In the activity described here, this link is generated through students' questions. An alternative is to describe the new problem to the students and to have them brainstorm ways in which that problem is related to questions they raised in the first unit.
V. QUESTIONS IN OUR RESEARCH

Think about things that you are still wondering about, confused about, curious about from our study of desert plant and animal species.

1. In your science journal, write down your questions and wonderings about desert plants and animals.

2. With your group, look through our Question Notebook and think about which questions we are now able to answer and which questions would take some further research.

   Mark the questions we can answer with a “!”
   Mark the questions we still cannot answer with a “?”

3. As a group pick one question that you would like to study together in our class. Write down your ideas of different ways we could get evidence about this question. Carefully describe your ideas about experiments we could do and other ways we could gather evidence to answer the question.
V. Questions in Our Research
Teacher's Guide

Purpose
This activity can help students understand how scientific inquiries raise new questions (not just answers) to explore.

Developing the Science Discourse Community
Students can learn how scientists generate questions from their inquiries to construct new inquiries. As they negotiate with their peers and the teacher, students can learn how scientific communities collaborate to plan research programs. You will need to make these connections to the scientific community explicit through asking questions like: Do you think scientists have discussions like this? How do scientists decide which questions they will study?

Student Response Pattern
Students sometimes have difficulty thinking up questions in response to the first journal writing task. Going through the Question Notebook, however, often stimulates a lot more thinking about questions as students remember the kinds of questions that came up during their inquiry.

Potential Pitfalls
Once you open up this exploration of questions, you will have to consider options for further inquiry that were not in your plan. If you are not ready to be that flexible in your curriculum planning, you could introduce the activity in a way that makes it clear that the ideas generated may not be the ones we pursue right now. However, they could be projects that students could pursue in small groups or individually outside of class or in later units during the year (for example, for a Science Fair or Science Day type of activity).

Variations
A different approach to the bridging between units is to start by explaining the new topic of study you have selected. In our case, the new problem was: How do plants get their food? Is the water their food? If not, what do plants do with the water that they take in?

You could then ask students to brainstorm ways in which this question relates to our studies of structures, functions, and adaptations of desert species. You could draw attention to places in the Question Notebook where students raised questions about the role of water in the plants.
TEACHER JOURNAL ENTRIES
FOR SELECTED LESSONS

Each teacher journal entry is coded to indicate the lesson activity
Beyond Processes and Beyond the Scientific Method:

Developing Concepts and a Science Discourse Community: Analysis Activity

On the following pages are selected pages from Roth's teaching journal during Fall, 1990. Read these entries and consider the ways that she is learning about how to support students' conceptual development and students' ways of thinking, talking, and acting in a science discourse community during this introductory unit.

- In what ways do these teacher journal entries reflect a simultaneous, intertwined concern for students' conceptual development and students' development as members of a science discourse community?

- In these journal entries, what aspects of scientific understanding is the teacher concerned with developing?

- In what ways do these teacher journal entries reflect a different image of what it means to know and do science than the traditional steps outlined in "the scientific method?"
Teacher Journal Entries

• 9/11/90 Activity Ix Exploring the Word “Stereotype”

The discussion about stereotypes of boys and girls was not helpful in clarifying the meaning of a stereotype, but I think it did bring to the forefront the issue of women in science. Maybe I need to figure out a definition of stereotype instead of trying to teach it by example.

• 9/14/90 Activities Ix, II, Ij Stereotypes and Important Parts of Scientists' Work

I was struck by how much the kids' writing really made me want to focus and develop this introductory “mini” unit into a full-fledged effort to help students change their conceptions. How can I better help my students see the distinction I'm making between “stereotypes” and “important work of scientists”? I think I'm now looking at this as an issue to keep pursuing throughout the year.

• 9/19/90 Activity IIa Being Scientists: Are there more different species of organisms living in the desert or here in Michigan?

Entry Written while eliciting students' written predictions—this is my prediction about the Central Question

I think there are more (or maybe about the same number) of different kinds of plants and animals in the desert as in Michigan, but that in Michigan there are more total numbers of organisms. I'm thinking that the desert might have a lot of unusual kinds of small organisms (bugs, snakes, lizards, birds) that we've never heard about. And also maybe there are just as many different kinds of cactus as there are kinds of trees in Michigan.

• 10/3/90 Activity IIb Planning an Inquiry: Which plants are best adapted to desert life?

Reflections about the Development of a Science Discourse Community

I felt good about how things went today, and I'm not sure why. Partly I liked the way pieces were being tied together—getting back to some of the ideas about the nature of scientists' work in the context of our desert study seemed natural. I also like the way Bobby's question led so nicely to a major point I wanted to make. We were discussing different kinds of experiments the groups had come up with to figure out how well the different kinds of plants we are examining are adapted to the desert. Bobby asked me, “Do you know which one is right?” I asked him to clarify—he meant which experiment was the right one. I used that to make my point about the idea that no single source of evidence can prove your idea right or wrong, the need to do different kinds of experiments. This led to my talking about the nature of scientific debate—this felt good except it was too much a “lecture.”

The kids seemed to handle listening to each other better in the whole group—maybe that's why it seemed like a lot of students were missing! To what extent did my allowing them to wander a bit off my topic help with the cooperative atmosphere today? They loved getting into stories about Nessie, ghosts, Unsolved Mysteries. [in margin: Tim and John drove me nuts with their constant private conversations. What to do about that?] I felt comfortable letting it go on because I kept linking it back to our discussion of the desert experiments they had suggested and to scientists' demands for evidence.
•10/4/90  Activity IIIc  National Geographic Video: Creatures of the Namib

"We're only watching a video."

Another day I felt good about! Jan Derksen came to watch today, and I thought about not having her come because we were "only" watching a video. But I decided to have her come anyway, and I'm glad for a couple reasons:

1. It made me aware of how much more was going on in this lesson than "just watching a video."

   Today felt like another content-rich lesson, and it's at least partly because enough content ideas are coming together (structure, function, organism, adaptation) and partly because kids are becoming more facile with the language of science (both these concepts and ways of "talking" science).

2. I used the opportunity of her visit to have the kids explain what we'd been studying. Mark's start, "plants and animals," was disappointing but things quickly picked up. Matt did a great job explaining about organisms, structure, function. Sarah added the part about scientists and how they work. Others (Annie? Tiffany?) contributed about the desert. No one mentioned adaptations until I said I hadn't heard one word mentioned. Bill then said, "adaptations" and gave at least a partially correct description of it. Jan's comment was "Wow! All that in 4 weeks?" That was a great booster for the kids I think. It seemed like they continued to want to demonstrate how much they know throughout the lesson. . . .

I'd like to listen to kids' comments during the video. Did any good questions come up? My sense is that kids are really starting to ask more questions. Maybe the debate /argumentation will start coming next.

•11/10/90  Activity IVd  Story of a time I really felt like a scientist

A model to read to the students--My Story about Ways I've Been a Scientist

In the desert adaptations unit I think we all were scientists (not just like scientists!) as we tried to figure out whether there were more different kinds of plants and animals in the desert or in Michigan. I liked this because we were trying to discover something that I don't think anybody has the answer to. It wasn't just something answered in a textbook. We studied the problem by asking questions like, "Do any flowers live on the desert? Do trees live on the desert?" We were scientists when we asked these questions. We then studied to get answers to our questions. We read in books. We also observed some plants that were adapted for desert life. We watched a video to find out more about desert organisms. We did a lot of writing in our science journals about our ideas and our findings. We started to solve the problem and change our predictions. At first most people thought there were many more kinds of organisms in Michigan, but now I think people are not sure. I bet if we had a discussion about it in class today, we would have a good scientific debate. People would have good evidence to support their hypotheses. I really feel like a scientist because I am still wondering about this question and how we could get better evidence to answer it!
11/15/90  Phase V  Continuing the Weaving--Links to the Next Unit

The Ongoing Development of a Science Discourse Community
I loved it when Maria-Yolanda said to Rachel, “good argument!” She [Rachel] had said air wasn’t energy for humans because people who are starving are breathing air but they still die. . . . Today I felt good about this class’s awareness of argumentation --they announced proudly to me, “We had some great arguments last week!” [while I was out-of-town due to my father’s death] I'm doing a better job this year of helping kids connect what we're doing with the scientific community.

11/26/90
Maria-Yolanda greeted me with an “argument” today! She got some cut flowers and when it was watered, the flowers opened up and got bigger. So water is food for plants?

12/12/90  Phase V
The Ongoing Development of a Science Discourse Community--
An Exciting, Learning Moment in Science

It was a Wednesday morning in Room 122. Nothing unusual about the day except that the MSU football players didn’t show up for an assembly. The students found it kind of different to go to an assembly that never happened! I was teaching science as usual and was going over a homework paper with the class. “Yes, water is needed by the plant but it doesn’t have energy...,” I said. I explained that chlorophyll is not food for plants. And then the questions started flying. “Couldn’t they store the chlorophyll somewhere?” “How do they make chlorophyll?” and then Nan demanded: “But where’s our evidence?!?” I took a step back. That’s right, I thought. We haven’t talked much about scientific evidence for photosynthesis. Here we’ve been doing such a good job of keeping track of evidence about the students’ hypotheses about how plants get their food, but ever since they read about photosynthesis I haven’t helped them understand the evidence for this new idea--photosynthesis. But before I could do much to respond to Nan’s question and to help them think about the evidence for photosynthesis, Sheila asked another big question: “What is the biggest question scientists are trying to answer?” I took another step back. Another terrific question, and I didn’t know what to do. Keep talking about unanswered scientific questions--cancer, AIDS, the universe--or get back to photosynthesis. As a teacher, that was an exciting, learning moment. I learned that I needed to think how to help us get more evidence about photosynthesis. And just as importantly, I learned something about these students. They’re thinking like scientists, and that is exciting to see! Inside I felt like dancing and cheering, but I decided the students might call me a “mad scientist” if I did!
References


National Geographic Society. *Creatures of the Namib*. Video.


