7 Remodelling Science Lessons

A critical approach to teaching science is concerned less with students accumulating undigested facts and scientific definitions and procedures, than with students learning to *think scientifically*. As children learn to think scientifically, they inevitably organize and internalize facts, learn terminology, and use scientific procedures. But they learn them deeply, because they are tied into ideas that they have thought through, and hence do not have to "re-learn" them again and again.

The biggest obstacle to science education is children's misconceptions. Although there are well-developed, defensible methods for settling many scientific questions, educators should recognize that children have intuitively developed their own ideas about the physical world. Merely presenting established methods to children does not usually affect their inner beliefs; they continue to exist in an unarticulated and therefore unchallenged form.

Rather than transferring the knowledge they learn in school to new settings, children continue to employ their pre-existing frameworks of belief. Children's own emerging egocentric conceptions about the physical world seem much more real and true to them than what they have superficially picked up in school. For example, a child was presented with evidence about current flow that was incompatible with his articulated beliefs. In response to the instructor's demonstration, the child replied, "Maybe that's the case here, but if you come home with me you'll see it's different there."[1] This child's response graphically illustrates one way children retain their own beliefs: they simply juxtapose them with a new belief.

Unless children practice expressing and defending their own beliefs, and listening critically to those of others, they will not critique or modify their own beliefs in light of school learning. "As children discover they have different solutions, different methods, different frameworks, and they try to convince each other, or at least to understand each other, they revise their understanding in many small but important ways."[2]

Elementary science materials often suffer from serious flaws which give students false and misleading ideas about science. Students are not encouraged to develop real experiments; rather,

they are typically told what is true and false and given demonstrations to perform. Typical science materials present children with the finished products of science. Materials often require students to practice the skills of measuring, graphing, and counting, often for no reason but mindless drill. Such activities merely reinforce the stereotype that scientists are people who run around counting, measuring, and mixing bizarre liquids together for no recognizable reason.

Lessons also introduce scientific concepts. But students must understand scientific concepts through ordinary language and ordinary concepts. After a unit on photosynthesis, a child who was asked, "Where do plants get their food?" replied, "From water, soil, and all over." The child misunderstood what the concept 'food' means for plants and missed the crucial idea that *plants make their own food.* He was using his previous (ordinary, human) concept of 'food'. Confusion often arises when scientific concepts that have another meaning in ordinary language (such as, 'work') are not distinguished in a way that highlights how purpose affects use of language. Children need to see that each concept is correct for its purpose.

Students are rarely called upon to understand the reasons for doing their experiments or for doing them in a particular way. Students have little opportunity to come to grips with the concept of 'the controlled experiment' or understand the reasons for the particular controls used. Furthermore, standard approaches often fail to make the link between observation and conclusion explicit. Rarely do students have occasion to ask, "How did we get from *that* observation to *that* conclusion?" Scientific reasoning remains a mystery to students, whereas education in science should combat the common assumption that, "Only scientists and geniuses can understand science."

To learn from a science activity, children should understand its purpose. A critical approach to science education would allow children to ponder questions, propose solutions, and develop and conduct their own experiments. Although many of their experiments would fail, the attempt and failure provide a valuable learning experience which more accurately parallels what scientists do. When an experiment designed by children fails, those children are stimulated to amend their beliefs.

Scientific thinking is not a matter of running through a set of steps one time. Rather, it is a kind of thinking in which we continually move back and forth between questions we ask about the world and observations we make, and experiments we devise to test out various hypotheses, guesses, hunches, and models. We continually think in a hypothetical fashion: "If this idea of mine is true, then what will happen under these or those conditions? Let me see, suppose we try this. What does this result tell me? Why did this happen? If *this* is why, then *that* should happen when I ...."

We have to do a lot of critical thinking in the process, because we must ask clear and precise questions in order to devise experiments that can give us clear and precise answers. Typically the results of experiments — especially those devised by children — will be open to more than one interpretation. What one child thinks the experiment has shown often differs from what another child thinks. Here then is another opportunity to try to get children to be clear and precise in what they are saying. "Exactly how are these two interpretations different? Do they agree at all? If so, where do they agree?"

As part of learning to think scientifically, clearly, and precisely, children need opportunities to transfer ideas to new contexts. This can be linked with the scientific goal of bringing different kinds of phenomena under one scientific law, and the process of clarifying our thinking through analogies. Children should seek connections and assess explanations and models.

Finally, although scientific questions have only one correct answer, they may have a number of plausible answers of which only one is correct. It is more important for children to get into the habit of thinking scientifically than to get the correct answer through a rote process that

they do not understand. The essential point is this: children should learn to do their own thinking about scientific questions from the start.

Once children give up on trying to do their own scientific thinking and start passively taking in what their textbooks tell them, the spirit of science, the scientific attitude and frame of mind, is lost. Never forget the importance of, "I can figure this out for myself! I can find some way to *test* this!" as an essential scientific stance for children in relationship to how they think about themselves as *knowers*. If they reach the point of believing that knowledge is something in books that people smarter than them figured out, then they have lost the fundamental drive that ultimately distinguishes the educated from the uneducated person.

Unfortunately, this shift commonly occurs in the thinking of most children some time during elementary school. We need to teach science, and indeed all subjects, in such a way that this shift never occurs, so that the drive to figure things out for oneself does not die, but is continually fed and supported by day to day scientific thinking.

From the outset, we must design science activities so that children cannot mindlessly perform them. We should look for opportunities that call upon children to explain or make intelligible what they are doing and why it is necessary or significant. In general, students should be asked to explain the justification for scientific claims.

Of course, all of the questions above need to be modified in the light of the grade level, the particular students, and the context. We must continually take into account precisely what questions in what form will stimulate their thinking. We want to make sure that we don't overwhelm them with questions they are not able to handle, for that will cause them to stop thinking as quickly as the straight didactic approach does.

In sum, whenever possible, children should be encouraged to express their ideas and try to convince each other to adopt them. Having to listen to their fellow students' ideas, to take those ideas seriously, and to try to find ways to test those ideas with observations and experiments are necessary experiences. Having to listen to their fellow students' objections will facilitate the process of self critique in a more fruitful way than if they are merely corrected by teachers who are typically taken as absolute authorities on "textbook" matters. Discussion with peers should be used to make reasoning from observation to conclusion explicit and help children learn how to state their own assumptions and recognize the assumptions of others.

Footnotes

[1] Hugh Helm & Joseph D. Novak, "A Framework for Conceptual Change with Special Reference to Misconceptions," *Proceedings of the International Seminar on Misconceptions in Science and Mathematics,* Cornell University, Ithaca, NY, June 20–22, 1983, p. 3.

[2] Jack Easley, "A Teacher Educator's Perspective on Students' and Teachers' Schemes: Or Teaching by Listening," *Proceedings of the Conference on Thinking, Harvard Graduate School of Education,* August, 1984, p. 8.

Linear Measurement

(Kindergarten)

Objectives of the remodelled lesson

The students will:

- develop confidence in their ability to understand and use systems for measuring
- discuss reasons for measuring
- discover the usefulness of standards of measurement through experience and discussing root questions

Original Lesson Plan

Abstract

The students use their hands to measure one side of a piece of paper. They then discuss why they arrived at different answers. Next, they use pencils to measure two sides of the paper. Then they use a meter-stick to measure different classroom objects, and determine which of four objects is longest and which shortest.

from *The Elementary School Science Program.*, Biological Sciences Curriculum Study. Colorado, J. B. Lippincott, Co. pp. 72–74.

Critique

The lesson covers an important point — the usefulness of having standard measuring lengths — in a concrete and vivid way. It can, however be made stronger. To better understand this point, students should further ground the experience in reality through some discussion of the purposes which measuring serves. Although the lesson gives students an experience which suggests the importance of standards of measurement, it has no *explicit* discussion of this idea. Students should discuss the potential problems arising from not using a standard.

Strategies used to remodel

S–9 developing confidence in reason
S–17 questioning deeply: raising and pursuing root or significant questions
S–1 thinking independently

Remodelled Lesson Plan *S-9*

As an introduction, the class could discuss the question, "Why do people measure things?" The teacher may begin by asking students to recall when they have seen people use rulers, tape measures, etc. The class could brainstorm reasons for measuring. Write these down, to be used in the later discussion. ***S–17***

Then, after the students have measured with their hands and discussed the differences in their answers, they could be given a chance to suggest the usefulness of everybody using the same length. Remind students of some of the reasons for measuring they gave earlier. Ask them if the "hand method" would work well in each case. Focus their attention on cases in which lack of standards would cause problems. Ask students what problems could arise, and how they might be solved. If they don't mention that everyone could use one agreed-upon length to measure, distribute pencils (or other objects of equal length). Have the students measure and discuss whether using this would solve the problems. ***S–1***

Before introducing the meter-sticks, the teacher could ask the class what problems could arise from using pencils to measure ("Would everybody know exactly what 'six pencils long' means?") When distributing the meter-sticks, mention that people all over the world use sticks that are exactly this length. Have the students compare their meter-sticks.

Before the students measure, give them a reason to want to know the lengths of objects or spaces. For example, you might say "Suppose we wanted to move these shelves over here? How could we tell if they would fit?" Or, to reinforce the importance of standards, have one student measure a space in the classroom, while others measure some outside object. ("Would the monkey-bars fit in our classroom?") ***S–17***

Are Seeds Living Things?

(1st Grade)

by Pamela Lane-Stamm, Mattole Union
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Objectives of the remodelled lesson

The students will:

- develop and conduct an experiment to answer a question
- learn the importance of the various elements to the growing process of plants
- Socratically explore the distinction between living and non-living things

Original Lesson Plan

Abstract

After reading three pages stating plants and animals are living things, students experiment to confirm that plants are living things. They put soil in a cup and put seeds in the soil. They label their cups, water the seeds and answer the questions, "Do they grow? Are they living things?"

from *Holt Science 1*, Holt, Reinhart, and Winston Publishers, 1986, pp. 14–20.

Critique

Because the text shows pictures of the experiment being performed, including the result, children don't have an opportunity to hypothesize for themselves about what will happen. The experiment doesn't allow the children to discover what helps the seeds to grow or even if the seeds will grow. This lesson also fails to allow children to separate their observations from conclusions.

Strategies used to remodel

S–1 thinking independently
S–24 practicing Socratic discussion: clarifying and questioning beliefs, theories, or perspectives

Remodelled Lesson Plan *S–1*

Children should not read the text first, because it tells them what the results of their experiment will be. Children will be encouraged by the teacher to hypothesize about what will and will not grow. Ask, "Would a pencil grow? Would a leaf grow a new plant? Would a frozen pea grow? Would a dried pea grow? Would an eraser grow? A seed?" etc. Make sure the children explain why they think these things will or will not grow. ***S–24***

Children can then plant the items that they think will grow and instead of planting one pot, two plants should be planted. One pot will be given soil, water, and light. The other pot will have either water, soil, or light omitted from the process. Children should chart their results on a graph and discuss what a seed needs to grow and what a seed needs to become a healthy plant. Then children may read the text and discuss if their conclusion concurs with that of the book.

editors' note: Before the experiment, the teacher could first see if students know or can guess what seeds will require to grow, perhaps letting them try their ideas first. "What do plants need to live? What do seeds need to grow? Do you have plants at home? Who takes care of them? What do they do to keep the plants alive and help them grow? What do we need to live? Can we compare that to what plants need?"

"How can you tell if something is a living thing?" (Seeds don't look like living things, or things that could live; they look more like pebbles.) ***S–24***

Lesson plan remodelling as a strategy for staff and curriculum development is not a simple one-shot approach. It requires patience and commitment. But it genuinely develops the critical thinking of teachers and puts them in a position to understand and help transform the curriculum into effective teaching and learning.

Making Things Move

(1st Grade)

Objectives of the remodelled lesson

The students will:

- begin to develop the scientific concept 'energy' by recognizing that energy is required to make things move and develop confidence in reason by using it to analyze experiences outside of class
- think independently by forming categories of different sources of energy
- discuss significant similarities and differences among different forms of energy
- make interdisciplinary connections between science or technology and history by exploring how people lived without electricity

Original Lesson Plan

Abstract

This unit attempts to develop the concept that "energy must be used to set an object in motion or to alter its motion". Each section provides an example or two to illustrate a use of a particular form of energy (electrical, chemical, mechanical, etc.) Each example is contrasted with a human powered or living counterpart (such as, motorcycle versus bicycle).

from *Concepts in Science,* Paul F. Brandwein, et al. Harcourt Brace & World, Inc. 1980. pp. 2–8.

Critique

This lesson could be improved by having the students come up with their own examples of things that move, thereby providing a wider range of examples and fostering independent thinking. Also, in choosing their own examples, students can better integrate the scientific insight (and scientific concept) that everything requires *energy* to move or change its motion. This better enables them to use this insight outside of class. Students themselves should categorize their examples and explain why they put them in the groups they did.

Strategies used to remodel

S–1 thinking independently
S–29 noting significant similarities and differences
S–9 developing confidence in reason
S-23 making interdisciplinary connections

Remodelled Lesson Plan S-1

To initiate the process of noting similarities and differences in energy sources, begin the unit with a brainstorming session in which students mention anything they can think of that moves. Record these responses. Afterwards, go through the list encouraging students to form their own categories by asking, "Does anything else mentioned earlier have the same source of movement as this one (chemical, electrical etc.)?" (Choose any item on the list that can be grouped easily with other items.) Continue this process until as many of the items as possible have been put into categories. Ask, "How are the items in this first category different from those in the second? Third?" and so on. Have the students label the groups. Or, students could begin by collecting or drawing pictures of things that move and sorting them into categories. ***S–29***

To develop the scientific concept 'energy' you could ask, "What do all of these groups have in common?" If necessary, remind students that the criteria they used for coming up with items was "anything that moves" and the criteria they used for forming categories was "things that have the same source of movement or 'energy source'." Then go back through the original lesson, asking of the examples given, "Do we already have a category of energy that this would fit, or do we need a new category? What would you call this category?"

Students could be given a homework assignment of finding examples of energy and its effects. These examples can be shared and discussed by the class. "Notice moving things. What made each move or change its motion? Was its source of energy natural or energy invented by people?" ***S–9***

This lesson could be extended to relate technological advancements to history. The teacher can ask, "Do you know what kinds of energy are fairly new? Electricity is one. Not long ago, people didn't have electricity; it hadn't been invented yet. What do you think things were like then? What things didn't people have? The engines in cars is another new form of energy." Finally, have students discuss how people managed without the technologies. ***S–23***

Weather Changes with the Seasons

(1st Grade)

by Victoria J. Martin, Cypress
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Objectives of the remodelled lesson

The students will:

- identify the four seasons and recognize the predictable pattern in the seasons through Socratic discussion
- think independently by categorizing pictures by season, rather than simply looking at pictures in the text
- discuss the effect of seasons on people and animals
- develop criteria for evaluating good summer clothing versus good winter clothing

Original Lesson Plan

Abstract

Students look at four pictures of the same scene during different seasons. The teacher reads a description of each season and asks "What season is it now?" The students look at more pictures and discuss them.

Critique

This lesson addresses the subject of the four seasons. It uses didactic teaching. The children just sit there and do very little interacting. More pictures and some manipulatives are needed. ***editors' note:*** Discussion of how the seasons affect people is extremely limited in the original (children play in leaves in the fall). More discussion of this point would make the concepts more real.

Strategies used to remodel

S–24 practicing Socratic discussion: clarifying and questioning beliefs, theories, or perspectives
S–1 thinking independently
S–15 developing criteria for evaluation: clarifying values and standards
S–10 refining generalizations and avoiding oversimplifications
S–33 giving reasons and evaluating evidence and alleged facts
S–34 recognizing contradictions

Remodelled Lesson Plan *S–24*

Divide the class into groups of 2, 3, or 4 children. Give them a seasonal picture and ask them to think about these questions and be ready to share

with the class: When do you think the picture was taken? Why? How did it feel outside when this picture was taken? How do you know? Have you ever been to a place that looked like this? Where was it? When was it? Did the place always stay the same? ***S–1***

Bring the class together. After discussing the pictures, you could ask them if any of the pictures seem to go together. "Why? What makes you say so? Do you agree with the way we have grouped the pictures? Why or why not? What do you think?" If grouped by season, ask them to discuss and list the seasons. If not grouped by seasons, ask them to group the pictures the way they're grouped in their texts.

Ask how seasons affect people, plants, and animals. Bring in the discussion of what farmers need to know to be successful, as in the original.

Look at the textbook and ask about how the trees look and how the people are dressed in each of the pictures. Discuss clothing used in each season. Brainstorm lists of clothing needed in each season and list on board, then discuss criteria for good summer clothes, etc. Students can discuss these criteria. "What would happen if we wore a sweater like this in the summer? Shorts in winter? Why? What do you think? Do you agree? Why? Why not?" ***S–15***

Summarize and give children opportunity to supply two facts about a season. List them on the chalk board.

editors' note: The teacher could also have students compare the pictures with seasons where they live, and discuss differences in what each season is like in different places. "Do all of these spring pictures look the same? What differences are there between what spring is like here and in the picture? Why do you think that might be?" ***S–10***

Have groups of students sort many pictures by season and explain their groupings, defending their views in cases of disagreement. ***S–33***

To engage students in a fuller discussion of how seasons affect people, allow students to discuss how each season makes them feel, what they like and dislike about each, and how people they know feel about each. "What things do people seem to disagree about when they talk about favorite seasons? Why?" ***S–34*** (Students could also distinguish how the season and weather make them feel from how holidays during each season make them feel.)

The teacher might begin the discussion of how seasons affect living things by asking students to find all such references in their text and brainstorming more ideas.

Using Your Senses

(1st Grade)

by Victoria J. Martin, Cypress
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Objectives of the remodelled lesson

The students will:

- identify and explore the five senses through discussion and activities
- avoid the oversimplification in the text by noticing how we often use several senses together to perform an activity or learn about a situation
- discuss, using critical vocabulary, how our senses and our thinking can help us uncover useful information

Standard Approach

The text explains that people use their senses to hear, to see, to taste, to smell, and to feel. Students examine pictures and identify the sense being used, the part of the body used (eyes, ears, etc.), and the place or situation in which the sense is used in each picture. The "Enrichment" discusses handicapped people.

Critique

This lesson is to introduce the five senses to a first grade class. There are no manipulatives used and this is necessary to help foster retention for this age group. Questioning strategies need to be changed to foster more independent thinking. Discussion of handicapped people is not relevant at this time.

Strategies used to remodel

S–12 developing one's perspective: creating or exploring beliefs, arguments, or theories
S–33 giving reasons and evaluating evidence and alleged facts
S–10 refining generalizations and avoiding oversimplifications
S–28 thinking precisely about thinking: using critical vocabulary

Remodelled Lesson Plan *S–12*

Before students get out their books and read page 2, we would discuss what they know about the senses: Have you ever heard the word 'sense'? What does it mean? What kind of senses are there? How do you know?

Then ask, "How do you know your mother is cooking when you walk into the house? How might you know who is in the next room if you can't see the person? How do you know if there is salt or sugar in a measuring spoon? How do you know when a window is open without seeing it? How would you

know if the traffic light changed if you weren't looking at it? Why do you think that? Do you agree? Why? Why not?"

The class could also brainstorm ideas about each sense and list them on the chalk board. "What are some different kinds of smells, tastes, and textures? What kinds of things can we tell by seeing (colors, shapes, etc.)?"

Then use the following activities with groups of four or five. Provide hands–on materials for discovering about the five senses.

- Feely box: Large shoe box with sock attached to one end. Child puts hand through sock into box, feels common object, and guesses what it is.
- Tasting jars: Ten painted baby food jars with lids with a nail hole in the lid. Q-tips can be dipped in for a taste and a guess.
- Smell Jars: Ten painted baby food jars with different scents on cotton inside.
- Sound tape: Play a tape of different sounds and provide pictures to be matched to them.
- Hidden picture cards can be used to illustrate how you can find new things if you look carefully.

For each, ask, "Which *sense* did you use here? What part of your body?" ***S–33***

To summarize, children could categorize pictures into five stacks. Discuss the fact that more than one sense is used with most objects in the pictures. ***S–10***

Make popcorn in an open popcorn popper while sitting on a sheet used to catch popcorn. Discuss which senses are influenced in this activity. ***S–33***

editors' note: Critical thinking vocabulary can be integrated into the lesson by discussing the idea that our senses provide us with evidence for the conclusions or inferences we make. For example: If we *feel* a breeze in the room, we might *infer* that the window is open. The *evidence* for our *conclusion* that someone is cooking is the smell of food and perhaps the sounds of dishes and appliances in the kitchen. Such a discussion can also make the importance and usefulness of the senses more explicit. ***S–28***

Pets

(1st Grade)

by Anne J. Harris, Jefferson Elementary School, Cloverdale, CA

Objectives of the remodelled lesson

The students will:

- realize pets are some kinds of animals under the care of people
- realize there are many types of pets
- practice independent thinking
- develop intellectual good faith by discussing ways that pets are not always fun, what needs they have, the consequences of ignoring their needs, and ways to be responsible pet owners
- make interdisciplinary connections by using or setting up a bar graph showing how many students have which kinds of pets

Original Lesson Plan

Abstract

On two pages showing people with pets (bird, horse, rodent, dog), students read the following: "Animals can be pets. Pets can be fun. People take care of pets. How can we take care of pets?" The class discusses what kinds of animals can be pets, how pets can be fun and helpful, what pets need (including attention and affection).

from *Accent on Science Level 1*, Charles Merrill Publishing Co. Columbus, Ohio, 1985, pp. 58–9.

Critique

This lesson can be expanded to draw from the children's own life experiences and to use critical thinking. It uses stereotypical pets in the pictures.

editors' note: This lesson can be expanded in many ways, taking advantage of young children's natural interest in pets, to develop their knowledge of animals and the sense of responsibility emphasized in the original. The remodel offers a number of these. The lesson can also be used to teach students about bar graphs.

Strategies used to remodel

S–1 thinking independently
S–7 developing intellectual good faith or integrity
S–18 analyzing or evaluating arguments, interpretations, beliefs, or theories
S–23 making interdisciplinary connections
S–20 analyzing or evaluating actions or policies

Remodelled Lesson Plan

I would take this basic lesson on pets and add more pictures, including exotic pets. During the discussion of pets, to encourage independent thought, I would ask why people have pets. ***S–1***

Prior to the start of the lesson, I would ask the children about their pets and graph the results — including a category for those who don't have pets. "How could our graph be different? Would it be different if we checked with another class? Why?" (Students could gather this data and make another graph.)

• The book says pets can be fun. In what ways are pets not fun? Are pets ever annoying or a bother? Why? What should you do about that? Is taking care of pets always fun? Why not? What would happen if a pet wasn't properly cared for? (Take each need and ask this question.) How much is this like how you would feel if you didn't get (food, affection, etc.)? ***S–7***

In conclusion, the children should decide if pets are worthwhile and support their decisions. They could also decide what type of pet would be most suitable for them and why, to use the strategy of analyzing beliefs. ***S–18***

editors' note: The students could be walked through the process of making the graph, thereby coming to see how it's made and discussing its usefulness. Put all of the pets and numbers on the board: "We're going to make a graph of this information so we can see it more clearly. Which category is the biggest? How many are in it? OK, so we'll make this height stand for that number. (Draw the bar and put in the number.) Now we have to mark off the rest of the numbers evenly. Now, lets take this one. Where should the top of this bar be? What number is it? OK. What label should I put for it? Now, would anyone like to make the bar for this category? ... Now. Look at the list of pets and numbers and look at the graph. If we want to know which pet is owned by the most kids and the least, which of these ways is easiest to see that? Why? Does your math book have any other kind of graph we could use?" If interest warrants, groups of students could make different kinds of graphs using the same data for comparison. ***S–23***

Another direction to take this lesson would be to begin to explore zoology. "How are pets different from farm animals? Why? Wild animals? Why? How are they like them?" Students could research other animals (wild cats, foxes, pigs, etc.) and compare them to their pet counterparts: In what ways is the pet like the wild animal? Unlike it? Why? Do those differences make the wild animal a bad choice for a pet? Why or why not?

To extend the objective of developing a sense of responsibility toward pets, you might ask, "What's the difference between being a good pet owner and a bad pet owner? How do they treat their pets? Why do some people neglect or abuse pets? What effects does that have? What information do people need to know before they get a pet? Where could they get that information? What questions should they ask?" ***S–20***

Students could discuss the problem of forgetting to take care of pets, and devise solutions: Why do people forget to take care of their pets? What might help people remember? Would that work for everyone? What would work for you? ***S–7***

Water from the Air

(1st–3rd Grades)

Objectives of the remodelled lesson

The students will:

- develop and conduct an experiment to determine where water on the outside of a glass of water comes from
- interpret the results of the experiment
- explore the implications of the experiment

Original Lesson Plan

Abstract

Students experiment to discover that the water which appears on the outside of containers of cold water comes from the air. They put food coloring in cold water and notice that the water appearing on the outside of the container is clear, not colored.

from *Discovering Science 1*, Albert Piltz, et al. Charles E. Merrill Publishing Co. 1973. pp. 82–83, T101–T102.

Critique

By presenting the experiment to the students, this lesson misses the opportunity to allow students to puzzle over how to answer the question, "Where did the water come from?" They should think about the question and figure out how to settle it. The lesson also fails to have students distinguish their observations from conclusions.

Strategies used to remodel

S–1 thinking independently
S–32 making plausible inferences, predictions, or interpretations
S–35 exploring implications and consequences

Remodelled Lesson Plan

To present the problem, rather than the solution to the problem, this lesson could begin, not with colored, but with clear ice water. Ask students to observe the container and describe what they see. Tell them that this lesson will focus on the question "Where did this water come from?" Allow discussion. "Why do you think so? How could we find out?" ***S–1***

To help students develop an experiment, you might ask (allowing discussion after each question): "Why can't we tell just by looking at the water? Is the water outside just like the water inside? Could we make the water inside differ-

ent in some way? How?" Have students choose one or more methods which use available materials (for instance, the water could be colored or flavored).

When students have conducted their experiments, you could ask "What do you *observe?* What can you *conclude?* Why? Is the water outside like the water inside? Where did the water come from?" **S–32** The student text could then be read and discussed as a sum up.

The class could also discuss implications of what they found out in this lesson. Possible discussion questions include the following: What have we learned about water? Air? Does all air have the same amount of water in it? What are the differences between regular water and water in the air? What effect does the water that is in the air have? What other questions could we ask? **S–35**

Despite the detail with which we have delineated the strategies, they should not be translated into mechanistic, step-by-step procedures. Keep the goal of the well-educated, fairminded critical thinker continually in mind.

Magnets

(1st–3rd Grades)

by Linda Hawk, Linda Johnson, and
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Objectives of the remodelled lesson

The students will:

- learn that a magnet has a force, either a push or a pull, through exploration and Socratic discussion
- develop confidence in their ability to reason scientifically by making, testing, and evaluating predictions
- transfer insights by applying what they have learned about magnets to other forces

Original Lesson Plan

Abstract

The students will share their knowledge of magnets through a webbing activity: organizing their ideas in a spider web shape. Next, they will use activity centers as a means for exploring many facets of magnets. Then further webbing will help students to recall and clarify their experiences in the various centers.

Critique

This lesson has several problems. It doesn't have a specific objective, it needs strategies for developing critical thinking, and it assumes that students have previous knowledge.

editors' note: Although the students may not have "school knowledge" about magnets, most have probably had some experiences with magnets. The original also had important strengths. By sharing their original beliefs, students learn from each other, make any misconceptions they have explicit (providing a better chance of correction), and can suggest their own ideas for exploration. The second webbing activity helps students develop perseverance by graphically showing them what they have learned. By allowing students to compare their original beliefs with their new beliefs, it helps students correct their original misconceptions and allows clarification and deeper processing of what they have learned.

Strategies used to remodel

S–9 developing confidence in reason
S–1 thinking independently
S–24 practicing Socratic discussion: clarifying and questioning beliefs, theories, or perspectives
S–32 making plausible inferences, predictions, or interpretations
S–12 developing one's perspective: creating or exploring beliefs, arguments, or theories
S–11 comparing analogous situations: transferring insights to new contexts

Remodelled Lesson Plan *S-9*

Procedure: Make magnets and materials available for exploration — all sizes, shapes, and powers of magnets and a variety of metals to test (different metals, shapes, sizes: paper clips, nails, coins, furniture, whatever). ***S–1***

After students explore magnets, use Socratic questioning for observations. "What happened? What had you done? Why did you do that, did you have an idea of what might happen or were you just messing around? Why do you think that happened? Does everyone agree? Why or why not? How does that relate to what John said? How could we test that idea?" ***S–24***

The teacher might then explain what took place with various magnets and why — at least enough to get across the concept of force as push or pull. (***editors' note:*** You could give a lecture here if every ten minutes or so you stopped and had students pair up and share their own experiences about what you have said.)

Students' understanding of magnets can be further developed and assessed by having them think hypothetically.

- What do you think would happen if ...

  You put two sphere magnets together?

  You put two bar magnets together?

  You put horseshoe magnets together?

  You put one sphere with one bar?

  You put one bar with one horseshoe? ***S–32***

editors' note: For each of these questions, have students predict (and give reasons). Then several students can test each prediction. Then ask what happened and why the magnets behaved as they did. ("John, you said the two magnets pushed each other away, but Sue said they pulled together. Why don't each of you switch one of your magnets around like this and try it again?")

Ask students to pose other questions or tests, and use the same process (predict, test, discuss).

The teacher could incorporate the webbing activities from the original lesson into the remodelled lesson before the initial exploration and after discussion. Students can compare their initial ideas with what they got from the lesson. "What did you know before? Did you have any mistaken ideas? Is what we discovered compatible with this [original] belief? Why or why not?" ***S–12***

Interested students could read about magnets, relating what they read with their own experiences, and later report back to the class.

If the main intention of the lesson is to introduce the scientific concept 'force', then students could brainstorm examples of force, and small groups or the class could evaluate individual items on the list, applying the scientific concept. "What other forces — physical pushes and pulls — do you know about? Which of these examples would a scientist consider a force? Why or why not?" (Disputed cases could be checked in resources.) ***S–11***

Plant and Animal Products in Food

(2nd Grade)

Objectives of the remodelled lesson

The students will:

- develop and discuss criteria for evaluating foods
- think fairmindedly by discussing their parents' criteria
- practice dialectical thinking by assessing reasons vegetarians and non-vegetarians give for their eating habits

Original Lesson Plan

Abstract

Students are asked to bring in empty food containers (cartons, envelopes, jars, boxes, etc.) with labels. They compare the ingredients of different brands of the same food, and divide the containers into foods which are from plants, animals, or a combination of the two. Also, they read that food provides us with the energy we need.

from *Science: Understanding Your Environment*, George G. Mallinson. Silver Burdett. 1978. p. 142.

Critique

This lesson provides the teacher with a natural place to introduce evaluation of food, but instead it focuses only on the distinction between plant and animal products. This constitutes a missed opportunity to have students develop criteria for choosing foods to eat, and apply the criteria to specific foods. The lesson also fails to discuss the differing points of view of vegetarians and meat eaters. Finally, the lesson could question students about what would happen if one didn't eat.

Strategies used to remodel

S–3 exercising fairmindedness
S–15 developing criteria for evaluation: clarifying values and standards
S–26 reasoning dialectically: evaluating perspectives, interpretations, or theories
S–24 practicing Socratic discussion: clarifying and questioning beliefs, theories, or perspectives

Remodelled Lesson Plan

After using the original lesson, the teacher could ask the students why it is important to know whether foods are made of animals, plants, or both. The class might then discuss other factors relevant to deciding which foods to choose. The teacher could ask "What are some of the things we should know about food before deciding to buy it?" List these responses. Allow room for disagreement and discussion. One student, for example, may argue that how food tastes is the most important factor; whereas another student believes that the food that is cheapest is best. If disagreement doesn't arise naturally, ask, "What do your parents think is most important when choosing food? ***S–3*** What do you think? What criteria do your parents use to decide? What criteria did you use? Who do you think is right? Why? Can you use both sets of standards? How?" ***S–15***

Then the teacher can facilitate a dialectical discussion concerning vegetarians and non-vegetarians. The teacher can ask, "What is a vegetarian? What reasons might a vegetarian give for not eating meat or animal products? What reasons might a meat-eater give for eating meat or animal products? Which reasons make the most sense? Why?" ***S–26***

Finally, ask students how we know that people require food for energy and to live. You can ask them questions such as these, "What would happen if someone were to quit eating completely? What if someone stranded on a desert island were to eat only coconuts or only fish? What does this tell about our need for food?" ***S–24***

It should not be assumed that there is a universal standard for how fast teachers should proceed with the task of remodelling their lesson plans. A slow but steady evolutionary process is much more desirable than a rush job across the board.

What the Scientist Does

(2nd Grade)

Objectives of the remodelled lesson

The students will:

- develop and clarify their concepts of 'science'
- form categories of different things that scientists study
- clarify some scientific questions by discussing how they can be settled
- deeply question reasons for doing science

Original Lesson Plan

Abstract

We have selected introductory and concluding lessons from a unit on "What the Scientist Does." In the first lesson, students list and discuss their ideas about what scientists do. The middle lessons develop the idea that scientists observe, experiment, read, keep records, and discuss their work, in order to learn about the physical world. Each lesson has pictures of scientists engaged in scientific activities in various fields and pictures of children doing the same. The text tells the students what the scientists are doing, why, and that they can do the same. Some lessons suggest specific activities. The final lessons summarize the ideas covered and encourage students to do science.

from *Today's Basic Science 2*, John Gabriel Navarra, et al. Harper & Row, Publishers. 1967. pp. 6–7, T1–T3, 8–9.

Critique

This unit has several strengths: it encourages students to see themselves as scientists; it gives a fuller description of science than most texts by including reading and discussion as part of science. The material, however, is incomplete. The students do not contrast science with other disciplines, and so do not develop the distinction between science and non-science. Students are not given an opportunity to come up with a more complete list of the objects of scientific study. The unit also has no material about why people do or study science.

Strategies used to remodel

S–14 clarifying and analyzing the meanings of words or phrases
S–1 thinking independently
S–17 questioning deeply: raising and pursuing root or significant questions
S–13 clarifying issues, conclusions, or beliefs

Remodelled Lesson Plan *S-14*

The teacher may want to have this series of discussions at both the beginning and end of the year. The ideas covered in this lesson could also be re-introduced whenever they seem relevant to a specific discussion during the year.

You might begin by asking, "What is science? (Discuss at length.) What do scientists study? When you study science in school, what do you study about?" Have students brainstorm examples. List all responses. Then have students categorize their responses. (For instance, if one item is "frogs" and another "living things", a student may point out that the first is a specific instance of the second.) ***S-1*** "What do all of these categories have in common? What does that tell us about science?" You might also have students compare science to other subjects. ***S-17***

The students could then select a few of the items and brainstorm questions a scientist might ask about each. List the questions. For each question ask, "How could we find out?" (If students answer, "By reading about it." you could ask, "How could we find out for ourselves? How did the people who wrote the books find out?" or similar questions.) Then have the students summarize common processes of settling scientific questions. ***S-13***

Then lead a discussion about why people do science. You may want to add ideas they miss: curiosity, the need to solve specific problems, desire to improve the quality of life. Encourage extended discussion about the reasons: Are these all good reasons? Why or why not? Take some reasons one by one: Why is this a good thing? Are some of these reasons more important than others? Which ones? Why? Does anyone disagree? ***S-17***

Finally, students could discuss questions like the following: What do you like about science? Why? Dislike? Why? What areas of science do you find the most interesting? What is interesting about it?

Rocks of the Earth

(2nd Grade)

Objectives of the remodelled lesson

The students will:

- practice developing and clarifying their own questions about rocks and answering them, thus engaging in intellectual perseverance
- clarify questions by discussing how scientific questions can be answered
- categorize questions by noting significant similarities and differences among questions

Original Lesson Plan

Abstract

The first lesson introduces a unit on rocks. The student page has a picture of two children by a stream in the mountains. The text draws attention to sizes and shapes of rocks. The students describe and discuss rocks they have found, compare their rocks to the picture, and discuss where rocks are found. The second lesson, which sums-up the unit, focuses on the following questions: What sizes and shapes are rocks? In what places can you find rocks? Are some rocks softer than other rocks? How can you find out which rocks are softer? Are some rocks harder than other rocks? How can you find out which rocks are harder? How can you find out if a rock is limestone? How can you make crystals? What do crystals look like? How are rocks used?

from *Discovering Science,* Albert Piltz, et al. Charles E. Merrill Publishing Co. 1973. pp. 2, 13T–T14.

Critique

The unit misses the opportunity to have students develop their own questions and reflect on how to settle them, thereby engaging in scientific reasoning. The text provides the teacher with the questions and suggests specific ways that experiments should be conducted. Students should be allowed to develop and explore their own questions, problems they are most interested in, and practice seeing how these questions guide their means of inquiry, that is, what kinds of things they need to do to answer them. This unit also misses the opportunity to have students practice classifying and discussing types of questions by comparing and contrasting the ways in which different questions are answered.

Strategies used to remodel

S–8 developing intellectual perseverance
S–1 thinking independently
S–13 clarifying issues, conclusions, or beliefs
S–29 noting significant similarities and differences

Remodelled Lesson Plan S-8

The teacher might begin the lesson by asking students, "What do you know about rocks? What would you like to find out about rocks?" ***S-1***

Help students recognize how good questions are an important part of scientific inquiry by asking, "Do you know what to do to answer this question? Is the question clear? (Do you know what it means or do you need to ask further questions?) How would you find out? Do you need facts? Do you need to do an experiment? Do you need to measure or count? How should you measure? Is there any other way you can find out? Is one way better than another? Why do you think so?" ***S-13*** You could also record specific methods students suggest for answering questions for later discussion.

After you have completed this process for at least several of the students' questions, encourage students to think about their responses and ask, "Are any of these questions similar in the way you find out the answers? Which ones? What would you do to answer the first question mentioned? What would you do to answer the second question mentioned? How are these similar?" The teacher can begin grouping the questions on the board. ***S-29***

"What are some of the kinds of things we decided that we must do to find out the answers to our questions about rocks? Were some questions harder than others? Can someone give me an example of a question they think is hard to answer? Why do you think so? Can anyone give an example of a question that is easier to answer? Why do you think so?" Conclude by mentioning that whatever problem they are trying to solve, it helps to think about what they must do to answer the questions they have.

For the rest of the unit, the students can answer the questions they find most interesting. (They may need to supplement their experiments with reading.)

Comparing Man to Animals

(2nd Grade)

Objectives of the remodelled lesson

The students will:

- probe the similarities and differences between people and animals
- practice scientific reasoning by clarifying and giving reasons for claims they make about animals and humans
- discuss the methods of and reasons for communication amongst humans and animals
- develop respect for and understanding of animals

Original Lesson Plan

Abstract

Students look at several pictures and notice the similarities between different animals. They review the names of the five senses, and discuss the characteristics of each animal individually. Students read about humans in their texts, then discuss the differences between humans and animals. What can humans do that animals can't? The children are assigned to make a picture collection showing activities that people do that animals can't do. Finally the importance of language is discussed. This is illustrated in a game where children try to give each other commands without talking.

from *Science: Understanding Your Environment,* George G. Mallinson. Silver Burdett. pp. 134–135.

Critique

This lesson is a missed opportunity to have students practice giving evidence in support of their beliefs, and to probe deeper into questions concerning the differences between animals and humans. Although students are asked to "share ideas about whether or not each animal has all the senses and how the senses are used" it is not clear how or if the teacher encourages them to *support* their claims with reasons. Also, this lesson emphasizes the things humans can do which animals cannot, but fails to make the point that animals don't need to do the things we do, and neglects to ask what animals can do that humans cannot (live underwater, run fast, survive outside, smell a lizard at forty paces, fly, hear better). This is a missed opportunity to develop respect and empathy for animals. Furthermore, activity 4, on communication, is not integrated with the lesson, since it is in no way related to questions about animal communication.

Strategies used to Remodel

S–29 noting significant similarities and differences
S–33 giving reasons and evaluating evidence and alleged facts
S–13 clarifying issues, conclusions, or beliefs
S–12 developing one's perspective: creating or exploring beliefs, arguments, or theories

Remodelled Lesson Plan S-29

For each student response concerning the similarities and differences between animal and human senses, ask "What makes you think so? ***S–33*** Did you learn it yourself or from someone else? What did you observe and conclude?" If the students say they learned it from someone else, ask, "What could you do to test this claim for yourself?" ***S–13***

When discussing things humans can do that animals can't, the teacher could add questions like the following: Do you think animals would like to be able to do that? Do they need to do that? Is there something similar that they do? For example, although animals can't play all of the same games we play, do they play games of their own? Although animals can't build roads or drive cars, do you think they want to do this or need to? What can animals do that we can't? Why can't we do that? Why can some animals do that? Are there things that animals can do that you wish you could do? What? Why? ***S–12***

To tie in the exercise on communication, you might add, "Do you think animals communicate? What makes you think so?" ***S–33*** If yes, "How do they communicate? What are the different ways humans communicate? How are these similar to or different from how animals communicate?"

The teacher could add further thought provoking questions, time and interest providing.

- What does it mean to think? Do animals think? How do you know?
- What kinds of things do animals communicate to each other? ("I'm hungry!" "I'm scared!" "Food!" "Get away!") What are some similarities and differences between what we and animals communicate? The class could also discuss how much human language dogs "understand". (Although such questions are difficult, there is no reason that children can't begin to ponder them early. This gives them valuable practice in asking further questions to clarify a problem, and distinguishing what they know from what they are unsure of.)
- Are all animals equally good or are the ones we can teach better than ones we can't? Are the ones we find useful or entertaining better than the ones we don't?

Students could research any area of animal behavior they find interesting, report the results, and the class can compare their findings to humans.

The Sun

(2nd–3rd Grades)

by Gloria Jordan, Linda Jadick, Karen Aycock, and Jane Higgins, Greensboro Public Schools, Greensboro, NC

Objectives of the remodelled lesson

The students will:

- discover information about the sun through research and discussion
- engage in scientific reasoning by exploring the consequences of imagining different facts
- through fulfilling the above objectives, develop confidence in their reasoning abilities

Original Lesson Plan

Abstract

Students use encyclopedias and library books to find facts about the sun. They take notes and then put facts on a mural of the sun. The class discusses any contradictory "facts" found, and words which need clarification, and they categorize the facts.

Critique

editors' note: Although the original lesson is an improvement over the usual slavish dependence on texts, some discussion questions could be added to take students further in considering what they have learned and what it means.

Strategies used to remodel

S–9 developing confidence in reason
S–1 thinking independently
S–35 exploring implications and consequences
S–8 developing intellectual perseverance

Remodelled Lesson Plan *S–9*

Have the children discuss the information researched about the sun. Allow room for discussion to make assumptions explicit. Have a discussion on how to find more information on the sun. "Where else could we look to find out more? Why would that be a good place to look? What would be good to learn? How can we find it?" ***S–1***

Students can engage in scientific reasoning by exploring the implications about the information found. Change the facts. For example, "If the sun were closer,

what would happen to people, animals, plants? Why? If it were further away? What would happen to the water and oceans? To living things? Why?" ***S–35***

"What has happened to the ozone? Why is it getting hotter and hotter?" Talk about the ozone layer, what has been done to damage it, short and long-term implications to plant and animal life on earth. ***S–35***

editors' note: This lesson provides a perfect opportunity to have students deeply learn from their research. Before sending them to sources, you could have them brainstorm everything they know or think about the sun. Then tell them not to copy complete sentences from their research, only words or phrases. Reconvene the class to share their notes and reconstruct what the sources said based on their notes. Conclude with a writing assignment. By having to reconstruct what they read from sketchy notes, students more deeply process what they read; the knowledge becomes more truly theirs. ***S–8***

One does not learn about critical thinking by memorizing a definition or set of distinctions.

What Will Decompose?

(2nd–3rd Grades)

by Jane Davis-Seaver, Karen Marks,
and Nancy Johnson, Greensboro Public
Schools, Greensboro, NC

Objectives of the remodelled lesson

The students will:

- distinguish between man-made and natural objects by categorizing examples collected on a nature walk
- use the scientific process to organize information, categorize, hypothesize, test, and draw conclusions
- develop a perspective on the uses and problems of using man-made materials, by recognizing assumptions
- discuss the implications of using man-made objects, such as those made from plastic

Original Lesson Plan

Abstract

The original lesson plan is a scientific experiment to investigate what objects will decompose. The children are told that water is needed to make bacteria grow. They bury various objects, add water, and dig up each one after a specified length of time. They record the results.

Critique

We feel that a separate experiment on bacteria's need for water should precede this lesson.

This plan misses the opportunity to help children categorize and find common characteristics among natural and man-made substances through small group discussions. It does have hands–on investigation and experimentation. Its strength lies in its use of the mechanical techniques of the scientific method. We would use the original lesson plan as a part of the lesson and encourage small group discussions on such questions as these: Why do we use plastic or other man-made materials? When are these materials good to use? When are they not good to use?

Strategies used to remodel

S–12 developing one's perspective: creating or exploring beliefs, arguments, or theories
S–35 exploring implications and consequences

Remodelled Lesson Plan S-12

Rather than beginning the lesson with the experiment, start by clarifying concepts about trash by taking a nature walk to find trash, and then brainstorming ideas about the kinds of trash found. Ask what trash is decomposing and which isn't. Encourage the students to suggest categories of things that do or don't decompose, and encourage hypotheses to test. Then execute the experiment by having students choose objects from each category, make predictions regarding which objects will decompose and how quickly, and follow through on the experiment.

Following the experiment, allow for a discussion focusing on critical thinking skills. Allow for discussion on what problems have been revealed in this experiment and discussion. "What kinds of things did you predict would decompose quickly? Slowly? Not at all? What happened? Which of your predictions was verified? Which weren't? Why not? What can we say about what kinds of things decompose? Why? How are the things that decompose similar? How do they differ from those that don't decompose? Do you think that's the reason these did and those didn't? Why or why not? Can we generalize?" The class can discuss this at length, trying out generalizations, and possibly testing them with follow-up experiments.

In evaluating man-made objects, and assumptions about their use, ask if it is important to use them, and under what circumstances can natural objects be substituted. "Do we really need to make it out of plastic, or are you just assuming we do because you've always seen them that way?"

editors' note: Why do people often prefer to use man-made materials such as plastic? What problems does this cause? Where do man–made materials end up? What effects does that have?" ***S–35***

Parts of a Wave

(3rd Grade)

Objectives of the remodelled lesson

The students will:

- engage in independent thinking about waves
- learn about the parts of a wave by noticing the similarities and differences in a variety of examples
- learn the standard terms and methods of measuring waves

Original Lesson Plan

Abstract

The teacher ties a rope to a post and creates a wave in the rope. The students draw a picture of the wave they observe. They read in their text that the high point of a wave is called the crest, the low point is the trough, and that the wavelength is the distance from one crest to the next.

from *The Young Scientist,* John Gabriel Navarra, et. al. Harper & Row, Publishers. 1971. pp. T63, 134.

Critique

The text suggests that the teacher create a wave with a rope for the students to observe, but this alone is not enough to foster critical thought, since all thinking is done by the text. Before using the text, the teacher should give the students a chance to discover the parts of waves for themselves, rather than simply presenting the answers to them. Furthermore, that waves are measured from crest to crest is arbitrary; students should realize this.

Strategy used to remodel

S–9 developing confidence in reason
S–29 noting significant similarities and differences

Remodelled Lesson Plan *S–9*

The teacher could create various waves with the rope while the students observe and draw different waves on paper. The teacher could also draw several different-looking waves on the board. Focus students' attention on the wave parts by asking questions like the following: How are these waves different? Similar? What parts do they have? How could we describe these waves? How could we distinguish them? Where could we measure them? ***S–29***

Help the students see the high points, low points, and the distance between repeating patterns. (They may also mention the distance up-and-down.)

If the students don't know the standard terms, introduce them, relating each to the students' descriptions (the up-and-down length is "amplitude").

Point out that, although the wavelength could be measured from any two corresponding points (trough, crest, half-way between, etc.) it is standard practice to measure it from crest to crest.

What is remodelled today can be remodelled again. Treat no lesson plan as beyond critique and improvement.

At Work on the Earth

(3rd Grade)

Objectives of the remodelled lesson

The students will:

- distinguish the ordinary usage of 'work' from the scientific usage and discuss important similarities and differences between them
- begin to deeply understand the differences between ordinary language and technical languages

Original Lesson Plan

Abstract

Students begin the lesson by observing a picture of children pushing a raft down a river, and discussing what the children are doing. The text asks, "Would you say they are doing work?" Students say what they think 'work' means; then they are introduced to the scientific meaning of 'work'. Each child is asked to demonstrate an action that illustrates his or her understanding of the scientific concept. Other children observe and identify the force that is applied and the motion that results. Next students are asked whether water can do work, and distinguish forces used to do work (child raking leaves, a boy holding a hose still while the water moves the leaves).

from *Concepts in Science*, Paul F. Brandwein, et al. Harcourt Brace Jovanovich, Inc. 1980. pp. T8–T11.

Critique

This lesson provides an important introduction to the idea that the same word can have different meanings and that scientists, especially, have special, technical meanings for ordinary words. Unfortunately, however, this lesson fails to give students valuable practice in moving back and forth between different meanings of the same word, and recognizing and generating examples of when one, both, or neither meaning applies. Instead of moving back and forth, this lesson moves immediately to the scientific usage of the word 'work' and assumes it throughout the lesson. It doesn't explicitly develop the concept of technical language. Students need to be able to distinguish ordinary from technical concepts. To be able to think scientifically, students need to understand why scientists develop the concepts they do.

Strategies used to remodel

S–14 clarifying and analyzing the meanings of words or phrases
S–29 noting significant similarities and differences
S–17 questioning deeply: raising and pursuing root or significant questions

Remodelled Lesson Plan *S-14*

After the students have read their texts and done the activities, they could better develop an understanding of technical language and compare the two concepts of 'work'.

• What do you think of when you hear the word 'work'? Which of these would be examples of, or related to the scientific concept? Why do you say so? In the picture of the boy using water to push leaves, is he working in the normal sense of the word? How could we tell? Is he doing work in the scientific sense? How do we know? What is doing the work? Why do you say so?

• What's the opposite of the normal meaning of 'work'? (rest or play) Which of these is closer to the opposite of the scientific concept? Why?

• When would doing schoolwork be doing what scientists call work? Why? When would it not be work in the scientific sense? Why not?

Students can comment on what seems to be intrinsic to their ideas of work and play — what all their examples of each have in common: Does the scientific concept of 'work' apply to these cases? Which ones would the scientist call an example of work being done? For the scientist, is 'play' the opposite of 'work'? What is? ***S-29***

Encourage students to see how our purposes guide how we use words by asking, "Is one of the uses of the word 'work' right and one wrong, or are both right? Why do you think so? Why do scientists have a different meaning of 'work'? Why don't they just use the ordinary meaning of the word? Should we always use 'work' the way scientists do?" ***S-17***

Socratic questioning should be available to the teacher at all times. Questions, not answers, stimulate the mind.

A Living System

(3rd Grade)

Objectives of the remodelled lesson

The students will:

- engage in scientific reasoning and develop confidence in reason by formulating hypotheses about how rocks are broken into soil
- design and conduct experiments to test their hypotheses
- clarify and analyze scientific conclusions by discussing how scientists might have proven them

Original Lesson Plan

Abstract

We selected lessons from a unit on soil. In them, students are introduced to the topic, examine soil samples, and conduct experiments designed to show how rocks are broken down. Students are shown how rubbing rocks together breaks pieces off. They record contents of soil samples. They rub two pieces of sandstone together for five minutes and count the pieces. Students are told how air, water, plants, and temperature changes break rocks.

from *Concepts In Science,* Paul F. Brandwein, et al. Harcourt Brace Jovanovich, Inc. 1980. pp. T32–T34, 53–54, 56–58, 63–64.

Critique

By presenting the processes by which rocks are broken down, and the experiments which illustrate them, the lessons discourage students from struggling with the issue and developing their own hypotheses and experiments; students don't engage in scientific reasoning.

Students are told to count the pieces of rock they have broken off, yet there is no reason for learning how many pieces are broken off by five minutes of rubbing. Students shouldn't be asked to measure or count unless doing so helps settle some issue of interest. Measuring and counting, in themselves, are pointless. The idea that scientists run around counting and measuring everything in sight, for no reason, is a stereotype. Students need to learn how to use quantification as part of the process of settling questions. They need to learn to distinguish times when such activities are useful from times when they are not. Thus, this part of the lesson should be dropped.

Strategy used to remodel

S–9 developing confidence in reason
S–8 developing intellectual perseverance
S–13 clarifying issues, conclusions, or beliefs

Remodelled Lesson Plan S-9

Before students read the text which covers the ways in which rocks are broken up, they should have a chance to reason about the issue, "How are rocks broken up?" First, you might remind students that one thing they found in their soil samples was rock and ask, "Where did the little pieces of rock come from? How did big rocks get broken into pieces?" Ask them to recall partly broken, crumbling, or cracked rocks they have seen. Ask them if they know or could guess the cause. Let the students brainstorm possible answers. Make a list of their answers and allow discussion. Choose several responses and ask, "How could we find out if this breaks rocks? What could we do?" Allow discussion. The class could be split into groups, each of which can design and conduct experiments to test a hypothesis and report the results to the rest of the class. ***S–8***

To summarize the lesson, the class could read and discuss the relevant passages in the text. "What are all of the things mentioned in the text that break rock into pieces? Which of these things did we test? How? Why did we do that? What happened? What did the results show? Which things mentioned in the text didn't we test for? How do you suppose scientists learned about and tested them? What might they have done? Why? What would that show?" ***S–13***

A teacher committed to teaching for critical thinking must think beyond compartmentalized subject matter teaching to ends and objectives that transcend subject matter classification. To teach for critical thinking is, first of all, to create an environment that is conducive to critical thinking.

Two Concepts of 'Soil'

(3rd Grade)

Objectives of the remodelled lesson

The students will

- practice deep questioning by distinguishing the scientists' concept of 'soil' from that of the farmers
- compare the two concepts noting significant similarities and differences between their uses
- learn about reading critically by distinguishing the two concepts as they come upon them in their text and by discussing the need to figure out whether a word is used in a technical or ordinary sense

Original Lesson Plan

Abstract

Seven pages from the students' text, and one page from the teacher's edition, were selected from a unit on soil. The first page distinguishes the scientists' concept of 'soil' (all of the earth's covering is soil) from the farmers' concept (soil is the part of the land in which crops can grow). The rest of the students' pages cover the following topics: kinds of soil, makeup of soil, layers of soil, and soil conservation. The last page (from the teacher's edition) has review questions for the unit.

from *Concepts in Science,* Paul F. Brandwein, et al. Harcourt Brace Jovanovich, Inc. 1980. pp. 55, 60, 79, 81–83, 86, T41.

Critique

A basic goal of science education is to introduce students to scientific concepts, many of which have ordinary counter-parts that have related but different meanings. One major obstacle to science education, then, is the tendency to confuse scientific with ordinary concepts. Students rarely recognize the nature of scientific or technical vocabulary or its relationship to normal uses of language. The standard approach (defining the technical vocabulary then moving along) does not adequately address the problem of students' ordinary uses of language and pre-conceptions getting mixed up with technical material. After introducing the distinction between the two concepts of soil, the text simply uses the word 'soil' without saying which sense of the concept is meant, or highlighting to students the differences between technical and ordinary concepts. Scientists do not develop technical vocabulary arbitrarily. To deeply understand science and technical vocabulary, and keep them distinct from non-scientific ways of talking, students must explicitly explore how purposes determine how a word is used.

Strategies used to remodel

S–14 clarifying and analyzing the meanings of words or phrases
S–29 noting significant similarities and differences
S–17 questioning deeply: raising and pursuing root or significant questions
S–21 reading critically: clarifying or critiquing texts

Remodelled Lesson Plan *S–14*

When discussing the page on which the distinction between 'soil' (science) and 'soil' (farming) is made, ask students to think about the two concepts: How are the concepts similar? Different? Which concept applies in a greater number of contexts? (The teacher could draw, or, if students are familiar with them, could have students draw a simple Venn or circle-within-a-circle diagram, showing that, though all farmers' soil is scientists' soil, not all scientists soil is farmers' soil.) ***S–29*** Is one concept clearer than the other? Which concept is more familiar to you? Why do scientists and farmers use the same word differently? ***S–17***

For the other pages, whenever the word 'soil' occurs, ask students which concept is meant. Have them explain how they know. (For instance, on page 60, the scientific concept is used. Sand is one kind of soil, but sand isn't "soil" to a farmer. On page 79 the text probably means the farmers' concept because it says "good soil", which probably means "good for growing crops".) "Would this meaning make sense in this sentence? That meaning? Why?" ***S–21***

When using the review questions, again, the students could explain which concept is meant each time 'soil' occurs. ***S–21***

Another way to approach this material would be to begin with a brainstorming session in which students (possibly starting with dictionaries) listed every word that comes to mind when they hear the word 'soil'. Then, after students read the definitions in their texts, they can evaluate each item on the list for its relationship to the concepts of soil in their texts: soiled clothes, dirt, sand, etc. As students read, they can distinguish the concepts as above. ***S–21***

Students can use this experience with technical vocabulary to develop insight into one aspect of critical reading. "How should we read differently when a book uses special or *technical* vocabulary? What can you do when you come to a word you don't know? What can you do when you come to a word with more than one meaning? What things did we do to figure out which meaning was used?" ***S–21***

School time is too precious to spend any sizeable portion of it on random facts. The world, after all, is filled with an infinite number of facts. No one can learn more than an infinitesimal portion of them. Though we need facts and information, there is no reason why we cannot gain facts as part of the process of learning how to think.