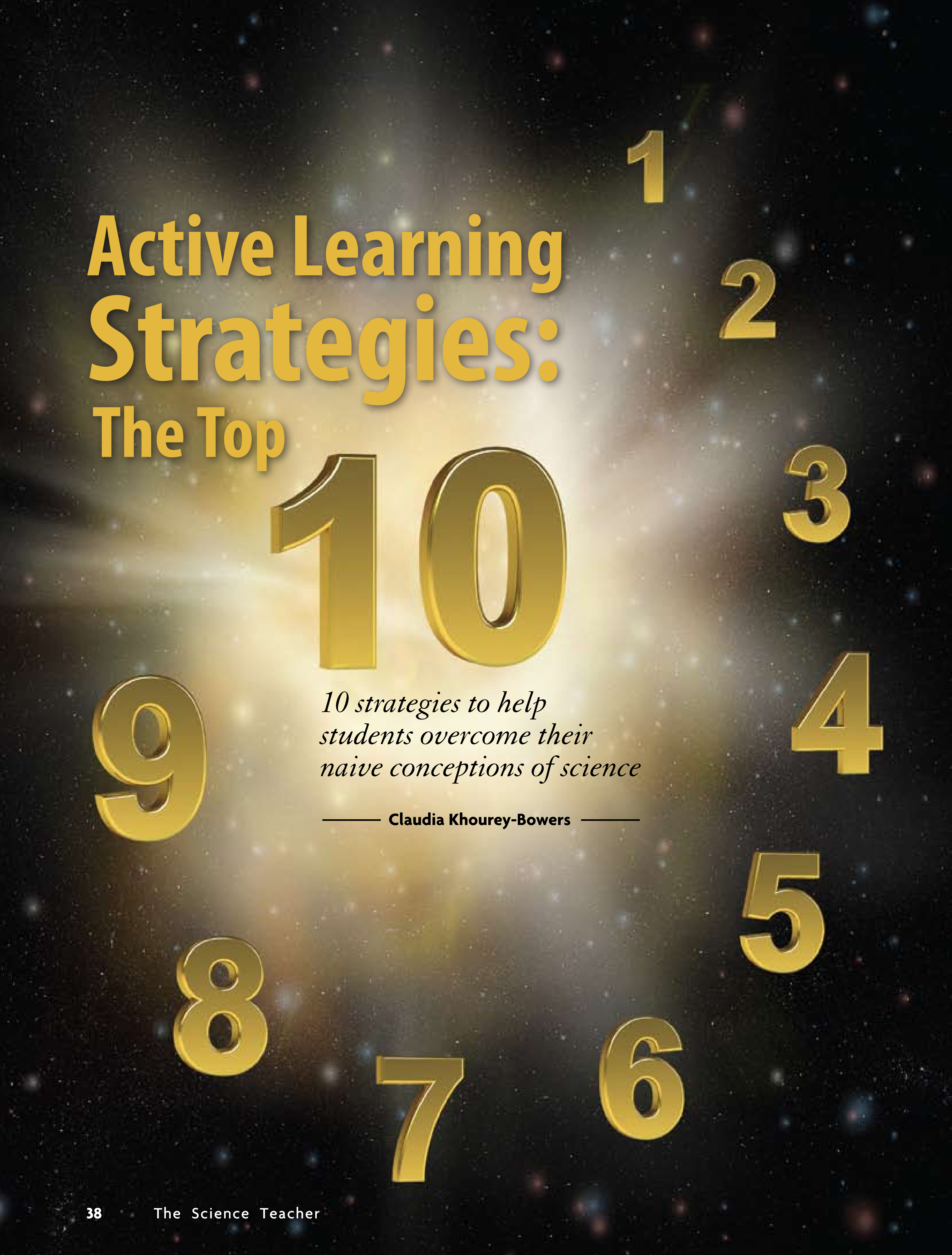

Active Learning Strategies: The Top 10

10 strategies to help students overcome their naive conceptions of science

Claudia Khourey-Bowers

Conceptual change instruction recognizes that students bring personal, or naive, conceptions to the classroom, which they use to explain their world, interpret situations, and create meaning (Driver et al. 2007). But what happens when students' personal conceptions are inconsistent with experts' views of scientific knowledge? Even after direct instruction, many students are held captive by their naive conceptions.

The persistence of these conceptions, as documented in *The Private Universe Teacher Workshop Guide* (Harvard-Smithsonian Center for Astrophysics 1995), provides compelling evidence that traditional instructional strategies are often ineffective at displacing naive conceptions. Conceptual change instruction, however, creates opportunities to replace students' naive conceptions with scientific concepts.

This article describes the conceptual change cycle and provides 10 active learning strategies to help students overcome their naive conceptions of science. I have found these strategies to be effective in teaching for conceptual change.

Conceptual change

Conceptual change theory (Posner et al. 1982) asserts that learners must first become dissatisfied with their existing conceptions, and then be provided new concepts they find to be intelligible, plausible, and fruitful:

- *Dissatisfaction* arises when learners realize that their preexisting ideas are no longer able to provide answers or solve problems.
- A new concept is *intelligible* when it can be used to represent a situation or solve a problem and it can be internalized by the learner; representations may take the form of analogies, metaphors, or images.
- For a new concept to be *plausible,* the learner must find it potentially believable and consistent with his or her experiences and worldview.
- For a concept to be *fruitful,* the learner must be aware of, generate, or understand novel practical applications or experiments that the new conception supports or explains.

A conceptual change lesson cycle, which incorporates the phases of *dissatisfaction, intelligibility, plausibility,* and *fruitfulness,* can be designed to address any of the National Science Education Standards (NRC 1996). The cycle begins and ends with students' understanding. In this kind of lesson cycle, teachers do the following (Figure 1 provides a more detailed outline):

- Reveal students' prior knowledge and establish instructional goals.
- Design a bridging lesson that will create *dissatisfaction.*
- Present the "experts'" perspective on the concept.

FIGURE 1

A conceptual change lesson cycle.

1. Reveal students' prior knowledge and establish instructional goals.
   - What are the recurring naive conceptions of students? How do you know?
   - What is the fundamental scientific concept you want students to understand?

2. Design a bridging lesson that creates dissatisfaction.
   - What bridging lesson can you use to challenge naive conceptions?
   - How will this lesson create dissatisfaction by helping students realize that their personal naive conceptions are inadequate to explain phenomena?
   - What active learning strategy will you use to engage your students?

3. Present the "experts'" perspective on the concept.
   - How will you present the experts' scientific perspective to students?
   - What representations (e.g., analogies, images, symbols, models) will you use to make the experts' perspective intelligible to your students?

4. Provide an opportunity for students to apply the scientific concept, to test its fruitfulness and plausibility.
   - What active learning strategy will students use to apply the experts' perspective to a novel situation?
   - Will students find the new concept preferable to their prior understanding and fruitful as a problem-solving strategy?
   - What kind of posttest will verify that students have developed new knowledge?
   - Will students find the new concept plausible in light of everything else they know about related concepts?

5. Ask students to reflect on their new understanding.
   - Have students self-assess their cognitive processes. What aspect of the lesson cycle caused them to change their thinking? What convinced them that the new concept was preferable to their naive conceptions?
   - How can journaling or other reflective strategies encourage students to think about thinking?

- Provide an opportunity for students to apply the scientific concept, to test its *fruitfulness* and *plausibility*.
- Ask students to reflect on their new understanding.

Top 10 strategies

As seen in Figure 1 (p. 39), the conceptual change cycle combines teacher-centered and student-centered activities. Student-centered activities should emphasize active learning (Blank and Alas 2009) strategies in which students are expected to manipulate knowledge and eventually construct understandings that are consistent with scientific conceptions.

Active learning strategies transform learning from a private, unexamined event to a public, shared process within the classroom community. By manipulating knowledge and talking about the phenomena with their classmates and teachers, students' naive conceptions are made visible and can be replaced with more scientific understandings.

The "top 10" active learning strategies presented here are suggested for conceptual change instruction. I have used these strategies with middle and high school students and preservice and inservice teachers. These strategies helped my students rethink their prior knowledge about science topics—allowing them to approach key concepts with fresh attitudes—and in the end, develop more scientific ways of thinking. Inservice teachers, eager to try novel strategies with their own students, enjoyed similar successes. These strategies are also supported by educational research, some of which is cited throughout this article.

Nonscientific conceptions: Misconceptions, alternative, or naive?

Each of these terms refers to strongly held interpretations of natural phenomena developed by the learner. The differences in these terms depend on the absolute or relative "inaccuracy" perceived by the teacher.

Misconceptions imply that the learner's ideas are simply wrong and should be removed from his or her cognitive framework.

Alternative and *naive conceptions* recognize that the learner's ideas are "prescientific"—meaning that they do not hold with accepted scientific explanations and have limited usefulness in solving problems or interpreting a pattern of phenomena—when compared to scientific ideas. Both terms imply that the learner's ideas are partially correct, relative to the scientific view.

The term *alternative conception* recognizes that the context of the learner's knowledge has a strong influence on the usefulness of this knowledge. The term *naive conception* recognizes the developmental nature of cognitive development. Teachers can actively build on students' naive conceptions to help them become more scientific thinkers.

#10: Watch your language!

Sometimes, multiple definitions of common words—such as *work, energy, size, shape,* and *growth*—affect students' understanding of fundamental scientific concepts. For example, you might think of *growth* as an increase in the size or number of cells, but students might think of it as an increase in height or width—overlooking the concept of cellular structure. Help students distinguish scientific meanings from everyday meanings of words. Word Walls (in which important terms are posted on a wall or bulletin board as the terms are taught), student-illustrated vocabulary cards, and science notebooks can help students create a working vocabulary and develop understanding (Roberson and Lankford 2010).

#9: Go for the long haul

Design longitudinal studies by having students collect data over an extended period of days, weeks, or months. Grow yeast colonies and make daily measurements of population growth and collapse. Raise fast-growing plants such as radishes and have students observe plant height, leaf number, length, and width over a period of several weeks. Have students select an independent variable. Make seasonal observations of ecosystems, including pond conditions, ground cover, light levels, and animal tracks. Long-term observations help students see trends and patterns, while minimizing transitory or insignificant changes. Patterns can be a powerful tool for analyzing the logic of students' prior knowledge and assumptions.

#8: Use discrepant events to awaken curiosity and inspire questioning

Dynamic models such as the "drinking bird," gyroscopes, and wind-up cars are surefire ways to get students asking questions about motion. A static model, such as a center-of-mass demonstration, can be placed in a corner of the classroom for students to discover. Students will eventually ask what it is and how it works. Predictions and hypothesis generation follow, as intrigued students are challenged to apply scientific knowledge to explain the "unexpected."

#7: Use novel associations to explore concepts

Rather than using textbook examples in the study of important concepts, use unique examples. Does every food web consist of grass, a rabbit, and a fox? Consider instead the food web on a rotting log. Why not use bacteria to convey concepts of population and abiotic factors? Study the physics of motion by observing the family pet. Encourage students to construct their own ecosystems or food webs by observing the school grounds or their backyards. Have students apply content knowledge and methods of scientific inquiry to investigate product claims, such as ultraviolet (UV) light-sterilizing toothbrushes and fat-free potato chips.

#6: Demystify diagrams

The most familiar diagrams—of food webs, the water cycle, and chemical equations, for example—attempt to convey complex relationships simply, using a combination of words, pictures, numbers, and symbols. But how many students really understand what these shorthand images represent? For example, in a food web, arrows point to the higher-order consumer. Why isn't the arrow pointing toward the organism that is consumed? How can we make sure that students understand that matter and energy are both moving from producers to consumers?

Similarly, the water cycle typically pairs specific processes with specific parts of Earth. For example, evaporation is shown over the ocean, and transpiration is shown over plants. Doesn't water both evaporate and transpire from plants? And doesn't water evaporate from roads, parking lots, and puddles, as well as from the ocean?

Chemical equations, symbolic of types and ratios of matter, present further problems. Do arrows in chemical equations mean the same thing as arrows in food webs? Are the products consuming the reactants?

In an effort to simplify, some diagrams can lead to incomplete understanding. Replace stereotypical thinking by presenting students with the opportunity to create their own images, before relying on standard diagrams. Have students make drawings and diagrams that depict their interpretations of the concept. As instruction proceeds, the drawings should become more complete and more consistent with standard representations.

#5: Measure twice, lecture once!

Just like the carpenter's adage of "measure twice, cut once," the suggestion here is to spend time making quantitative observations to develop understanding of fundamental concepts, particularly the conservation of matter. Measurement can be used in the study of physical and chemical changes. Start by measuring matter involved in physical changes, such as mixtures or solutions. When working with chemical changes—especially when gases play a role—use closed-system designs, such as reactions in freezer bags. Measurement can help students realize that matter is conserved in both chemical and physical changes.

By massing matter before and after physical or chemical changes, quantitative data (e.g., measurements) and qualitative data (e.g., observations of changes in state, color, or shape) can help structure classroom discussions. For younger students, discussion can center on how changes in appearance or state of matter are simply rearrangements of the building blocks of matter. For older students, those building blocks can be identified as specific atoms and molecules. Measurement helps develop the concepts of particulate nature and conservation of matter by guiding students to make and interpret observations and support their interpretations with experimental evidence.

#4: Say it with flowers...

...and pictures, words, and mathematical symbols! Difficult concepts such as photosynthesis can be represented with concrete examples (flowers), images and diagrams (pictures), words (descriptions), and symbols (the equation for photosynthesis). We expect that high school students are abstract thinkers, but in some domains, they may still think concretely. For example, students tend to think that individual atoms demonstrate the same properties as macro-amounts of substances. Give students time to talk or write about their macroscopic perceptions of matter *before* presenting theories based in the particulate nature of matter. Then scaffold students' progress through multiple levels of representation by specifically addressing their current understanding. As you and your students discuss different models used to explain the phenomena, they will begin to understand that each model has strengths and limitations.

#3: Use concept maps

Concept maps are versatile learning tools, which can be used as pretests to determine students' prior knowledge or as posttests to assess learning. More important, concept maps can help build knowledge as students actively construct meaning through recognizing associations between concepts. These relationships, or *propositions,* reveal how students are organizing ideas. Begin the process of concept-mapping with a focus question that serves to guide the organization of concepts, such as "What are the parts of a cell?" "How are parts of the cell adapted for specific functions?" and "How are prokaryotic cells different from eukaryotic cells?" Each of these focus questions results in a unique concept map, using different propositions to organize key terms.

Remember to provide students with key terms and a skeleton template for the concept map (Novak and Cañas 2008). The template should provide enough structure that the primary divisions are suggested, but be open enough for students to incorporate their own associations.

#2: Write to learn

Use of structured writing tasks, such as observations, interactive lab reports, and science notebooks, can improve conceptual understanding through metacognition (McDermott 2010; Roberson and Lankford 2010). Metacognition, or knowing how you learn, is itself a form of learning produced by writing; at the same time, it is a catalyst for the process of content learning (Wallace, Hand, and Prain 2007).

Writing can be used for knowledge-telling and knowledge transformation (Wallace, Hand, and Prain 2007). Knowledge-telling focuses on the recall of information through observations, reading summaries, vocabulary reviews, and lecture notes. To encourage knowledge transformation, have students interpret and present knowledge in new ways, such as through interactive or reflective lab reports, creative writing (including poetry and rap), and group writing (Jackson, Dickinson, and Horton 2010; McDonald and Dominguez 2009).

Ask students to create a rap about mitosis or a haiku about solutions. In group writing, have students begin by anonymously writing one important idea about a specific topic, such as the rock cycle, on a piece of paper. Then ask students to pass their papers on to one or two other students, who in turn, add a new concept or clarification. This process encourages students to think more deeply about their current knowledge.

#1: Talk the (science) talk

Encourage teacher-student and student-student dialogue in the classroom. Take the time to ask questions that require students to think, use evidence, and listen to others. Discussion, by its very nature, requires that the participants integrate knowledge from others into their own understandings.

Have students work in small groups that are accountable for learning. Groups can share their ideas orally, write brief reports, or include their findings in lab reports or on tests. Just as we learn as we teach, students learn as they talk science. Concept development and language development are interrelated, so the more our students talk about science, the more opportunities they have to refine their understandings of important concepts.

The impact

Each of these 10 strategies combines tangible experiences with focused communication (i.e., discussing, writing, drawing). This combination gives learners an important reason to use language—to find and convey meaning in scientific phenomena. Communication as a transformative learning tool is far different than memorizing lists of vocabulary terms or filling in bubbles on a worksheet. Sensory-rich lessons can arouse curiosity, which leads students to question their own assumptions and, ultimately, creates an intrinsic desire to understand important concepts.

It is important to note that if learners merely assimilate knowledge, rather than accommodate it, naive conceptions may persist. But if learners actively reconsider prior knowledge in light of new knowledge, they can create new and more scientific cognitive models.

Conclusion

What really matters in our classrooms? If we want students to develop deep understanding, we must teach directly to their existing conceptions and help guide them into more scientific ways of thinking. The heart of conceptual change instruction is helping students gain and reconfigure knowledge, which, in turn, enhances their capacities for abstract reasoning. By designing instruction that specifically addresses naive conceptions, we enhance opportunities for the construction of scientific conceptions. ■

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