By Elizabeth Hammerman

Middle level science curricula should integrate science with students' lives and communities.

"The World's Most Magnificent Animals Face New Threats of Extinction"
"More of the Mysteries of Saturn Discovered"
"Journal Reports Advancements in Technology and Medicine"
"Scientists Detail and Make Predictions About Climate Changes"

These are just a few of the many headlines that flood the media and point to current and future issues that students will face as adults. Understanding such issues requires a knowledge of scientific concepts and principles and their relationships to technology and society. Science programs that prepare students to understand and adapt to the continually changing scientific and technological world must be a high priority in K–12 education.

State and national standards identify what students should know and be able to do, including what it means to "do" science, the historical significance of science achievement and its ethical underpinnings, and science from the human perspective. Middle level science programs that address the full range of science standards and connect learning to students' lives and their community enable them to recognize and appreciate the significance of their learning, which better prepares them to think critically and act responsibly as citizens.

For example, integrated science courses can be designed to explore the biological, geological, physical, chemical, and technological factors that operate within a community. Students can deepen their understanding of science concepts and principles as they study local water quality and availability, weather and climate, natural resources,

FIGURE 1

Self-Assessment: Examining Beliefs and Practices

For each statement, place a mark on the line to indicate your beliefs and practices, 0 = least extent and 10 = greatest extent. Record additional comments.

To what extent do you:

1. Focus instruction on a clearly identified set of standards-based key concepts and principles, skills, and dispositions of science found in the state or district curriculum?
   Belief: 0 _____ 10 Practice: 0 _____ 10
   Comments:
2. Create interesting, student-centered contexts for learning?
   Belief: 0 _____ 10 Practice: 0 _____ 10
   Comments:
3. Provide flexible grouping patterns for investigations, problem-solving activities, experiments, research, and projects?
   Belief: 0 _____ 10 Practice: 0 _____ 10
   Comments:
4. Use inquiry, investigation, and firsthand experiences regularly in the science program?
   Belief: 0 _____ 10 Practice: 0 _____ 10
   Comments:
5. Integrate technology by using equipment and tools to engage learners—such as calculators, magnifiers and microscopes, balances and mass sets, meter sticks, graduated cylinders, models, and computers?
   Belief: 0 _____ 10 Practice: 0 _____ 10
   Comments:
6. Create meaning by providing opportunities for students to collect, record, and make sense of data they generate?
   Belief: 0 _____ 10 Practice: 0 _____ 10
   Comments:
7. Provide opportunities to reflect on experiences through questioning, writing, and illustrating?
   Belief: 0 _____ 10 Practice: 0 _____ 10
   Comments:
8. Provide frequent interaction between students and teachers (and among students) to develop and extend critical and creative thinking, formulate thought, and enhance concept understanding?
   Belief: 0 _____ 10 Practice: 0 _____ 10
   Comments:
9. Provide opportunities for students create and share models, graphics, projects, and products?
   Belief: 0 _____ 10 Practice: 0 _____ 10
   Comments:
10. Model and require students to model dispositions that are valued by the scientific community?
    Belief: 0 _____ 10 Practice: 0 _____ 10
    Comments:
11. Use a variety of formative assessment strategies to inform instruction and provide feedback? Give students opportunities to self-assess and monitor their own learning?
    Belief: 0 _____ 10 Practice: 0 _____ 10
    Comments:
12 Provide opportunities for extended learning and for making connections to technology; the lives of students; community, state, national, and world concerns; and careers?
    Belief: 0 _____ 10 Practice: 0 _____ 10
    Comments:

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energy production and facilities, soil and land use, native plants and animals, pollution, waste management, chemical use, and other science- and technology-related factors and relate them to their own lives. When students understand how science and technology operate within the community and affect them personally, they can better comprehend the significance of global issues.

Practical Reform

Although teachers are working harder than they ever have to manage classrooms, deal with issues of diversity, and deliver high-quality instruction, student achievement on national assessments falls short of the high expectations U.S. citizens have for their nation's schools. With only a scant 7% of middle level science and mathematics classrooms considered high quality (Weiss, Pasley, Smith, Banilower, & Heck, 2003), principals can play an essential role in raising the standards in middle level science by giving teachers the support, knowledge, and resources they need for successful teaching and meaningful learning.

Two practical approaches for providing high-quality science education to all students provide a starting point for a collaborative effort for developing and implementing standards-based high-quality instruction over time:

1. Examine teachers and administrators' current beliefs and practices to determine how well they align with standards-related content and research-based practices that promote learning
2. Plan instruction that addresses standards through the use of research-based and creatively applied strategies for meeting the needs and interests of students and enhancing learning.

Examining Beliefs and Practices

A self-assessment inventory (see figure 1) enables administrators and teachers to take a critical look at beliefs and practices that are related to important dimensions of high-quality classrooms, including:

- Standards-based concepts and principles of science
- Inquiry-based teaching and effective strategies
- Process skills, critical and creative thinking skills, and valued dispositions
- Integrating science with technology, math, and literacy
- Using formative assessment to monitor and guide learning
- Differentiating instruction to meet the needs of students.

The insights gained through self-assessment will help administrators and teachers identify and clarify goals for improving classroom practice. When the results of the inventory are discussed, a set of high-priority goals for improving teaching and learning can be identified. Many of the goals that are related to strengthening classroom teaching and learning can be achieved through thoughtful planning. As teachers are guided through the planning process, they focus on aspects of effective instruction they know well and identify areas they need to know more about. Thus, the second approach to excellence focuses on instructional planning.

Planning for Effective Teaching and Learning

Instruction is the collective process by which the messages of the standards come alive in rich and meaningful experiences. Instruction, to be effective, must engage and motivate students. Professional organizations, national standards projects, and most state standards documents endorse inquiry as the process by which students actively acquire knowledge and develop an understanding of and appreciation for the disciplines of science.

Inquiry is a social and thoughtful activity that requires much more than the practice of skills or the completion of a set of steps that lead to the "right" answer. Exploring one's environment, asking theoretical and operational questions, making observations, developing hypotheses, engaging in experimentation and investigation, collecting and analyzing data, drawing conclusions, making inferences, and formulating new questions are some of the exciting processes that are practiced through inquiry-based science. Through inquiry, students ask and answer questions that are interesting and meaningful. Integrated instructional units should not only address the important concepts and skills of science and mathematics but also develop the broad range of skills needed for success in the 21st century. The Partnership for 21st Century Skills (2002) identified the following skills that students will need:

- Information and media literacy
- Communication skills
- Critical and systems thinking
- Problem identification, formulation, and solution
- Creativity and intellectual curiosity
- Interpersonal and collaborative skills
- Self-direction
- Accountability and adaptability
- Social responsibility
- Contextual learning skills.

An Action Plan

The Five Es lesson plan format (see figure 2) is a teacher-friendly approach to developing high-quality lessons. The stages of the plan—engage, explore, explain, elaborate, and

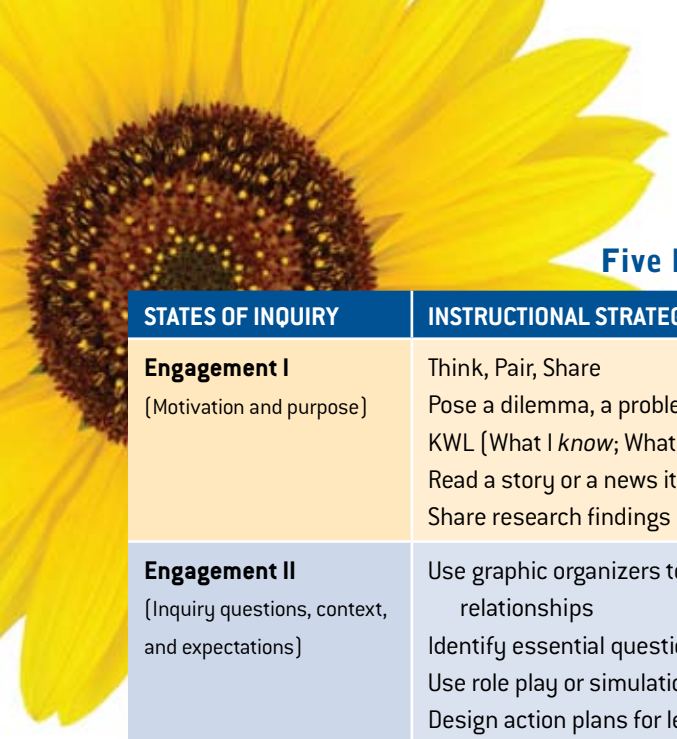

FIGURE 2

Five Es Lesson Plan Format

STATES OF INQUIRY	INSTRUCTIONAL STRATEGIES TO ENHANCE LEARNING
Engagement I (Motivation and purpose)	Think, Pair, Share Pose a dilemma, a problem, or an issue KWL (What I *know*; What I want to *know*; What I *learned*) Read a story or a news item Share research findings
Engagement II (Inquiry questions, context, and expectations)	Use graphic organizers to show relationships between concepts; ask questions to explore relationships Identify essential questions from standards Use role play or simulations to define a context Design action plans for learning Develop hypotheses
Exploration (Process of instruction)	Investigations and controlled experiments Field experiences Observations; collect and record data Writing, drawing, and illustrating; conduct surveys or interviews Videos, software programs, Internet research Jigsaw; tiered learning; stations
Explanation I (Processing information)	Analyze and graph data Discuss and compare results of investigations and experiments Explain or describe findings; make suggestions for further study Connect learning to prior knowledge Describe relationships between concepts
Explanation II With Elaboration (Checking understanding, creating meaning, and framing thought)	Apply learning to new contexts Defend a position Connect learning to personal experience and other subject areas Describe meaning in new context
Elaboration (Applications, research, and new questions)	Further research and application of concepts to self, technology, and society Action plans for dealing with problems and issues Design and develop new structures or products or modify existing ones Invent or design something new Engage in Internet or action research
Evaluation (Goals achievement; instruction effectiveness)	Notebook entries; observation checklists Presentations; demonstrations Written reports, essays, analyses, and summaries Self-assessments using rubrics Peer reviews; interviews Performance assessments; teacher-made tests

Source: *Modified from Hammerman, E. (2006).* Becoming a better science teacher. *Thousand Oaks, CA: Corwin*. A more complete chart is available at www.principals.org/PL.

evaluate—guide teachers through a process that engages students in active learning and critical thinking through a variety of methods and strategies to differentiate learning and meet the needs of students. Students are given opportunities to ask questions, investigate, record observations and data, reflect on processes, explain and apply their learning, and demonstrate learning in a variety of ways. The student-centered approach enables teachers to identify and address misconceptions students may have developed and assess the effectiveness of the instructional process.

In this model, some phases of the plan are further divided to enable more-purposeful planning. A range of strategies that can be used to enhance learning and differentiate instruction is suggested for each phase. The specific strategies that are selected and used will depend on the objectives of the lesson, the readiness and ability of learners, the context and content of the lesson, the available materials and resources, and the creativity of the designer.

A Commitment to Excellence

Well-designed professional development initiatives can address critical needs that are related to standards and accountability and offer teachers opportunities to increase knowledge and develop skills and confidence that lead to more-effective teaching and learning. The approaches offered here provide a starting point for recognizing and clarifying goals for change. Once a commitment to excellence is made, administrators and teachers can work collaboratively to develop and implement student-centered instruction that will enhance learning in science. PL

REFERENCES

- Partnership for 21st Century Skills. (2002). *Learning for the 21st century: A report and mile guide for 21st century skills*. Tucson, AZ: Author.
- Weiss, I. R., Pasley, J. D., Smith, P. S., Banilower, E. R., & Heck, D. J. (2003). *Looking inside the classroom: A study of K–12 mathematics and science education in the United States*. Chapel Hill, NC: Horizon Research Inc.

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