Research-Based Strategies Used to Develop

Glencoe Life Science, Earth Science, and *Introduction to Physical Science*

RAISING THE BAR

The National Science Education Standards

The *National Science Education Standards* consist of four over-arching principles **(Figure 1)** and a total of 50 specific standards in the areas of Science Teaching, Professional Development for Teachers of Science, Assessment in Science Education, Science Content (broken down by topic area and grade levels), Science Education Program, and Science Education System. To say that the *Science Standards* have raised the bar for science education in the United States is truly an understatement. Never before has science education been guided by a single national set of principles and standards. Never before have our science education goals been set this high. And never before have science teachers and administrators been this challenged to meet goals of excellence in science programs.

Science teachers have always worked to motivate students to read science texts, coordinate visual and verbal information, and study using effective, research-proven strategies. However, most teachers have limited resources and must choose how much time and energy to devote to helping students develop these strategies while still allowing them to become self-reliant and independent learners. Administrators and teachers are challenged to reach multiple goals, simultaneously helping students to:

- understand, remember, and apply standards-based science to new contexts,
- perform well on high-stakes achievement tests,
- prepare to succeed in their next science course, and
- become productive and scientifically literate citizens.

The *Science Standards* describe a vision of the scientifically literate person and present criteria for science education that will allow that vision to become reality. But now, more than ever, science educators are struggling to find appropriate resources to help them meet the ideals set by the *Science Standards*. This paper focuses on the *Science Standards* as they apply to middle school, as well as the resources now available to those involved in middle school science education.

Figure 1

***Science Standards'* Four Principles**

- Science is for all students.
- Learning science is an active process.
- School science reflects the intellectual and cultural traditions that characterize the practice of contemporary science.
- Improving science education is part of systemic educational reform.

For more information, see the National Research Council's *National Science Education Standards* (1996) available at www.nap.edu.

Figure 2

Statements from NSTA Regarding Inquiry Learning

NSTA Position Statement – *The National Science Education Standards:*
The National Science Teachers Association strongly supports the *National Science Education Standards* by asserting that:

- Teachers, regardless of grade level, should promote inquiry-based instruction and provide classroom environments and experiences that facilitate students' learning of science…
- Professional development activities should involve teachers in the learning of science and pedagogy through inquiry…
- Inquiry should be viewed as an instructional outcome (knowing and doing) for students to achieve in addition to its use as a pedagogical approach…
- Science programs should provide equitable opportunities for all students and should be developmentally appropriate, interesting and relevant to students, inquiry-oriented, and coordinated with other subject matters and curricula.

(Adopted by the NSTA Board of Directors, January 1998. For more information, see www.nsta.org.)

The Inquiry Teaching Approach
Teaching science using an inquiry approach means teachers must go far beyond merely lecturing students and encouraging them to memorize fact-based lecture notes and textbook explanations in preparation for exams. Rather, students should be allowed to experience the scientific process as scientists do, developing critical-thinking and problem-solving skills through the use of engaging activities and active learning strategies. Both the *Science Standards'* Teaching Standards and Content Standards put high value on inquiry as an important component of science teaching and learning. According to the National Science Teachers Association's *Pathways to the Science Standards: Guidelines for Moving the Vision into Practice,*

> Inquiry is a natural process in which individuals ask questions, gather information through many and varied activities, examine data, and develop explanations about these data to answer the original questions. Inquiry is basic to science itself—it is how scientists work. Giving students opportunities to inquire is a vital component in helping them become scientifically literate…Teachers must provide the appropriate classroom setting for students to carry out inquiry investigation if the best science learning is to occur (pp. 6–7).

For more detailed information on the inquiry teaching approach, see *NSTA Pathways to the Science Standards: Guidelines for Moving the Vision into Practice, Middle School Edition, Second Edition* (2000) available at www.nsta.org.

CHANGING PEDAGOGY: INQUIRY-BASED SCIENCE LEARNING

To guide the Teaching, Professional Development, Assessment, Content, Program, and System Standards, the *Science Standards* begin with four principles. One principle stressed consistently throughout the standards is that learning science should be an active process.

> **Teaching Standard A:**
> Teachers of science plan an inquiry-based science program for their students.

> **Content Standards—Grades 5–8**
> **Science as Inquiry/Content Standard A:**
> As a result of activities in grades 5–8, all students should develop
> - Abilities necessary to do scientific inquiry.
> - Understandings about scientific inquiry.

> **Science Education Program Standard B:**
> The program of study in science for all students should be developmentally appropriate, interesting, and relevant to students' lives; emphasize student understanding through inquiry; and be connected with other school subjects.

This stress on inquiry learning has been echoed in the position statement of the National Science Teachers Association, shown in **Figure 2,** which strongly supports the *Science Standards*. The repeated recommendations to use an inquiry approach reflect the growing trend toward constructivism in science education. Constructivism is the idea that students construct their own knowledge in a process that is both individual and social. Research shows that teachers cannot simply transfer knowledge to students by lecturing or assigning readings. Students have to take an active role in their own learning, and to accomplish this, science programs must include ample opportunities for students to explore, experiment, question, debate, discuss, and discover.

This is not to say that teachers are removed from the educational process. Rather, the learning experience should include an appropriate balance of explicit and implicit instruction. Implicit instruction occurs when students figure out for themselves how to grapple with problems and construct conceptual knowledge (Pressley, Harris & Marks, 1992; Shulman & Keislar, 1966). This is encouraged when students engage in project-based and subject-integrated science activities, open-ended science labs, and science fair projects. Explicit instruction occurs when teachers and textbook authors clearly explain science concepts and problem-solving strategies to students in a direct, low-inference fashion (Duffy, 2002).

Explicit instruction also provides students with needed background knowledge and other information on how, why, and when to use learning and studying strategies. This leads to learner independence (Zimmerman, 1998, 2000, 2001) and productive dispositions toward achievement (Alderman, 1999). Explicit instruction is critical to good science teaching. Using implicit instruction exclusively often fails to equip students who are developing and implementing needed reading, writing, and studying strategies (Graham & Harris, 1994, 2000).

Teachers, curricula directors, and administrators are left with a difficult task: How can we design a science program that provides the right balance of implicit and explicit instruction and that includes a curriculum with the proper age-appropriate content and ample opportunities for exploration and inquiry learning?

History of the Science Reform Movement

- **1983** – National Commission on Excellence in Education releases *A Nation at Risk: The Imperative for Educational Reform. A Nation at Risk* sparks a wealth of studies and evaluations comparing U.S. students in literacy, science, and mathematics to students in other countries.
- **1986** – American Association for the Advancement of Science launches "Project 2061" to develop a high level of science literacy among all U.S. citizens.
- **1989** – "Project 2061" publishes *Science for All Americans,* which outlines the knowledge and characteristics necessary for a scientifically literate citizen.
- **1990** – National Governors' Association and President Bush release the National Education goals during the State of the Union Address. Goal Four states: "…by the year 2000, U.S. students will be first in the world in science and mathematics achievement."
- **1991** – National Research Council begins coordination of the development of *National Science Education Standards.* NRC convenes a National Committee on Science Education Standards and Assessment and a Chair's Advisory Committee that begin development of national content, teaching, and assessment standards in science education.
- **1993** – "Project 2061" publishes *Benchmarks for Science Literacy* which establishes minimum goals for what students should know and be able to do at various grade levels in a number of content areas.
- **1995** – National Research Council publishes the *National Science Education Standards.*

For more detailed information on the history of the science education reform movement, see *NSTA Pathways to the Science Standards: Guidelines for Moving the Vision into Practice, Middle School Edition, Second Edition* (2000) available at www.nsta.org.

SUPPORTING THE SCIENCE STANDARDS WITH *GLENCOE SCIENCE*

One of the concepts explained in the *Science Standards* is that the Standards are meant to serve as descriptive ideals and guidelines. They represent what can be accomplished, but they leave the specifics of implementation to others. The responsibility of putting the vision of the *Science Standards* into action belongs to everyone with an interest in science education: teachers, superintendents, administrators, supervisors, policymakers, assessment specialists, scientists, teacher educators, parents, businesses, local community members, curricula developers, and publishers. Glencoe / McGraw-Hill, one of the nation's largest textbook developers, has risen to the challenge of the *Science Standards* and created an inquiry-based program for middle school: *Glencoe Life Science, Earth Science,* and *Introduction to Physical Science.*

Each Glencoe Science text responds to the need of science educators for a curriculum that accomplishes multiple goals.

To help educators reach the *Science Standards*' goals, such a curriculum must:

- Support the recommended Content Standards,
- Give students consistent opportunities for active and extended science inquiry,
- Provide opportunities for scientific discussion and debate,
- Provide various tools to regularly assess student understanding, and
- Connect science to other areas of learning, including natural phenomena and science-related social issues that students discover in everyday life.

REACHING THE SCIENCE STANDARDS—RESEARCH-BASED STRATEGIES USED IN *GLENCOE SCIENCE*

To better fulfill the characteristics of a standards-supporting curriculum, each Glencoe Science text is based on six specific, research-based strategies, all of which are particularly important in a science inquiry teaching approach. These strategies support inquiry-based instruction by providing ideas for and examples of how scientific inquiry can be conducted and by providing the highest quality information to support student inquiry. These six strategies are as follows:

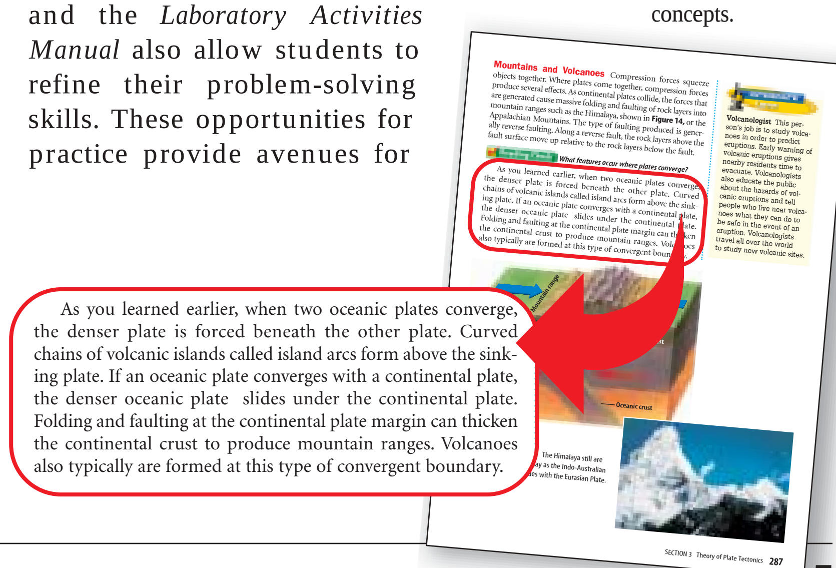
1. Using prior knowledge to learn new information

When students recall previously learned information, they can learn new, related information more effectively. These strategies include: 1) recalling remembered information, asking questions, and elaborating on textbook and teacher information; and 2) referring students to the textbook (including use of analogies) and other meaningful information. Each Glencoe Science text continuously references information previously explained to facilitate learning of new information, as shown in **Figure 3.** It may refer to material in previous chapters, to different branches of science, or to students' personal experiences to make science more relevant. The text is written with many references to common activities and processes so that students can make connections between science concepts and their own lives. Tie to Prior Knowledge and Use an Analogy elements are found in the Teacher Wraparound Edition and provide teacher support for these strategies. Asking students to use prior knowledge located in a text may remind them of information already in their long-term memory that, for some reason, is not easily remembered (Bransford, 1979; Pressley & McCormick, 1995). This research-based strategy is central to successful performance in reading and writing (Guthrie & Alvermann, 1999; Holliday, Yore, & Alvermann, 1994).

2. Practicing important tasks

Providing students opportunities to practice important tasks has long been considered a successful strategy to improve understanding and memory. Giving students individual feedback on their practice helps in monitoring and fostering their science learning (Baker, 1991). Practicing helps students acquire additional information as they search and productively struggle, with teacher help, for the understanding and application of science information. The text of each Glencoe Science book includes self-check quizzes, standardized test question examples, Applying Math and Applying Science problem-solving activities, embedded reading and writing exercises, and multiple laboratory activities (including Design Your Own Labs, Use the Internet Labs, Model and Invent Labs, and Extra Try at Home Labs). Inquiry Labs in the Teacher Wraparound Edition allow students to practice scientific thinking skills. Ancillary products such as *Critical Thinking/Problem Solving* and the *Laboratory Activities Manual* also allow students to refine their problem-solving skills. These opportunities for practice provide avenues for

Figure 3 In-text references ask students to relate prior knowledge to newly introduced concepts.



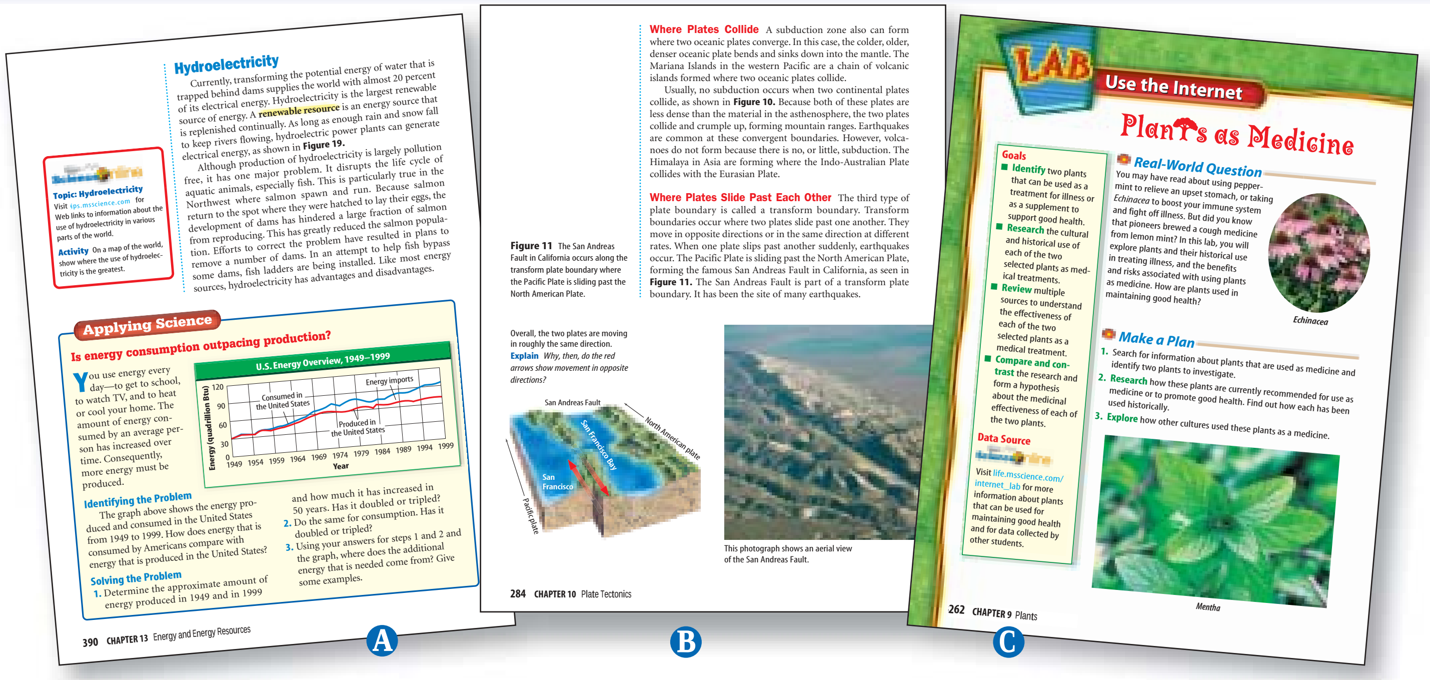


Figure 4

A Applying Science provides students the opportunity to practice important tasks.

B High-quality illustrations and photos help communicate concepts.

C Relevant activities, such as Use the Internet Labs, motivate students to achieve.

students to fine tune their problem-solving abilities and learn new information, which will be indispensable for solving difficult problems on standardized tests.

3. Using visuals to communicate, organize, and reinforce science learning

Visuals—such as complex diagrams and elaborate line drawings—used in conjunction with verbal descriptions increase students' chances of learning, understanding, and remembering relationships and subtle properties of science concepts and problems. Visuals often are the only way to effectively communicate ideas that explain central science concepts. Each Glencoe Science text includes high-quality charts, tables, art, and photographs throughout the text. Visuals often are accompanied by caption questions and provide ideas for effective use of models, as shown in **Figure 4B.** Visual Learning elements in the Teacher Wraparound Edition tie to specific concepts illustrated with art or photographs. Students are able to organize and group ideas better when visuals illustrate different and common characteristics (Hegarty, Carpenter & Just, 1991). Also, the mental images that high-quality visuals stimulate are an indispensable tool for recalling information, especially compared to information presented with only text or lower-quality visuals (Willows & Houghton, 1987).

4. Getting students motivated to achieve

Students are motivated to learn when materials provide explicit, attractive, relevant-to-student presentations (Alderman, 1999; Corno, 1994) of key concepts. Motivational strategies also can include long-term projects of real-world relevance, and carefully constructed problem-solving activities that require effort, persistence, and flexibility. Such motivational strategies will stimulate scientific curiosity and instill confidence through personal scientific exploration and discovery. Each Glencoe Science text provides explicit, attractive, student-relevant presentations of key concepts. It provides students with opportunities to explore science from many different perspectives. Launch Labs, MiniLabs, Science Online activities, and *Probeware Labs* can motivate students and spark their enthusiasm. Students also have the opportunity to focus on personally meaningful questions in the Inquiry Labs found in the Teacher Wraparound Edition and in the *Science Inquiry Lab Manual*. These strategies also help develop patience in solving problems and understanding important scientific information, and encourage students to initiate short-term achievement goals. Students will learn to stand on their own academic feet through textbook learning coupled with selected levels of teacher facilitation.

5. Developing decoding strategies and reading comprehension proficiencies

Reading and decoding strategies include: (1) pronunciation guides to facilitate decoding of unfamiliar words; (2) questions and practice items for self-assessment of reading comprehension and concept understanding; and (3) reading exercises designed for students to solve verbally presented problems and comprehend complex prose. Students need to read from textbooks that are challenging and that contain science vocabulary compatible with their prior knowledge and academic abilities (Guthrie & Alvermann, 1999; Holliday, Yore & Alvermann, 1999). Students also need pronunciation and other language-learning information to decode words, a prerequisite to reading comprehension (Pressley & Block, 2002). Students also must have opportunities to engage in writing (Graham & Harris, 2000) and establish reading comprehension strategies such as questioning, visualizing, clarifying, elaborating, inferring, concluding, summarizing, and predicting (Pressley, 2002). To accomplish this, each Glencoe Science text incorporates pronunciation guides, Review Vocabulary, New Vocabulary, Reading Checks, and Science Journal activities, as well as a wealth of ancillary resources, including *Reading and Writing Skill Activities* and *Reading Essentials*. Reading, decoding, and writing skills help students to remember important ideas needed to learn new information, understand information required to practice important tasks, and develop verbal skills needed to perform well on achievement tests and later in life.

6. Learning by using study strategies

According to the research literature (Bransford, 1979; Corno, 1994), there are no shortcuts to learning, but study strategies help students understand, organize, remember, and apply new information presented in science textbooks. Study strategies used to learn from textbooks include concept mapping, highlighting, outlining, note taking, summarizing, and underlining (Peverly, Brobst, Graham & Shaw, 2003). Study strategies and organizational tools offered in each Glencoe Science text include: Dinah Zike's Foldables™ Study Organizers (Refer to the example shown in **Figure 5.**), concept maps in Visualizing Main Ideas, summary outlines, tables, and Science Journal activities that prompt students to organize the information they study. Utilizing these types of strategies takes years of practice and help from teachers through monitoring and thoughtful feedback to students (Pressley & McCormick, 1995).

VERIFYING LEARNING—ASSESSMENTS OF STUDENT UNDERSTANDING IN *GLENCOE SCIENCE*

Another key concept stressed in the *Science Standards* is the importance of continuously assessing student understanding.

> **Teaching Standard C:**
> Teachers of science engage in ongoing assessment of their teaching and of student learning. In doing this, teachers use multiple methods and systematically gather data about student understanding and ability.

Each Glencoe Science text offers teachers many choices to probe students' understanding of key concepts and skills. Assessment features include:

- Reading Checks – provide ongoing opportunities for student self-assessment. Students are challenged to summarize, restate, apply, and explain important concepts in the reading they've just completed.

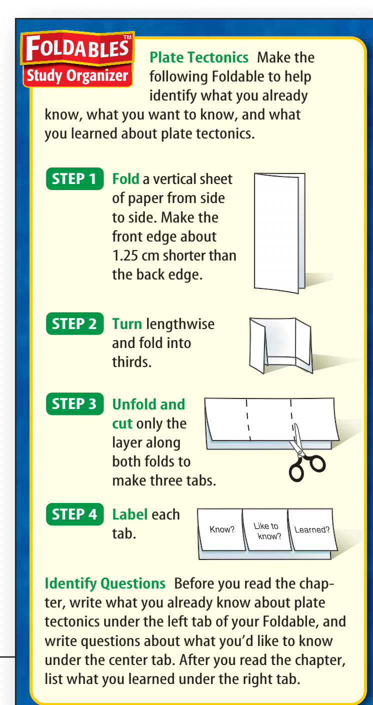


Figure 5
Dinah Zike's Foldables™ Study Organizers focus students on key concepts so they can study more efficiently.

- Section Review – provides an immediate summary and self check of each section's main ideas.
- Chapter Review – provides a comprehensive review of all the chapter's key concepts and vocabulary. Questions range from multiple choice to open-ended and contain opportunities for performance assessment and reviewing math concepts.
- Standardized Test Practice – prepares students for the types of questions they'll find on state and national tests.
- Assessment in the Teacher Wraparound Edition – offers ideas for students who need an alternative method of accessing knowledge and skills of the concept presented.
- Rubrics in the Teacher Wraparound Edition – help teachers grade students' work more precisely to correct misconceptions, increase understanding, and perform more effectively on future assessments.
- *Performance Assessment in the Science Classroom* – includes alternative assessment activities and rubrics for evaluation of student knowledge.

REACHING EVERY LEARNER—SCIENCE FOR ALL STUDENTS WITH *GLENCOE SCIENCE*

Another key principle of the *Science Standards* is that science is for all students. Each Glencoe Science text offers a variety of instructional methods for all learning styles and ability levels—reading, writing, graphics, hands-on labs, and much more. Resources include:

- Differentiated Instruction – provides ideas to engage all learners, including English-language learners, gifted students, learning disabled, hearing and visually impaired, and behaviorally disordered students.
- Intervention and Remediation supplements – supplements such as *Reading Essentials* offer additional assistance for struggling students.
- Enrichment – creates opportunities for gifted students to enrich their learning.
- *Study Guide* – provides review activities for major concepts in every section.
- *ELL Strategies for Science* – offers specific strategies for integrating science and language learning.
- Daily Intervention – provides daily assessment strategies for all students.

The *Glencoe Life Science, Earth Science,* and *Introduction to Physical Science* series is complemented by a full line of multimedia resources that offer a range of technology options to enhance skills, promote critical thinking, and connect the classroom to the world in which students live. Multimedia resources include: Virtual Labs CD-ROM, StudentWorks + Audio, Exam*View*® Pro Testmaker, Interactive Chalkboard CD-ROM with Image Bank, Online Vocabulary PuzzleMaker, MindJogger Videoquizzes, and VideoLabs. By offering such diverse resources and learning tools, each Glencoe Science text ensures that every student can reach the goals set by the *National Science Education Standards.*

SUMMARY

The *National Science Education Standards* have provided a new gold standard in science education. More than ever before, science teachers and administrators are being called upon to challenge their students to become inquisitive and active science learners. To achieve the high goals set by the *Science Standards*, educators and others involved in science education reform will need to use an array of state-of-the-art strategies and tools. Their toolbox must include an inquiry-based curriculum that can support the *Science Standards* in every way. Glencoe / McGraw-Hill is proud to offer *Glencoe Life Science, Earth Science,* and *Introduction to Physical Science* as that curriculum. With each Glencoe Science text's focus on inquiry learning and continuous assessment, teachers can achieve the goals set by the *Science Standards*, now and in the coming years.

Examples of Research-Based Strategies in Glencoe Science

Learning Strategy	Select Examples from *Glencoe Science*
Using prior knowledge to learn new information	**Student Edition (SE):** *Glencoe Life Science*—126, 259; *Glencoe Earth Science*—282, 287, 662; *Introduction to Physical Science*—550, 716, 721 **Teacher Wraparound Edition (TWE):** *Glencoe Life Science*—130, 132, 134, 243, 246; *Glencoe Earth Science*—273, 276, 628, 745; *Introduction to Physical Science*—556, 561, 716, 721, 730 **Interactive Chalkboard CD-ROM** **McGraw-Hill Learning Network Web site** at mhln.com **Section Focus Transparencies**
Practicing important tasks	**SE:** *Glencoe Life Science*—131, 140, 144–145, 251, 261, 268–269; *Glencoe Earth Science*—279, 282, 294–297, 407, 548; *Introduction to Physical Science*—559, 728, 732, 742–745 **TWE:** *Glencoe Life Science*—127, 150–151, 259; *Glencoe Earth Science*—279, 596–597; *Introduction to Physical Science*—559, 720, 732 ***Study Guide, Critical Thinking/Problem Solving, Laboratory Activities Manual,*** and ***Mathematics Skill Activities*** **Interactive Chalkboard CD-ROM** and **VideoLabs**
Using visuals to communicate, organize, and reinforce science learning	**SE:** *Glencoe Life Science*—134, 139, 141, 243, 249; *Glencoe Earth Science*—276, 278, 284, 287, 464, 523; *Introduction to Physical Science*—722, 726, 730 **TWE:** *Glencoe Life Science*—127, 139, 254; *Glencoe Earth Science*—285, 638; *Introduction to Physical Science*—551, 552, 558, 718, 723 ***Interactive Chalkboard CD-ROM*** ***Reading Essentials*** **Teaching Transparencies**
Getting students motivated to achieve	**SE:** *Glencoe Life Science*—136, 262–263; *Glencoe Earth Science*—250, 271, 273, 274; *Introduction to Physical Science*—722, 733 **TWE:** *Glencoe Life Science*—127, 144, 259, 262; *Glencoe Earth Science*—290, 404, 497; *Introduction to Physical Science*—564, 569, 717, 738 **MindJogger Videoquizzes, Virtual Labs** and **VideoLabs** **McGraw-Hill Learning Network Web site** at mhln.com ***Probeware Labs, Science Inquiry Labs***
Developing decoding strategies and reading comprehension proficiencies	**SE:** *Glencoe Life Science*—126, 130, 241, 261; *Glencoe Earth Science*—270, 273, 292, 558; *Introduction to Physical Science*—554, 717, 721, 733 **TWE:** *Glencoe Life Science*—136, 243; *Glencoe Earth Science*—281, 282, 496; *Introduction to Physical Science*—551, 561, 718, 719 ***Reading and Writing in the Science Classroom, Reading Essentials,*** and ***Reading and Writing Skill Activities***
Learning by using study strategies	**SE:** *Glencoe Life Science*—125, 139, 265; *Glencoe Earth Science*—271, 289, 293, 573, 619, 638; *Introduction to Physical Science*—549, 557, 741 **TWE:** *Glencoe Life Science*—135, 256, 257; *Glencoe Earth Science*—279, 546, 588 692; *Introduction to Physical Science*—560, 731, 735, 739 **Vocabulary PuzzleMaker, online quizzes, Interactive Tutor, StudentWorks + Audio,** ***Dinah Zike's Teaching Science with Foldables,*** and ***Reading Essentials***

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