The Research Base for

Glencoe Biology

Research-Based Strategies Used to Develop *Glencoe Biology*

White Paper

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Research shows us that teachers cannot simply transfer knowledge to students by lecturing or assigning readings. Students have to take an active role in their own learning. 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.

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 provides students with needed background knowledge 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, because exclusively using implicit instruction often fails to equip developing students with the necessary reading, writing, and studying strategies (Graham & Harris, 1994, 2000).

Implicit instruction occurs when students figure out for themselves how to grapple with problems and construct conceptual knowledge (Pressley et al., 1992; Shulman & Keislar, 1966). This occurs when students engage in project-based and subject-integrated science activities, open-ended science labs, and science fair projects.

The Science Standards consistently emphasize that learning science should be an active process.

- Teaching Standard A: Teachers of science plan an inquiry-based science program for their students.
- Science as Inquiry/Content Standards (Grades 9-12): As a result of activities in grades 9-12, all students should develop (a) abilities necessary to do scientific inquiry and (b) 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.

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 National Science Education 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 (Rakow, 2000),

> Students develop new knowledge for themselves when they make connections between the evidence they gather through their own observations and the main body of knowledge accumulated by science. Teachers should facilitate extensive and varied experiences that allow students to examine enough evidence to develop logical descriptions, explanations, predications, and models (p. 44).

> An inquiring mind, curiosity, and the ability to apply critical thinking to problems are basic to scientific inquiry. Carefully phrased questions will lead the students toward the scientific method of investigation. Students should be allowed to ask questions, make observations, and ask more questions, thus refining the investigative process. How to ask a good science question should be part of every science class (p. 46).

This emphasis on inquiry learning, through laboratory activities and other methods, has been echoed in the position statements of the National Science Teachers Association and the National Association of Biology Teachers (**See Appendix**) that strongly support the Science Standards. The repeated recommendations to use an inquiry approach reflect the growing trend toward constructivism in science education. Constructivism is based on the idea that students construct their own knowledge in a process that is both individual and social.

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 includes a curriculum with the proper, age-appropriate content and ample opportunities for exploration and inquiry learning?

To fulfill the characteristics of standards-supporting curricula, *Glencoe Biology* was developed using specific, research-based instructional strategies. 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.

Differentiating Instruction to Help All Students Learn Science

Differentiated instruction provides for varying ability levels, learning styles, and special needs. Students engage in activities that are appropriately challenging and have opportunities to experience a wide variety of activities. Students with special needs — such as English-language learners, and students with physical impairments or learning disabilities — engage in activities keyed to their abilities. Differentiated instruction provides access to curriculum by presenting a range of entry points, activities, and outcomes which meet the individual needs of each student (Hall et al., 2003). *Glencoe Biology* offers a variety of instructional methods for all ability levels and learning styles — reading, writing, discussions, graphics, hands-on labs, and much more.

The *Teacher Wraparound Edition* focuses attention on differentiated instruction with four full pages in the Teacher Handbook and differentiated instruction suggestions throughout the program to engage all students, including gifted students, English language learners, and students with special needs. *Unit Resources* include diagnostic tests, enrichment activities, study guides and chapter tests aimed at a range of student performance.

Additional resources are available to address differentiated instruction for below level students and English language learners. *Reading Essentials for Biology* is structured to support struggling readers and learners. *ELL Strategies for Science* provides additional suggestions for tools and modifications that can help students master scientific concepts while developing their English language skills.

Glencoe Biology 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. These resources include TeacherWorks™ and StudentWorks Plus™, Exam*View*® Pro Testmaker, *What's BIOLOGY Got to Do With It?* videos on DVD and Virtual Labs. By offering such diverse resources and learning tools, the *Glencoe Biology* program ensures that every student can reach the goals set by the Science Standards.

Using Prior Knowledge to Learn New Information and Correct Misconceptions

When students recall previously learned information, they learn new, related information more effectively. Strategies to do this include: 1) recalling information, asking questions, and using analogies; and 2) elaborating on information from the textbook or teacher. 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 also central to successful reading and writing performance (Guthrie & Alvermann, 1999; Holliday et al., 1994).

Glencoe Biology references information previously explained to facilitate learning of new information. The Develop Concepts feature in the *Teacher Wraparound Edition* provides various strategies, such as activating prior knowledge, scaffolding, and integrating other school subjects, to help teachers make the concepts more relevant for their students.

Another advantage of using prior knowledge to help learn new information is that it provides an opportunity to correct misconceptions. Effective teaching elicits students' preconceptions and provides opportunities to extend or challenge those understandings (Donovan et al., 1999). With support from *Glencoe Biology*, students learn to recognize their preconceptions and evaluate them using scientific evidence. The Develop Concepts feature in the *Teacher Wraparound Edition* includes suggested strategies for clarifying common student misconceptions.

Practicing Important Tasks

Providing students with opportunities to practice important tasks has long been considered a successful strategy to improve understanding and memory. Giving students individual feedback on their performance helps in fostering and monitoring 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. *Glencoe Biology* was designed with the philosophy that practice is absolutely necessary for learning to occur.

Glencoe Biology has a variety of features that provide extensive practice in scientific skill development and test preparation. These features include Self-Check Quizzes, Think Scientifically, Section Reviews, Chapter Reviews, and multiple laboratory activities (including

MiniLabs, Launch Labs, BioLab, and Data Analysis Lab). The *Teacher Wraparound Edition* includes a Skill Practice feature with suggestions for additional practice. These opportunities provide avenues for students to fine tune their problem-solving abilities and learn new information, which will be indispensable for solving difficult problems on standardized tests. *Glencoe Biology* also offers Standardized Test Practice sections that include the multiple choice, short response/grid in, and open ended questions usually found on standardized tests.

Using High-Quality Visuals to Communicate, Organize, and Reinforce Science Learning

Visuals, such as photographs, diagrams, and 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 the central concepts needed to understand biology concepts. Students are able to organize and group ideas better when visuals illustrate different and common characteristics (Hegarty et al., 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).

Glencoe Biology was designed with consistent, clear structures and easy to follow page layouts with effective use of color and graphics. The program includes high quality charts, tables, diagrams, art, and photographs. National Geographic Visualizing feature illustrates important concepts with eye-catching diagrams and photographs. The program also includes an array of supplementary materials that allow for the use of visuals, including Virtual Labs CD-ROMs, Interactive Classroom CD-ROM, Video Labs DVD, and Biology Online, which provides access to Concepts in Motion.

Motivating all Students to Achieve

Students are motivated to learn when materials provide explicit, attractive, relevant presentations of key concepts (Alderman, 1999; Corno, 1994). Motivational strategies can include long-term projects of real-world relevance and carefully constructed problem-solving activities that require effort, persistence, and flexibility. Effective strategies also include using examples from many cultures, using a variety of teaching techniques, and incorporating cooperative learning activities (Banks, 2001; Winzer & Mazurek, 1998). Research has shown that both inquiry learning and cooperative learning approaches work well for all students, including English learners and those with learning disabilities (Rosebery et al., 1992; Stoddart, 2002; Scruggs et al., 1993). Such motivational strategies stimulate scientific curiosity and instill confidence through scientific exploration and discovery. Group activities also promote positive attitudes towards learning by building a community of learners (Brown & Campione, 1994).

Glencoe Biology provides students with exciting opportunities to explore concepts in biology from many different perspectives. Many features, such as Launch Lab, Cutting Edge Biology, BioDiscoveries and Biology & Society, encourage student curiosity and link scientific topics to everyday life. Group activities, discussions, e-communication and labs help students become part of a community of learners. The *Teacher Wraparound Edition* provides a variety of supplemental teaching strategies incorporating cooperative learning and the Content Background feature provides information regarding real world connections.

Supplemental instructional strategies included in the *Teacher Wraparound Edition* are also categorized to provide differentiated instruction for reaching all students, including struggling students, gifted students, and English language learners. Differentiated Instruction features are included in chapters to help teachers identify and address predictable challenges for some students.

Developing Reading Comprehension Strategies and Mathematical Skills

Success with scientific skills is strongly tied to competency in reading and mathematics. Important reading and decoding strategies include: 1) pronunciation and word origin guides to facilitate decoding of unfamiliar words; 2) questions and practice items for self-assessment of reading comprehension and conceptual understanding; and 3) reading exercises designed to help 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 et al., 1999). Students also need pronunciation and other language learning information to decode words, a prerequisite to reading comprehension (Pressley & Block, 2002). Students 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 predicating (Pressley, 2002). These 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.

Another area strongly related to science learning is mathematics. Mathematical concepts such as ratio, rates, proportion, percent, measurement, graphing, data analysis, statistics, and probability are crucial in the development of scientific reasoning (Lehrer, 2003).

Glencoe Biology was designed with thorough and consistent integration of reading and mathematics skills. Each chapter incorporates strategies for reading and writing development including Dinah Zike's Foldable™ Study Organizers, Reading Guides with Review Vocabulary, New Vocabulary, and Word Origins, Reading Checks, and Chapter Vocabulary Review as well as Writing in Biology features. The *Teacher Wraparound Edition* includes Reading Strategy and Writing Support features which offer further ideas for incorporating reading and writing activities.

Mathematical concepts are also consistently integrated through Math in Biology features, Connection to Math notations, Data Analysis Lab, tables and graphs. Additional suggestions for integrating mathematics are included in the *Teacher Wraparound Edition*. These activities serve to reinforce mathematical skills and increase their relevance.

Learning by Using Study Strategies

According to the research literature, there are no shortcuts to learning, but study strategies help students understand, organize, remember, and apply new information presented in textbooks (Bransford, 1979; Corno, 1994). Study strategies used in textbooks include concept mapping, highlighting, outlining, note taking, summarizing, and underlining (Peverly et al., 2003). These study skills promote learner activity, improve metacognition, and provide an effective form of review for tests (Hattie et al., 1996; Carter & Van Matre, 1975).

Study strategies and organizational tools offered in *Glencoe Biology* include Dinah Zike's Foldables™ Study Organizers, Study Tips, Chapter Study Guides, Standardized Test Practice, and tables. Supplemental materials such as Science Notebook, Interactive Tutor, Study to Go, and Student Works Plus offer additional assistance.

Assessing Student Understanding

Assessment provides opportunities for feedback, and research has shown that the most improvement occurs when feedback is given often and immediately following tests or activities (Bangert-Drowns et al., 1991). An evaluation of students' understanding throughout a lesson provides the teacher with valuable information to be used in planning and remediation and future instruction (Bransford et al., 2000).

Glencoe Biology offers many formative assessment opportunities to probe students' understanding of key concepts and skills including Reading Checks, Section Assessment, Caption Questions, Standardized Test Practice, and Self Check Quizzes. The *Teacher Wraparound Edition* includes Formative Assessment features and suggestions for alternative assessment strategies for each section. Supplemental materials in the TeacherWorks™ CD-ROM include rubrics for evaluating Foldables™ and laboratory activities. *Unit Resources* provide diagnostic tests and scaffolded section quick checks.

Summary

More than ever before, science teachers are being called upon to challenge their students to become inquisitive and active science learners. To achieve the high goals set by the standards as well as to help all students achieve scientific literacy, 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 inquiry-based curricula that support science learning in every way. Glencoe/McGraw-Hill is proud to offer *Glencoe Biology*. With its focus on inquiry learning, differentiated instruction, and continuous assessment, teachers can help all their students achieve their goals, now and in the coming years.

Appendix

Statements on Inquiry Learning and Laboratory Activities

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.
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.

NABT Position Statement — Role of Laboratory and Field Instruction in Biology Education

The most effective vehicle by which the process of inquiry can be learned appears to be a laboratory or field setting where the student experiences, firsthand, the inquiry process. Laboratory and field study have also been demonstrated to be effective means for comprehension, understanding and application of biological knowledge . . . Thus, study in a laboratory and/or field setting is an integral and essential part of a biology course.

Adopted by the NABT Board of Directors September 1990. Revised 1994, 2005. For more information, see www.nabt.org.

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