Implementing the Supplement

We designed the five lessons in this supplement to be taught in sequence for approximately 10 days, assuming class periods of about 50 minutes. The following pages offer general suggestions about using these materials in the classroom; you will find specific suggestions in the procedures of each lesson.

What Are the Goals of the Supplement?

*Evolution and Medicine* is designed to help students attain these major goals associated with scientific literacy:

- to understand a set of basic scientific principles related to evolution and how evolution relates to medicine,
- to experience the process of scientific inquiry and develop an enhanced understanding of the nature and methods of science, and
- to recognize the role of science in society and the relationship between basic research and human health.

What Are the Science Concepts and How Are They Connected?

The lessons are organized into a conceptual framework that allows students to start with what they already know about evolution, some of which may be incorrect. They then move to a scientific perspective on evolution and its importance to medicine and to their lives.

In Lesson 1, students begin by considering their initial thoughts about how methicillin-resistant *Staphylococcus aureus*, or MRSA, evolved antibiotic resistance. They next consider their ideas about how common ancestry helps explain the use of model systems for medical research. Students then explore the frequency of lactase persistence in different groups of people around the world and compare two alternative hypotheses for the evolution of this trait (Lesson 2). By conducting two case studies in Lesson 3, students explain how studies of both evolutionary processes (such as natural selection) and evolutionary patterns (such as changes in genetic sequences) inform medicine. In Lesson 4, students use what they learned about evolution and how it affects medicine to better understand influenza. The main question that drives the lesson is, Why is a new flu vaccine needed every few years?

Lesson 5, the final lesson, gives students an opportunity to consider what they have learned in the previous lessons. Students review an article that a fictional student prepared for the school newspaper about how humans and other species lack the ability to synthesize vitamin C. The task is to identify—and then correct—errors in the article. The lesson concludes with students writing a summary of how evolution informs medicine. The following chart (Table 3) illustrates the science content and conceptual flow of the lessons.
Table 3. Science Content and Conceptual Flow of the Lessons

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Learning Focus, from BSCS 5E Instructional Model</th>
<th>Major Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson 1—Ideas about the Role of Evolution in Medicine</td>
<td>Engage</td>
<td>Understanding mechanisms of evolution, particularly adaptation by natural selection, provides many insights that enhance medical practice and understanding. Common ancestry explains why experiments in model systems inform human health. Students may have naïve preconceptions about how organisms change over time and about common ancestry.</td>
</tr>
<tr>
<td>Lesson 2—Investigating Lactose Intolerance and Evolution</td>
<td>Explore</td>
<td>Some of the variation among humans that may affect health is distributed geographically. Natural selection helps explain some of these patterns. Scientists use data to evaluate evidence for claims about evolution.</td>
</tr>
<tr>
<td>Lesson 3—Evolutionary Processes and Patterns Inform Medicine</td>
<td>Explain</td>
<td>Human health and disease are related to our evolutionary history. Understanding evolution helps explain why some diseases are more common in certain parts of the world. Common ancestry explains why information about other organisms is useful for studying health-related issues in humans. Rates of evolutionary change in genetic sequences give clues about the role of natural selection on that genetic region. Scientists use data to evaluate evidence for claims about evolution.</td>
</tr>
<tr>
<td>Lesson 4—Using Evolution to Understand Influenza</td>
<td>Elaborate</td>
<td>We can compare genetic sequences; the rates of evolutionary change in them give clues about the role of natural selection in that genetic region, which informs medical scientists. Understanding evolution helps explain the emergence and spread of infectious diseases. Scientists use data to evaluate evidence for claims about evolution.</td>
</tr>
<tr>
<td>Lesson 5—Evaluating Evolutionary Explanations</td>
<td>Evaluate</td>
<td>Interpreting examples of evolution and medicine requires careful attention to evidence. Natural selection and common ancestry help explain why humans are susceptible to many diseases.</td>
</tr>
</tbody>
</table>

How Does the Supplement Correlate to the National Science Education Standards?

*Evolution and Medicine* supports teachers in their efforts to reform science education in the spirit of the National Research Council’s 1996 *National Science Education Standards* (NSES). The content of the supplement is explicitly standards based. The following chart (Table 4) lists the specific content standards that this supplement addresses.
### Table 4a. NSES Standard A, Science as Inquiry

<table>
<thead>
<tr>
<th>Abilities necessary to do scientific inquiry</th>
<th>Correlation to Evolution and Medicine Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Identify questions and concepts that guide scientific investigations.</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>• Design and conduct scientific investigations.</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td>• Use technology and mathematics to improve investigations and communications.</td>
<td>2, 3, 4</td>
</tr>
<tr>
<td>• Formulate and revise scientific explanations and models using logic and evidence.</td>
<td>All</td>
</tr>
<tr>
<td>• Recognize and analyze alternative explanations and models.</td>
<td>2, 3, 5</td>
</tr>
<tr>
<td>• Communicate and defend a scientific argument.</td>
<td>2, 3, 4, 5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Understandings about scientific inquiry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Scientists usually inquire about how physical, living, or designed systems function. Conceptual principles and knowledge guide scientific inquiries. Historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists.</td>
<td>All</td>
</tr>
<tr>
<td>• Scientists conduct investigations for a wide variety of reasons. For example, they may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories.</td>
<td>2, 3, 4, 5</td>
</tr>
<tr>
<td>• Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.</td>
<td>3, 4</td>
</tr>
<tr>
<td>• Mathematics is essential in scientific inquiry. Mathematical tools and models guide and improve the posing of questions, gathering data, constructing explanations and communicating results.</td>
<td>3, 4</td>
</tr>
<tr>
<td>• Scientific explanations must adhere to criteria such as: a proposed explanation must be logically consistent; it must abide by the rules of evidence; it must be open to questions and possible modification; and it must be based on historical and current scientific knowledge.</td>
<td>2, 3, 4, 5</td>
</tr>
<tr>
<td>• Results of scientific inquiry—new knowledge and methods—emerge from different types of investigations and public communication among scientists. In communicating and defending the results of scientific inquiry, arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge. In addition, the methods and procedures that scientists used to obtain evidence must be clearly reported to enhance opportunities for further investigation.</td>
<td>2, 3, 4, 5</td>
</tr>
</tbody>
</table>


| Table 4b. NSES Standards C and F, Life Science and Science in Personal and Social Perspectives |
|-----------------------------------------------|-----------------------------------------------|
| **As a result of activities in grades 9–12, all students should develop understanding of** | **Correlation to Evolution and Medicine Lessons** |
| **Standard C. Biological Evolution** |  |
| • Species evolve over time. Evolution is the consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring. | All |
| • Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms. | 2, 3, 4, 5 |
| • The millions of different species of plants, animals, and microorganisms that live on earth today are related by descent from common ancestors. | All |
| **Standard C. The Molecular Basis of Heredity** |  |
| • In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular “letters”) and replicated (by a templating mechanism). Each DNA molecule in a cell forms a single chromosome. | 2, 3, 4, 5 |
| • Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Only mutations in germ cells can create the variation that changes an organism’s offspring. | 2, 3, 4, 5 |
| **Standard C. The Cell** |  |
| Cells can differentiate, and complex multicellular organisms are formed as a highly organized arrangement of differentiated cells. In the development of these multicellular organisms, the progeny from a single cell form an embryo in which the cells multiply and differentiate to form the many specialized cells, tissues and organs that comprise the final organism. This differentiation is regulated through the expression of different genes. | 1, 2, 3, 5 |
| **Standard F. Personal and Community Health** |  |
| The severity of disease symptoms is dependent on many factors, such as human resistance and the virulence of the disease-producing organism. Many diseases can be prevented, controlled, or cured. Some diseases, such as cancer, result from specific body dysfunctions and cannot be transmitted. | 2, 3, 4, 5 |
**Teaching Standards**
The suggested classroom strategies in all the lessons support educators as they work to meet the teaching standards outlined in the *National Science Education Standards* (National Research Council (NRC), 1996). The supplement helps science teachers plan an inquiry-based program by providing short-term objectives for students. It also includes planning tools such as the Science Content and Conceptual Flow of the Lessons chart (Table 3) and a suggested timeline for teaching the supplement (page 18). Teachers can use the supplement to update their curriculum in response to their students’ interest in this topic. The focus on active, collaborative, and inquiry-based learning helps teachers support the development of student understandings and nurture a community of science learners.

The structure of the lessons enables teachers to guide and facilitate learning. All the activities encourage and support student inquiry, promote discourse among students, and challenge students to accept and share responsibility for their learning. Using the BSCS 5E Instructional Model, combined with active, collaborative learning, allows teachers to respond effectively to the diversity of student backgrounds and learning styles. The supplement is fully annotated, with suggestions for how teachers can encourage and model the skills of scientific inquiry, as well as foster the curiosity, skepticism, and openness to new ideas and data that characterize the successful study of science.

**Assessment Standards**
Teachers can engage in ongoing assessment of their teaching and of student learning by using the assessment components embedded in each lesson. The assessment tasks are authentic; they are similar in form to tasks that students will engage in outside the classroom or that scientists do. Annotations guide teachers to these opportunities for assessment and provide answers to questions that can help teachers analyze students’ feedback. The assessments include one or more of the following strategies:

- performance-based activities, such as developing graphs or participating in a discussion of health effects or social policies;
- oral presentations to the class, such as reporting experimental results; and
- written assignments, such as answering questions or writing about demonstrations.

**How Does the BSCS 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning?**
The lessons in this supplement use a research-based pedagogical approach called the BSCS 5E Instructional Model, or the BSCS 5Es. The BSCS 5Es are based on a constructivist theory of learning. A key premise of this theory is that students are active thinkers who build (or construct) their own understanding of concepts out of interactions with phenomena, the environment, and other individuals. A constructivist view of science learning recognizes that students need time to

- express their current thinking;
- interact with objects, organisms, substances, and equipment to develop a range of experiences on which to base their thinking;
- reflect on their thinking by writing and expressing themselves and comparing what they think with what others think; and
- make connections between their learning experiences and the real world.

The three key findings related to student learning identified in *How People Learn* (Bransford et al., 2000), a comprehensive review of research on learning, support the pedagogical strategies promoted by implementing the BSCS 5Es:

- Students enter class with a variety of preconceptions that may later significantly interfere with learning if those preconceptions are not engaged and addressed.
- To develop competence in a given subject, students must build a strong foundation of
factual knowledge within the context of a coherent conceptual framework.

- Students benefit from a metacognitive approach to learning that emphasizes goal setting and self-monitoring.

The BSCS 5Es sequence the learning experiences so that students can construct their own understanding of a science concept over time. The model leads students through five phases of active learning that are easily described using words that begin with the letter *E*: Engage, Explore, Explain, Elaborate, and Evaluate. Rather than just listening and reading, students are also analyzing and evaluating evidence, experiencing, and talking with their peers in ways that promote the development and understanding of key science concepts. These inquiry-based experiences include both direct experimentation and development of explanations through critical and logical thinking. Students often use technology to gather evidence, and mathematics to develop models or explanations.

The BSCS 5Es emphasize student-centered teaching practices. Students participate in their learning in ways that are different from those seen in a traditional classroom. Tables 5 and 6 exemplify what teachers do and what students do in the BSCS 5E Instructional Model.

The following paragraphs illustrate how we implemented the BSCS 5Es in *Evolution and Medicine*.

**Engage**

Students come to learning situations with prior knowledge. The Engage lesson gives you the chance to find out what students think about evolution.

The Engage phase of this supplement (in Lesson 1) is designed to

- pique students’ curiosity and generate interest in natural selection and common ancestry;
- determine students’ current understandings about natural selection and common ancestry;
- encourage students to compare their own thinking about natural selection and common ancestry with that of others; and
- give you a chance to hear or read about students’ current conceptions of natural selection and common ancestry, which you can address in the later lessons.

**Explore**

In the Explore phase of the supplement (Lesson 2), we challenge students to make sense of patterns of lactase persistence around the world. Using an interactive map that shows lactase persistence in Africa, Asia, and Europe, students explore patterns of different variables. They then use actual data from scientific research to compare two alternative hypotheses for the evolution of lactase persistence. Students will reflect and improve on their preliminary explanations after further experiences in Lesson 3. Lesson 2 allows students to express their developing understandings of evolution and medicine through analyzing and comparing data, analyzing alternative explanations, and answering questions.

**Explain**

The Explain phase provides opportunities for students to connect their previous experiences and formulate explanations about case studies that deal with natural selection and common ancestry. It also allows you to introduce formal language, scientific terms, and content information that might make students’ previous experiences easier to describe and explain.

In the Explain phase (Lesson 3), students participate in two case studies. In the first one, they diagnose patients with a mystery disease and then develop an explanation, based on natural selection, for the frequency of the disease in certain parts of the world. In the second case study, students develop an explanation for the conservation of genetic sequences across different organisms by using a combination of natural selection and common ancestry. Students

- explain, in their own words, concepts and ideas about evolution and medicine;
- listen to and compare others’ explanations of the results with their own;
Table 5. Understanding the BSCS 5E Instructional Model: What the Teacher Does

<table>
<thead>
<tr>
<th>Phase</th>
<th><strong>Consistent with the BSCS 5E Instructional Model</strong></th>
<th><strong>Inconsistent with the BSCS 5E Instructional Model</strong></th>
</tr>
</thead>
</table>
| Engage | • Piques students’ curiosity and generates interest  
• Determines students’ current understanding (prior knowledge) of a concept or idea  
• Invites students to express what they think  
• Invites students to raise their own questions | • Introduces vocabulary  
• Explains concepts  
• Provides definitions and answers  
• Provides closure  
• Discourages students’ ideas and questions |
| Explore | • Encourages student-to-student interaction  
• Observes and listens to the students as they interact  
• Asks probing questions to help students make sense of their experiences  
• Provides time for students to puzzle through problems | • Provides answers  
• Proceeds too rapidly for students to make sense of their experiences  
• Provides closure  
• Tells the students that they are wrong  
• Gives information and facts that solve the problem  
• Leads the students step-by-step to a solution |
| Explain | • Encourages students to use their common experiences and data from the Engage and Explore lessons to develop explanations  
• Asks questions that help students express understanding and explanations  
• Requests justification (evidence) for students’ explanations  
• Provides time for students to compare their ideas with those of others and perhaps to revise their thinking  
• Introduces terminology and alternative explanations after students express their ideas | • Neglects to solicit students’ explanations  
• Ignores data and information students gathered from previous lessons  
• Dismisses students’ ideas  
• Accepts explanations that are not supported by evidence  
• Introduces unrelated concepts or skills |
| Elaborate | • Focuses students’ attention on conceptual connections between new and previous experiences  
• Encourages students to use what they have learned to explain a new event or idea  
• Reinforces students’ use of scientific terms and descriptions previously introduced  
• Asks questions that help students draw reasonable conclusions from evidence and data | • Neglects to help students connect new and former experiences  
• Provides definitive answers  
• Tells students that they are wrong  
• Leads students step-by-step to a solution |
| Evaluate | • Observes and records as students demonstrate their understanding of concept(s) and performance of skills  
• Provides time for students to compare their ideas with those of others and perhaps to revise their thinking  
• Interviews students as a means of assessing their developing understanding  
• Encourages students to assess their own progress | • Tests vocabulary words, terms, and isolated facts  
• Introduces new ideas or concepts  
• Creates ambiguity  
• Promotes open-ended discussion unrelated to the concept or skill |
<table>
<thead>
<tr>
<th>Phase</th>
<th>Consistent with the BSCS 5E Instructional Model</th>
<th>Inconsistent with the BSCS 5E Instructional Model</th>
</tr>
</thead>
</table>
| Engage  | • Become interested in and curious about the concept/topic  
          • Express current understanding of a concept or idea  
          • Raise questions, such as, What do I already know about this? What do I want to know about this? How could I find out? | • Ask for the “right” answer  
          • Offer the “right” answer  
          • Insist on answers or explanations  
          • Seek closure |
| Explore | • Use materials and ideas  
          • Conduct investigations in which they observe, describe, and record data  
          • Try different ways to solve a problem or answer a question  
          • Acquire a common set of experiences so they can compare results and ideas  
          • Compare their ideas with those of others | • Let others do the thinking and exploring (passive involvement)  
          • Work quietly with little or no interaction with others (only appropriate when exploring ideas or feelings)  
          • Stop with one solution  
          • Demand or seek closure |
| Explain | • Explain concepts and ideas in their own words  
          • Base their explanations on evidence acquired during previous investigations  
          • Record their ideas and current understanding  
          • Reflect on and perhaps revise their ideas  
          • Express their ideas using appropriate scientific language  
          • Compare their ideas with what scientists know and understand | • Propose explanations from “thin air” with no relationship to previous experiences  
          • Bring up irrelevant experiences and examples  
          • Accept explanations without justification  
          • Ignore or dismiss other plausible explanations  
          • Propose explanations without evidence to support their ideas |
| Elaborate | • Make conceptual connections between new and former experiences  
          • Use what they have learned to explain a new object, event, organism, or idea  
          • Use scientific terms and descriptions  
          • Draw reasonable conclusions from evidence and data  
          • Communicate their understanding to others  
          • Demonstrate what they understand about the concept(s) and how well they can implement a skill | • Ignore previous information or evidence  
          • Draw conclusions from “thin air”  
          • Use terminology inappropriately and without understanding |
| Evaluate | • Compare their current thinking with that of others and perhaps revise their ideas  
          • Assess their own progress by comparing their current understanding with their prior knowledge  
          • Ask new questions that take them deeper into a concept or topic area | • Disregard evidence or previously accepted explanations in drawing conclusions  
          • Offer only yes-or-no answers or memorized definitions or explanations as answers  
          • Fail to express satisfactory explanations in their own words  
          • Introduce new, irrelevant topics |
• become involved in student-to-student discourse in which they explain their thinking to others and debate their ideas;
• record their ideas and current understandings; and
• revise their ideas.

**Elaborate**

In the Elaborate lesson (Lesson 4), students make conceptual connections between new and previous experiences. They draw on their knowledge about natural selection and common ancestry to investigate why we need a new influenza vaccine every few years. In this lesson, students
• connect ideas and apply their understandings of natural selection and common ancestry to the study of influenza,
• use and understand scientific terms and descriptions accurately and in context,
• draw reasonable conclusions from evidence and data,
• add depth to their understandings of natural selection and common ancestry, and
• communicate to others how an understanding of evolution helps explain why a new influenza vaccine is needed every few years.

**Evaluate**

The Evaluate lesson is the final phase of the instructional model, but it only provides a “snapshot” of what students understand and how far they have come. In reality, the assessment of students’ conceptual understanding and ability to use skills begins with the Engage lesson and continues through each of the other phases. Combined with the students’ written work and performance of tasks throughout the supplement, however, the Evaluate lesson can be a summative assessment of what students know and can do.

The Evaluate lesson (Lesson 5) gives students a chance to demonstrate their understandings of natural selection and common ancestry. Students
• demonstrate what they understand about evolution and medicine by identifying and correcting misconceptions contained in a fictional article about vitamin C biosynthesis,
• share their current thinking with others, and
• assess their own progress by describing in detail one example about natural selection from the examples in the supplement.

**What’s the Evidence for the Effectiveness of the BSCS 5E Instructional Model?**

Support from educational research studies for teaching science as inquiry is growing (for example, Geier et al., 2008; Hickey et al., 1999; Lynch et al., 2005; and Minner et al., 2009). A 2007 study, published in the *Journal of Research in Science Teaching* (Wilson et al., 2010), is particularly relevant to the *Evolution and Medicine* supplement.

In 2007, with funding from NIH, BSCS conducted a randomized, controlled trial to assess the effectiveness of the BSCS 5Es. The study used an adaptation of the NIH supplement *Sleep, Sleep Disorders, and Biological Rhythms*, developed by BSCS in 2003 (NIH and BSCS, 2003). Sixty high school students and one teacher participated. The students were randomly assigned to the experimental or the control group. In the experimental group, the teacher used a version of the sleep supplement that was very closely aligned with the theoretical underpinnings of the BSCS 5Es. For the control group, the teacher used a set of lessons based on the science content of the sleep supplement but aligned with the most commonplace instructional strategies found in U.S. science classrooms (as documented by Weiss et al., 2003). Both groups had the same master teacher.

Students taught with the BSCS 5Es and an inquiry-based approach demonstrated significantly higher achievement for a range of important learning goals, especially when the results were adjusted for variance in pretest scores. The results were also consistent across time (both immediately after instruction and four weeks later). Improvements in student learning were particularly strong for measures of student reasoning and argumentation. The following chart (Table 7) highlights some of the study’s key findings. The results
of the experiment strongly support the effectiveness of teaching with the BSCS 5Es.

Evidence also suggests that the BSCS 5Es are effective in changing students’ attitudes on important issues. In a research study conducted during the field test for the NIH curriculum supplement *The Science of Mental Illness* (NIH and BSCS, 2005), BSCS partnered with researchers at the University of Chicago and the National Institute of Mental Health. The study investigated whether a short-term educational experience would change students’ attitudes about mental illness. The results showed that after completing the curriculum supplement, students stigmatized mental illness less than they had beforehand. The decrease in stigmatizing attitudes was statistically significant (Corrigan et al., 2007; Watson et al., 2004).

### How Can Challenges to Teaching Evolution Be Handled in the Classroom?

Teachers sometimes feel pressure to avoid teaching evolution because some groups view the topic as controversial. These pressures can come from groups outside the school, parents, students, or even from teachers themselves. In fact, some teachers show clinically measurable levels of stress when asked to simply think about teaching evolution (Griffith and Brem, 2004). But you can make many preparations that will *help you teach evolution effectively and appropriately*.

First and foremost, it is important that you feel comfortable with your content knowledge. The Information about Evolution and Medicine section provides useful background information. Being aware of common misconceptions

### Table 7. Differences in Performance of Students Receiving Inquiry-Based and Commonplace Instructional Approaches

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean for Students Receiving Commonplace Teaching</th>
<th>Mean for Students Receiving Inquiry-Based Teaching</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total test score pretest (out of 74)</td>
<td>31.11</td>
<td>29.23</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Total test score posttest</td>
<td>42.87</td>
<td>47.12</td>
<td>0.47</td>
</tr>
<tr>
<td>Reasoning pretest (fraction of responses at the highest level)</td>
<td>0.04</td>
<td>0.03</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Reasoning posttest</td>
<td>0.14</td>
<td>0.27</td>
<td>0.68</td>
</tr>
<tr>
<td>Score for articulating a claim (out of 3)</td>
<td>1.58</td>
<td>1.84</td>
<td>0.58</td>
</tr>
<tr>
<td>Score for using evidence in an explanation (out of 3)</td>
<td>1.67</td>
<td>2.01</td>
<td>0.74</td>
</tr>
<tr>
<td>Score for using reasoning in an explanation (out of 3)</td>
<td>1.57</td>
<td>1.89</td>
<td>0.59</td>
</tr>
</tbody>
</table>


*Note: Effect size is a convenient way of quantifying the amount of difference between two treatments. This study used the standardized mean difference (the difference in the means divided by the standard deviation, also known as Cohen's d). The posttest scores controlled for the variance in students’ pretest scores. The reasoning posttest scores controlled for variance in students’ reasoning pretest scores at the highest level.*
about evolution is also important, so details on some of them are included in that section, too. For additional background on evolution and teaching evolution, consider the following resources:

- The University of California Museum of Paleontology’s Web site, Understanding Evolution for Teachers, about evolution in general (http://evolution.berkeley.edu/evosite/evohome.html),
- *The Nature of Science and the Study of Biological Evolution* (BSCS, 2005), about evolution in general, and
- The Smithsonian’s National Museum of Natural History’s Web site, What Does It Mean to Be Human?, about human evolution (http://humanorigins.si.edu/).

It is also important to be aware of relevant state and district standards that relate to evolution. Standards are compiled by experts and reflect the concepts that the community believes are important. Standards are an important line of defense if outside pressure is applied to require teachers to avoid or dilute the teaching of evolution. As we described previously, the lessons in this supplement align directly with the *National Science Education Standards* (NRC, 1996).

To help relieve potential student fears, it is crucial to establish that, as a teacher, you are trying to help students understand the scientific concepts related to evolution, not change their beliefs. Scientists accept evolution as the explanation for the unity and diversity of life because of the large amount of evidence that supports evolutionary theory. Science class is about understanding explanations based on evidence, not on beliefs. Some teachers find it helpful to tell students that they will not be asked to believe in evolution, but that they do need to understand concepts important in evolution and how scientists use evidence to support claims about evolution. Having students reflect on the nature of science continuously throughout their studies, not just when talking about evolution, helps reinforce that evidence and explanations are important in all aspects of science.

Many resources are available to you if specific issues or challenges to teaching evolution arise in your classroom. Two excellent resources follow:

- For dealing with roadblocks to teaching evolution, the Understanding Evolution for Teachers Web site: http://evolution.berkeley.edu/evosite/Roadblocks/index.shtml.
- For handling challenges to teaching evolution, The National Center for Science Education (http://ncse.com/evolution). This site also contains valuable information about legal decisions in the United States about teaching evolution and numerous statements from a large array of organizations supporting the teaching of evolution.