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Section 1: Implementation Guide

Copymasters for Implementation Guide

Implementation Guide

1.1 Introduction

Successfully implementing an innovative program such as *BSCS Biology: A Human Approach* involves changing the way you think about biology as well as the way you teach it. Such change does not occur automatically with the adoption of the program. You must learn about the curriculum—its content and pedagogy—and you must have time to use the curriculum in your classroom. Finally, you must receive ongoing support as you put this new program into effect in your classroom. Successful implementation requires patience, planning, support, and time.

There are many factors in the formula for successfully implementing *BSCS Biology: A Human Approach*. One set of factors involves obtaining support from your school and district. For *BSCS Biology: A Human Approach* to become an integral part of the instructional program of a school, the administrators should sanction and actively support the program. Your principal should understand and believe in the program and actively support teachers during the implementation process. You, other biology teachers, and your principal also must develop a support system that anticipates and responds to your concerns and needs during the implementation process. Such a support system includes release time to develop the skills to teach the program successfully, a colleague or colleagues to work with you to implement various innovations, and a materials support system that ensures that you have the supplies you need to teach the program.

Another set of factors concerns your willingness and ability to adapt your teaching style to meet the instructional goals of the curriculum. The implementation process should allow you to progress from a level of basic knowledge of the program to a level in which you redesign lessons to maximize students' learning yet remain within the basic philosophy and framework of the original program. Depending on your familiarity with the features of this program, this process is likely to take 3 to 5 years.

Implementation is facilitated when most of the biology teachers in a school use the program in a manner consistent with its philosophy and goals. In this setting, you and your colleagues can support each other. To be successful, you must be actively committed to the ongoing learning involved in implementing the innovations built into *BSCS Biology: A Human Approach*. You must view yourselves as students and as inquirers who will apply your learning to your classroom situations.

You will know that you have successfully implemented the program when you find yourself emphasizing major concepts and skills when teaching biology, consistently using the BSCS 5E instructional model, frequently integrating formative assessments into lessons, and using collaborative learning. You also will know that implementation is successful when your students are inquiring actively, thinking critically, and working in teams that function independently.

Because the process of implementation is so critical to teaching this program successfully, we have developed this implementation guide to assist you through the necessary steps. This guide is designed to

- help you decide whether this program is right for you,
- help you implement the program,
- prepare you to understand and use a constructivist model of instruction,
- prepare you to understand and use the techniques and perspectives of inquiry, and
- prepare you to teach biology conceptually.

1.2 How to Use This Guide

Your first task is to decide whether this program is right for you and your students. Read Section 1.3, *Is This Program Right for You?* and Section 1.4, *Implementing Innovative Teaching Strategies*, to determine if this program meets your vision of learning, teaching, and professional growth. These sections provide you with an overview of how this program compares with other high school biology programs and what is involved in successfully implementing this program.

Once you have become familiar with the features of *BSCS Biology: A Human Approach* and decide to use it in your classroom, you will need to begin the implementation process. Set up your plan for implementation using the guidelines in Section 1.5, *Planning for Successful Implementation and Professional Development*. This section provides important information, including models for conducting ongoing implementation of *BSCS Biology: A Human Approach*. These models also can serve as models for professional growth for your entire teaching career.

We strongly recommend that you begin by implementing the BSCS 5E instructional model, because it is integral to the conceptual organization of the program. This instructional model supports constructivist approaches to learning and facilitates the learning of biology as an integrated process. Learn how to use this model by reading Section 1.4. For more information, consult resources found in the bibliography at the end of this guide. Use one of the implementation strategies from Section 1.5 to guide your implementation of the instructional model. Once you become comfortable routinely using the 5Es in your classroom, layer in additional innovations over time. It is appropriate to delay integrating some innovations until your second or third year implementing the program.

1.3 Is This Program Right for You?

A. The Curriculum

At Biological Sciences Curriculum Study (BSCS), our mission is to provide leadership in science education. In this curriculum, as in our elementary curriculum (*BSCS Science Tracks: Connecting Science & Literacy*) and our middle school curriculum (*BSCS Science & Technology*), we have developed a program that provides leadership, in part, by helping students assume responsibility for their own learning and helping teachers facilitate this process. At the same time, *BSCS Biology: A Human Approach* is designed to help the students connect their understanding of biology to science as an important human endeavor that is relevant to their lives.

Our vision is for *BSCS Biology: A Human Approach* to provide teachers with a starting place to develop individualized, inquiry-based programs that suit their own classroom needs. To support this goal, *BSCS Biology: A Human Approach* provides you with a sequential program composed of core activities; optional activities, further challenge activities, and ideas for extensions; and guidelines for the support needed to implement the BSCS 5E instructional model, assessment, inquiry, and the other innovations that are central to the program.

BSCS Biology: A Human Approach helps students become more responsible for their own learning. By incorporating hands-on and inquiry-oriented activities, essays as resources, alternative assessments, and collaborative learning strategies, this program encourages interdependence among students and independence in students, and it reduces dependence on the teacher as the primary source and repository of knowledge.

Another of our goals is to improve the biological literacy of all students. We developed this program with the belief that all students can attain biological literacy and all students can understand biology when it is taught in a conceptually oriented, activity-based fashion. By focusing on six unifying principles of biology, we allow time for the students to thoroughly experience how those fundamental concepts apply to numerous situations and to make associations with contexts that have personal, social, historical, or ethical meaning. By creating active learning environments, we help the students become independent students, thus enhancing their ability to gain biological literacy beyond high school.

Evidence that supports our assertion that this program can help all students become more biologically literate comes from field-test data and first-edition users. This program has been field tested successfully in more than 40 schools nationwide, including classes in which more than 50 percent of the students were identified as "learning disabled," most of the students were identified as "gifted," students were primarily from low-income families, students were primarily from middle-class families, and many other classrooms typical of the United States today. In those classrooms in which teachers strove to implement the program's innovative instructional strategies, teachers found that *BSCS Biology: A Human Approach* was effective in helping students grasp the fundamental understandings and skills of biology.

As is true of any high school biology curriculum, we have made a number of assumptions regarding students, teachers, and classrooms. We assume that all students have had previous life science education sometime during grades 6 through 8. We assume that all students can learn to inquire and can gain a conceptual understanding of major biological principles. We assume that teachers are professionals who have the desire and ability to continually challenge students to achieve high levels of conceptual understanding in biology. This means we assume teachers are able to view biology conceptually, are aware of recent research about how children learn, and are committed to helping students understand major biological concepts. Also, we assume that teachers have made an informed, consensual decision to implement this curriculum.

This program has been designed to complement the changing educational environment of students as they move into the 21st century. Because many changes in the learning environment involve interactive multimedia components, this program incorporates a number of tested educational technologies. It is essential that users of this curriculum have frequent access to a computer. We also strongly recommend that the biology classroom contain several computers with printers and high speed internet access. Students will use computers for content simulations, to run *The Commons* interactive learning experience, to support the collection of lab data using probe ware, and to research SciLinks Internet sites. This program is also available in ebook format that students can access with a high-speed internet connection. An acceptable alternative would be to arrange for students to have access to these computers elsewhere in your school, such as in a computer laboratory or library, as computer-based activities arise.

B. Unifying Principles

Before developing *BSCS Biology: A Human Approach*, BSCS invited 41 scientists and educators to conduct a design study to determine what biological concepts and principles are critical to the study of biology at the high school level. The subsequent report, *Developing Biological Literacy*, published by Kendall/Hunt Publishing Company, listed six unifying principles of biology. We have used these principles to organize the content of *BSCS Biology: A Human Approach*. They are

- **Evolution: Change in Living Systems**
  Lineages of organisms change across time.
- **Homeostasis: Maintaining Dynamic Equilibrium in Living Systems**
  Organisms maintain a relatively stable internal environment through their regulatory mechanisms and behavior.
- **Energy, Matter, and Organization: Relationships in Living Systems**
  Organisms and ecosystems are complex and highly organized, and they require matter and energy to maintain this organization.

- **Continuity: Reproduction and Inheritance in Living Systems**
  Organisms are related to other generations by genetic material passed on through reproduction.
- **Development: Growth and Differentiation in Living Systems**
  Organisms grow and differentiate during their lifetimes based on a genetic plan that is influenced by the environment.
- **Ecology: Interaction and Interdependence in Living Systems**
  Organisms interact with their environment and are interdependent with other biotic and abiotic systems.

High school biology is, for many students, the last science class they complete at the high school level. For this reason, it is important to make biology relevant to the students' lives and to focus on the concepts that will enable them to function as scientifically literate citizens. By using these unifying principles as the framework, we have crafted a program that includes the major ideas of biology without becoming encyclopedic. As a way to reinforce these conceptual themes, we have adopted each unifying principle as the title and conceptual framework for one unit. Each theme reappears in many contexts, and complete coverage of a topic often is not accomplished until it has been revisited in several different chapters and/or units. **Figure TR1.1** outlines the scope and sequence of the program.

C. Major Subthemes

Two subthemes are used as threads for establishing a link between students and the role and importance of biology in their lives: Science as Inquiry and Science and Humanity. We chose a human perspective for these themes because teenagers are interested in how the world relates to them and because the *National Science Education Standards* call for scientific literacy in all students, which means "understanding scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (NRC, 1996).

Science as Inquiry

Science as Inquiry refers both to the abilities that characterize the discovery process (that is, the means by which data are obtained, evaluated, and incorporated into the dynamic body of knowledge that reflects current scientific understanding) and to the understandings that characterize scientific habits of mind (that is, the critical-thinking, problem-solving, and communication skills so important in life). We use this subtheme to take the students in progressive steps through the processes of science, including making observations, making inferences, assembling evidence, developing hypotheses, designing experiments, collecting data, developing explanations of results, synthesizing findings, and communicating conclusions. The progressive development of students' inquiry abilities culminates in a full inquiry, which requires them to complete a scientific investigation of their own choosing.

Science as Inquiry involves a set of attitudes and beliefs that pertains to how scientists try to understand the natural world. The process of inquiry requires that scientists collect evidence and use it to explain and predict natural events. To examine evidence objectively, scientists try to avoid bias and to suspend their personal beliefs. Because scientific ideas are based on existing evidence, they are subject to change as additional evidence becomes available. Scientists critically examine each bit of evidence in order to make inferences about the natural world.

In an inquiry-based biology program, students use discovery to construct explanations of biological structures, processes, and natural phenomena. The conceptual, hands-on inquiry approach to teaching in *BSCS Biology: A Human Approach* organizes the curriculum around opportunities for students to practice and develop skills in experimentation, critical thinking, analysis, and decision making. For instance, instead of simply being told how muscles function, students build their own models of muscles and develop their own understanding of how muscles work in antagonistic pairs.

Figure TR1.1 Scope and Sequence of *BSCS Biology: A Human Approach*

Scope and Sequence

Unit 1 Evolution: Change in Living Systems

Unifying Principle: Lineages of change across time.

Chapter 1 The Human Animal

Major Concepts:

Characteristics of the human animal
Characteristics of the higher primates
Human capacity for culture and learning
Brain structure and function
Recognizing and describing life
Evidence and inference
Testable questions

Chapter 2 Evolution: Change across Time

Major Concepts:

Change in ancient hominids
Role of inference in understanding change
Variation
Natural selection
Adaptation
Acquired and inherited traits
Evidence for evolutionary change
Earth's history
Deep time
Theory of evolution
Processes of evolution
Microbial evolution
Scientific models

Chapter 3 Products of Evolution: Unity and Diversity

Major Concepts:

Evidence for common ancestry
Species and speciation
Diverse organisms share common characteristics
Biological classification schemes
Adaptation and an organism's environment
Multiple lines of evidence in science
The dynamic nature of science

Unit 2 Homeostasis: Maintaining Dynamic Equilibrium in Living Systems

Unifying Principle: Organisms maintain a relatively stable internal environment through their regulatory mechanisms and behavior.

Chapter 4 The Internal Environment of Organisms

Major Concepts:

Internal conditions change in response to external conditions
Compartmentalization and boundaries
Cell membrane characteristics and selective permeability
Diffusion, osmosis, and active transport
Exchanging substances between internal and external environments
Surface area—volume relationship and cell size
Role of organ systems in regulation
Circulatory system
Urinary system
Modeling compartments and boundaries
Controlled experiments
Supporting explanations with evidence and reasoning

Chapter 5 Maintaining Balance in Organisms

Major Concepts:

Homeostatic responses
Interaction of homeostatic systems
Regulation in the human body
pH, buffering, and homeostasis
Chemistry of acids and bases
Positive feedback
Negative feedback
Gas exchange system
Endocrine and nervous system integration
Behavioral mechanisms that maintain homeostasis

Chapter 6 Human Homeostasis: Health and Disease

Major Concepts:

Disruption of homeostasis
Vital signs
Immune system
Vaccines
Regulatory mechanisms
Mental health and homeostasis
Behavioral effects on immune function
Risk and behavior
Cost/benefit analysis
Ethical analysis
The dynamic nature of science

Unit 3 Energy, Matter, and Organization: Relationships in Living Systems

Unifying Principle: Organism and ecosystems are complex and highly organized, and they require matter and energy to maintain this organization.

Chapter 7 Physical Fitness and Performance

Major Concepts:

Fitness as a function of activity level and diet
Matter and energy stored in food
Biologically important molecules
Enzyme function
Digestive system
Biosynthesis
Muscle structure and function
Matter and energy in human performance
Controlled experimental design
Comparing predicted and actual results

Chapter 8 The Cellular Basis of Activity

Major Concepts:

Potential and kinetic energy
Energy stored in matter
Organization of matter
Conservation and transfer of energy
Cellular respiration
Photosynthesis
Links between energy-producing and energy-requiring reactions
Metabolism and the movement of matter
Variables in experimental design
The accumulation of scientific knowledge

Chapter 9 The Cycling of Matter and the Flow of Energy in Ecosystems

Major Concepts:

The cycling of matter in ecosystems
The flow of energy in ecosystems
Food webs
Interactions among organisms
Organization in communities
Decomposers and the cycling of matter
Energy conversion into heat
Disruption of matter and energy movement in ecosystems

Figure TR1.1 Scope and Sequence of *BSCS Biology: A Human Approach (continued)*

Unit 4 Continuity: Reproduction and Inheritance in Living Systems

Unifying Principle: Organisms are related to other generations by genetic material passed on through reproduction.

Chapter 10 Reproduction in Humans and Other Organisms

Major Concepts:

- Species continuity requires reproduction
- Diversity of reproductive strategies
- Structure and function of human reproductive systems
- Hormonal regulation of human reproduction
- Birth control as a form of technology
- Evolution and mating behaviors
- Human reproduction and culture

Chapter 11 Gene Action

Major Concepts:

- Codes and information transfer
- DNA as an information molecule
- DNA structure and function
- Chromosomes
- DNA replication
- Transcription of RNA
- Translation of proteins
- Genetic code
- Genetic technologies
- Ethical analysis
- Scientific models
- Mutations, variation, and evolution

Chapter 12 Continuity of Information through Inheritance

Major Concepts:

- Inheritance of genetic information
- Probability and sample size
- Simple Mendelian inheritance
- Hetero- and homozygosity
- Dominant and recessive traits
- Meiosis
- Variation and evolution
- Segregation of alleles
- Discrete and continuous variation
- X-linkage
- Acquired and inherited traits

Genotype and phenotype
Interaction of genes and environment in generating phenotype
Monohybrid crosses
Autosomes and sex chromosomes
Linkage and recombination
Human genetic disorders

Unit 5 Development: Growth and Differentiation in Living Systems

Unifying Principle: Organisms grow, develop, and differentiate during their lifetimes based on a genetic plan that is influenced by the environment.

Chapter 13 Processes and Patterns of Development

Major Concepts:

Accumulation of scientific knowledge
Patterns of animal development
Cell division
Cell differentiation
Differential gene expression
Regulation of development
Cell-cell interactions (induction)
Interaction of growth and differentiation
Genetic and environmental influences on development
Birth defects
Cancer

Chapter 14 The Human Life Span

Major Concepts:

Stages of human life
Human cognitive development
Human social development
Human physical development
Human emotional development
Genetic and environmental influences on human development and variation
Cultural influences on human life stages
Ethical study of humans

Figure TR1.1 Scope and Sequence of *BSCS Biology: A Human Approach (continued)*

Unit 6 Ecology: Interaction and Interdependence in Living Systems

Unifying Principle: Organisms interact with the environment and are interdependent with other biotic and abiotic systems.

Chapter 15 Interdependence among Organisms in the Biosphere

Major Concepts:

- Interactions among organisms
- Limiting factors
- Carrying capacity
- Population growth
- Exponential growth
- Logistic growth
- Population dynamics
- Ecosystems change across time
- Global interdependence

Chapter 16 Decision Making in a Complex World

Major Concepts:

- Ecosystem complexity
- Impacts of human activities on ecosystems
- Systems analysis as a tool for analyzing complex interactions
- Impact of human decision-making on ecosystems
- Interaction of science and society
- Contribution of science to public policy

Studies on the use of inquiry approaches in science courses suggest that inquiry laboratory strategies involve students in active learning, give them more responsibility, and require them to make extensive use of science process skills. Evidence also suggests that inquiry approaches produce significantly greater educational gains than traditional approaches and appear to work equally well for students of all ability levels (Leonard, 1989; Wilson, Taylor, Kowalski, & Carlson, 2010).

Science and Humanity

The rationale for adopting a human perspective as the starting point for teaching biology is linked strongly to the issue of relevancy, and justifications for such an approach abound in many national reports. For example, the National Research Council (1990) recommended in *Fulfilling the Promise: Biology Education in the Nation's Schools* that concepts "be presented in such a manner that they are related to the world that students understand in a language that is familiar." Likewise, the American Association for the Advancement of Science supports a human approach to biology when it recommends that topics such as human identity, the life cycle, the basic functions of the body, and health be considered integral to scientific literacy (1989). Articles in the biology education literature also support a human perspective (Clark, 1989; Johnson, 1989; Moore, 1988; Nickels, 1987; Hurd, 1980, 1982). Note that these recommendations call for a human emphasis; this is not the same as anthropocentrism. In *BSCS Biology: A Human Approach*, we often use human examples to engage the students' interest in fundamental biological concepts and then expand on this interest with examples from other kingdoms. At no time are humans portrayed as the most important component of the universe.

The Science and Humanity subtheme makes the students' study of biology relevant to their lives by presenting biology in the context of human culture, the history of science, and the importance of ethics, ethical analysis, and decision making in today's controversial technological world. It also addresses how humans have used technology as a way of adapting. For example, in Unit 5, which addresses the unifying principle of development, the students examine how various cultures use different traditions and technologies to influence the social and personal growth of humans. In another activity in the unit, students interpret some of the historical, experimental evidence from studies in developmental biology. An activity in Unit 2, which addresses the unifying principle of homeostasis, asks students to identify and analyze an ethical issue related to a health care program that they propose to develop. By using this human approach, we give students the opportunity to become directly involved in investigations that are relevant and that apply outside the classroom. This approach also helps students connect fundamental biological concepts to other concepts and disciplines.

D. Instructional Goals

BSCS Biology: A Human Approach has been developed to achieve a number of specific goals for students and teachers. Students who experience this curriculum will have opportunities to

- understand major biological concepts;
- understand the role, place, and interactions of humans in the biosphere;
- understand the personal, social, and ethical implications of biology and biotechnology;
- learn to apply biological knowledge to new situations in and out of the classroom;
- demonstrate mastery of the processes of scientific inquiry;
- understand that science is a way of knowing and that technology is a way of adapting;
- take increased responsibility for their own learning; and
- develop cognitive skills including literacy, critical thinking, problem solving, and ethical analysis.

Teachers who use *BSCS Biology: A Human Approach* will have opportunities to

- think about and teach biology conceptually;
- facilitate students' learning about biology;
- use a variety of instructional materials and strategies;
- use a variety of inquiry-based activities that encourage students to become responsible for their own learning;
- enhance their understanding that science is a way of knowing and technology is a way of adapting, and lessen their perceptions that science is a body of knowledge and that technology is the application of knowledge; and
- use alternative science assessments, such as hands-on performance tests, rubrics, and projects, while they decrease their use of traditional tests.

In addition to program goals, you will find unit goals, chapter goals, and outcomes and indicators of success for each activity in the teacher's edition. The unit goals indicate what we expect students to know and be able to do relevant to that unit's unifying principle. The chapter goals address the concepts and skills that we expect students to understand and use in their pursuit of knowledge of the unifying principle. The outcomes and indicators list the major understandings and skills that students should achieve during the course of an activity. Outcomes and indicators also serve as a tool for conducting internal, ongoing assessment and as a rich resource for constructing assessment items.

E. Comparison with Standards

Before you decide whether to implement this program, we recommend that you compare your district's or state's goals and outcomes with those of *BSCS Biology: A Human Approach*. Many school districts and states have adopted standards or other guidelines for student understandings and abilities. (For a comparison of how *BSCS Biology: A Human Approach* aligns with the *National Science Education Standards*, see *Correlating BSCS Biology: A Human Approach with National Science Education Standards*, Section 3 of the *Teacher Resources*.)

Even though no nationally developed program can match every goal and outcome that a local district or state adopts, a curriculum that you purchase should provide a solid framework on which to build. *BSCS Biology: A Human Approach* provides a strong content, assessment, and teaching foundation, one that was developed according to the principles of *Developing Biological Literacy* and the *National Science Education Standards*. After you have compared the program with your district and/or state standards, you need to decide how to supplement, reinforce, or adapt the program to meet your needs. Use the following guidelines as you make your comparisons:

1. Obtain a list of goals for your district's or state's high school biology education program.
2. Compare the program goal statements for *BSCS Biology: A Human Approach*, listed in Section 1.3D, *Instructional Goals*, with the goals of your district or state guidelines.
3. Obtain a list of your district's/state's standards, outcomes, or other guidelines for high school biology.
4. Compare the unit goals, chapter goals, outcomes and indicators, and major concepts for *BSCS Biology: A Human Approach*, found in the teacher's edition, with your district's or state's standards/outcomes.
5. Answer these questions:
   - Are the district's/state's guidelines mandated or recommended?
   - Are the goals of the district/state compatible with those of *BSCS Biology: A Human Approach*? To what degree are they compatible? If they are not, do you need to rethink the district's/state's guidelines?
   - What areas of your district/state guidelines are not addressed by *BSCS Biology: A Human Approach*? Where can you add those areas and what resources are necessary to teach those areas?
   - How will you obtain the resources you need? How will you use them?

Once you have completed your comparisons, you should have enough information to make an informed decision as to whether you should adopt this curriculum.

1.4 Implementing Innovative Teaching Strategies

"Learning science is something students do, not something that is done to them."
(National Research Council, 1994)

A. The BSCS 5E Instructional Model

The work of cognitive psychologists across many years has improved our understanding of the learning process. Many researchers now support a psychology-based theory of learning that effectively accommodates all students. The theory, which grew the work of Jean Piaget and Lev Vygotsky, is referred to as constructivism, a term that expresses the view of the student as an active agent who "constructs" meanings out of his or her interactions with events (Perkins, 1992). Rather than passively absorbing information, the student redefines, reorganizes, elaborates, and changes initial understandings through interactions with phenomena, the environment, and other individuals. The student interprets objects and phenomena and internalizes the interpretation in terms of previous experiences.

Students' past personal experiences have a profound effect on their understanding of the world (Watson and Konicek, 1990). For change in conception to occur, teachers first must become aware of students' previous experiences and conceptions. The video *A Private Universe* powerfully communicates the importance of prior conceptions to learning. For example, it illustrates how one student's early conceptions about how Earth revolves around the Sun inhibited further understanding because the teacher was not aware of the student's ideas. This video can be viewed at the Web site for Annenberg Media.

For another example, many students can recite the definition of the term species as a group of organisms that can interbreed successfully in their natural environment. But few students understand what this means without further experiences. In one biology class that had completed a study of species, the following interchange took place as the teacher asked questions and students responded:

Q: What is a species?

A: A group of different animals.

Q: Are dogs different species?

A: Yes, a Chihuahua is a different species from a Labrador retriever. It's obvious because they look so different.

The teacher shows the class a picture of four different species of zebras.

Q: Do you think these zebras are different species?

A: No, they look nearly identical.

Construction of a more adequate conception than the original one requires time and experiences (Saunders, 1992). These students went on to take a second look at what a species is because the teacher had recognized that they did not understand what the concept meant, despite their earlier studies.

Yet such in-depth learning means that fewer concepts and subjects will be covered during the school year. This teacher decided that it was more important for students to understand fewer things well than to be exposed to a wide range of subjects and gain a superficial, or incorrect, understanding of the concepts involved. Thus, for students to come away with a strong conceptual grasp of the most important principles of biology, you need to focus instruction on a small number of essential concepts that you want them to understand, and spend more time developing these concepts.

As the information explosion continues, teachers have become increasingly more aware that it is impossible to teach students everything. Educators increasingly have turned to seeking out those concepts that are most important for students to grasp because they are essential for understanding the basic nature of a subject. Major concepts are those that apply to numerous situations in the original field of study and often can be transferred to other areas of endeavor. We refer to learning that emphasizes understanding of major concepts as conceptual learning.

Interestingly, research has shown that students who are given time and opportunity to thoroughly grasp a small number of important concepts do better on traditional tests than students who are exposed briefly to a large number of ideas (Sizer, 1992; Knapp, 1995). The intensive learning and thinking involved in constructing a thorough understanding of a few major ideas appears to benefit all students regardless of ability. Students of all ages and abilities who are encouraged to think deeply, argue ideas, and test understandings have shown significant intellectual gains (Sizer, 1992).

BSCS has developed an instructional model, based on constructivism, that enhances conceptual learning and provides a structure for developing inquiry skills (Bybee, 1997). We call our model the "BSCS 5Es" because it takes the students through five phases of learning that are easily described using five words that begin with the letter E: Engage, Explore, Explain, Elaborate, and Evaluate (**figure TR1.2**).

Figure TR1.2 The BSCS 5E Instructional Model

Engage

These lessons mentally engage the students with an event or question. Engage activities help students reflect on what they know and can do.

Explore

Students work with one another to explore ideas through activities. This exploration provides a common experience for all learners. Under the guidance of the teacher, students begin to clarify their understanding of major concepts and skills.

Explain

Students construct explanations of the concepts and processes about which they are learning. Teachers probe students' understanding to help them gain clarity and develop skills.

Elaborate

These activities challenge students to apply what they have learned and to build on the students' understanding of concepts in ways that extend their knowledge and skills.

Evaluate

Students synthesize their learning across the instructional model and assess their own knowledge, skills, and abilities. These activities also allow teachers to evaluate students' progress.

This instructional model allows students and teachers to experience common activities, to use and build on prior knowledge and experience, to construct meaning, and to continually assess their understanding of a major concept. It avoids excessive use of lecture because research has shown that 10 minutes of lecture is near the upper limit of comfortable attention that students give to lecture material; however, the attention span in an investigative laboratory is far longer (Project Kaleidoscope, 1991). In the BSCS 5E model, the teacher acts as facilitator and coach much more frequently than he or she acts as the disseminator of information. In *BSCS Biology: A Human Approach*, we organized the instructional experiences in each chapter around one cycle of the BSCS 5E model.

Engage: This phase of the instructional model initiates the learning sequence and introduces the major concept to be studied. Its primary purpose is to capture the students' attention. The introductory activity should make connections between past and present learning experiences, and it should anticipate upcoming activities. The students should become mentally engaged in the major concept, process, or skill to be studied and should begin to think about how that concept, process, or skill relates to their previous experiences.

Your role during *engage* activities is to engage the students' interest and focus them on the instruction task. Asking a question, defining a problem, showing a discrepant event, and acting out a problematic situation are a few ways to capture student interest and define the purpose of a chapter. Successful engagement results in students who are intrigued by the concepts they are about to study in depth.

Explore: This phase of the teaching model provides students with a common base of experiences within which they identify and develop current concepts, processes, and skills. During this phase, students actively explore their environment or manipulate materials. This is your opportunity to identify or assess your students' false or incomplete conceptions by listening to their descriptions or examples of related ideas. Keeping these prior conceptions in mind will help you focus later instruction and identify potential problem areas.

Use *explore* activities to establish common experiences that you and your students can use later to discuss concepts, processes, or skills. Allow the students time and opportunities to investigate objects, materials, and situations based on each students' ideas of the phenomena. As a result of their mental and physical involvement in the activity, the students should establish relationships, observe patterns, identify variables, and question events.

Explain: This phase of the instructional model allows students to develop an explanation for the concepts they have been exploring. You should give them opportunities to verbalize their developing conceptual understanding or to demonstrate their skills or behaviors. *Explain* activities require that students and teachers use common terms related to the learning task. This is the appropriate time to introduce terms and detailed explanations. Keep in mind, however, that these activities still are student-centered, that is, the students are developing their own explanations. Your role is to guide them through activities so that they have ample opportunities to develop a more complete understanding of a concept or event. Students ultimately should be able to explain their understanding of the concept by bringing together their experiences, prior knowledge, and vocabulary.

Elaborate: This phase of the instructional model challenges and extends the students' conceptual understanding and allows further opportunity for students to practice desired skills and behaviors. In some cases, they still may have misconceptions, or they may understand a concept only in terms of the exploratory experience. Through new experiences, the students develop a deeper and broader understanding of major concepts, obtain more information about areas of interest, and refine their scientific skills. Your primary goal is to guide students to evince generalizations and extensions of concepts, processes, and skills that are relevant to their lives.

This is a time to assess student understanding informally, and if necessary, to revisit topics that present difficulties. Some students may not progress beyond a very basic understanding of the concepts. The BSCS 5E instructional model allows some students to develop a fundamental understanding by spending their time on the basic *explore*, *explain*, and *elaborate* of the BSCS 5E model, while other students move through the basic cycle plus several *elaborates*.

Evaluate: At some point, it is important that students receive feedback on the adequacy of their explanations and understandings. During this phase of the instructional model, encourage students to assess their understanding and abilities. This will provide opportunities for you to evaluate their understanding of key concepts and development of essential skills.

As you implement the model, keep in mind the goals of the particular phase of the model that an activity addresses. This will allow you to orient the activity properly to fit the students' present level of understanding of a particular concept, process, or skill. Adapt a teaching style for a given activity that complements the stage of the BSCS 5E model that the activity represents. *The Outcomes and Indicators of Success* and the *Strategies for Guiding Learners* for each activity will guide you in this task.

When preparing to do an activity, first examine what stage of the instructional model it represents. Refer to **figure TR1.3**, What the Teacher Does, and **figure TR1.4**, What the Student Does, for that particular stage and organize your lesson accordingly. Also, note that students will come to recognize the different phases of learning that they are experiencing as they move through each chapter (and therefore each cycle of the instructional model).

The development of student abilities to reflect not only on what they are learning but also how they are learning it is an important part of education. The BSCS 5E model thus serves as both a learning model and an instruction, or teaching, model.

Keep in mind that students may grasp concepts at different paces. Some students may be ready to move on to new experiences while others are still struggling for understanding. The activities in this program often offer multiple levels of understanding. Allow those students who quickly grasp the essential concept of an activity to delve for a more detailed understanding by offering them additional learning opportunities, such as the activities listed in the student book under Further

Figure TR1.3 What the Teacher Does

Stage of the Instructional Model	What the Teacher Does	
	That Is **Consistent** with the BSCS 5E Model	That Is **Inconsistent** with the BSCS 5E Model
Engage	Creates interest Generates curiosity Raises questions Elicits responses that uncover what the students know or think about the concept/topic	Explains concepts Provides definitions and answers States conclusions Provides closure Lectures
Explore	Encourages the students to work together without direct instruction from the teacher Observes and listens to the students as they interact Asks probing questions to redirect the students' investigations when necessary Provides time for students to puzzle through problems Acts as a consultant for students	Provides answers Tells or explains how to work through the problem Provides closure Tells the students that they are wrong Gives information or facts that solve the problem Leads the students step-by-step to a solution
Explain	Encourages the students to explain concepts and definitions in their own words Asks for justification (evidence) and clarification from students Formally provides definitions, explanations, and new labels Uses students' previous experiences as the basis for explaining concepts	Accepts explanations that have no justification Neglects to solicit the students' explanations Introduces unrelated concepts or skills
Elaborate	Expects the students to use formal labels, definitions, and explanations provided previously Encourages the students to apply or extend the concepts and skills in new situations Reminds the students of alternative explanations Refers the students to existing data and evidence and asks: What do you already know? Why do you think . . .? (strategies from explore apply here also)	Provides definitive answers Tells the students that they are wrong Lectures Leads students step-by-step to a solution Explains how to work through the problem

Figure TR1.3 What the Teacher Does *(continued)*

Stage of the Instructional Model	What the Teacher Does That Is **Consistent** with the BSCS 5E Model	What the Teacher Does That Is **Inconsistent** with the BSCS 5E Model
Evaluate	Observes the students as they apply new concepts and skills Assesses students' knowledge and/or skills Looks for evidence that the students have changed their thinking or behaviors Allows students to assess their own learning and group-process skills Asks open-ended questions, such as Why do you think . . .? What evidence do you have? What do you know about x? How would you explain x?	Tests vocabulary words, terms, and isolated facts Introduces new ideas or concepts Creates ambiguity Promotes open-ended discussion unrelated to the concept or skill

Figure TR1.4 What the Student Does

Stage of the Instructional Model	What the Student Does That Is **Consistent** with the BSCS 5E Model	What the Student Does That Is **Inconsistent** with the BSCS 5E Model
Engage	Asks questions, such as Why did this happen? What do I already know about this? Shows interest in the topic	Asks for the "right" answer Offers the "right" answer Insists on answers or explanations Seeks one solution
Explore	Thinks freely, but within the limits of the activity Test predictions and hypotheses Forms new predictions and hypotheses Tries alternatives and discusses them with others Records observations and ideas Suspends judgment	Lets others do the thinking and exploring (passive involvement) Works quietly with little or no interaction with others (only appropriate when exploring ideas or feelings) "Plays around" indiscriminately with no goal in mind Stops with one solution

Figure TR1.4 What the Student Does *(continued)*

<table>
<tr><th rowspan="2">Stage of the Instructional Model</th><th colspan="2">What the Student Does</th></tr>
<tr><th>That Is Consistent with the BSCS 5E Model</th><th>That Is Inconsistent with the BSCS 5E Model</th></tr>
<tr><td>Explain</td><td>Explains possible solutions or answers to others
Listens critically to others’ explanations
Questions one another’s explanations
Listens to and tries to comprehend explanations the teacher offers
Refers to previous activities
Uses recorded observations in explanations</td><td>Proposes explanations from “thin air” with no relationship to previous experiences
Brings up irrelevant experiences and examples
Accepts explanations without justification
Does not attend to other plausible explanations</td></tr>
<tr><td>Elaborate</td><td>Applies new labels, definitions, explanations, and skills in new but similar situations
Uses previous information to ask questions, propose solutions, make decisions, design experiments
Draws reasonable conclusions from evidence
Records observations and explanations
Checks for understanding among peers</td><td>“Plays around” with no goal in mind
Ignores previous information or evidence
Draws conclusions from “thin air”
Uses only those labels that the teacher provided</td></tr>
<tr><td>Evaluate</td><td>Answers open-ended questions by using observations, evidence, and previously accepted explanations
Demonstrates an understanding or knowledge of the concept or skill
Evaluates his or her own progress and knowledge
Asks related questions that would encourage future investigations</td><td>Draws conclusions without using evidence or previously accepted explanations
Offers only yes or no answers and memorized definitions or explanations
Fails to express satisfactory explanations in his or her own words
Introduces new, irrelevant topics</td></tr>
</table>

Challenges, the optional activities in Section 5 of the *Teacher Resources*, and the activities listed in the teacher wraparound edition under the heading of Extensions. Other students may continue to work on the basic concepts until they achieve a firm understanding.

In this curriculum, each activity focuses on one or two particular phases of the model. Thus, if you modify or add new activities, be sure to maintain the phase or phases of the instructional model addressed in the original activity.

B. Incorporating Learning Strategies into Instruction

The old view of education was that children needed the basic skills of reading, writing, and arithmetic and enough extra knowledge (facts) to function in a largely factory-based job market. In today's world, with the volume of information doubling every few years, the role of education has changed. The developing consensus among educators is that today education must focus on developing students' learning and critical-thinking skills so they can access, interpret, analyze, and use information to make informed decisions. Critical thinking includes the skills of reasoning, questioning, and problem solving. It also involves knowing how to acquire further knowledge and understanding, knowing what to do with ideas, and knowing how subject matter is organized (Perkins, 1992). Perkins rightly argues that thinking-centered skills are crucial to all aspects of life.

If we expect students to be able to think and use knowledge when they leave school, learning strategies and critical thinking must be modeled and practiced throughout a student's school career. Both learning strategies and critical thinking are important overarching components of the BSCS 5E instructional model, and they are extensively incorporated into activities in this program. Recent research has revealed ways to foster learning and critical thinking with specific strategies. Below, we provide a short explanation of each major learning strategy embedded in the program. To learn more about implementing these learning strategies with your students, please read the Appendix B *How To* guides.

Chapter Organizers. Knowledge is more coherent if it is organized. Organized knowledge gives students a sense of the big picture. And having a big-picture view of knowledge leads to more-enduring understanding.

Often, though, it is difficult for students to see the overall organization of knowledge in a unit or chapter, especially at a glance. This program provides one-page graphic organizers for each chapter. These charts use graphic design principles to map the connections among activities and concepts. Each chapter organizer helps students see the flow of activities in a chapter within the context of important concepts. Progress from one activity to another occurs through the use of linking questions. Thus, chapter organizers use questions to drive students' construction of the big picture—the contextualized set of conceptual relationships inherent in a topic.

Both the student book and teacher wraparound edition have chapter organizers. As you might expect, the chapter organizers in the teacher wraparound edition have planning features included on the charts to help you document your progress through the unit and plan the amount of time you spend in each unit.

Literacy Strategies. Much of what students learn comes in the form of printed text or graphical images such as charts, tables, graphs, and diagrams. A literate student moves fluidly among these forms of information, acquiring, interpreting, and applying knowledge. Few students are born with this level of literacy. They must be taught literacy strategies explicitly (Thier & Daviss, 2002). This program includes research-based, effective literacy strategies in the day-to-day progress through each chapter. You'll better recognize each strategy and be able to use them more effectively if you read an overview of each one before lessons begin. The literacy strategies most frequently used in *BSCS Biology: A Human Approach* are talking with partners, Think-Share-Advise-Revise (TSAR), organizing tables, Venn diagrams, concept maps, and highlight comments and captions.

Talking Strategies. Talking about what you read helps you *understand* what you read (Rosenshine & Meister, 1994; Lemke, 1990). That is because reading involves input, and speaking involves generating (Wittrock, 1990). When we generate sentences in speech, we reconfigure knowledge based on its meaning to us. Other people listen to what we say and give us feedback on whether our explanations make sense. That feedback tells us if we need to reread or rethink. This back-and-forth process is essential to constructing understanding (Vygotsky, 1962).

This program frequently asks students to read a passage or view a graph, then talk to a classmate about the reading or graph. As you would expect, the rules of discussion are explicit and aimed at improving students' ability to acquire, interpret, and apply written and graphical information. You will see these discussion strategies as part of every aspect of activities including laboratory work, text questions, and team projects. These strategies form a major component of the collaborative learning strategies integral to this program.

One specific example of a talking strategy is called Think-Share-Advise-Revise, or TSAR for short. In this strategy students think about questions or problems posed by readings or activities, share their thoughts, advise each other on ways to improve solutions, then revise their original answers based on feedback.

In this program, we also invite students to become absorbed in extended dialogues about things that matter to them (Lipman, 1991). Such dialogues promote critical thinking to the degree that they tend to be complex, tend to unify ideas, and use evidence to support ideas. This curriculum offers you and your students frequent opportunities to develop dialogues during team and class discussions. Some of the discussions are in contexts that matter to students personally, such as issues of teenage risk, and others are in contexts that allow them to seek complex connections to earlier understandings.

Organizing Tables. Organizing and relating information helps readers form coherent meaning from text materials (Fisher, Frey, & Williams, 2002). For example, when students read an essay in Chapter 1 about the brain, they read many new words. In that activity, they are directed to start a specific type of organizing table, called a Personal Glossary, that helps students pinpoint what terms are new to them then connect it to the essential meaning. Using many types of organizing tables, students learn to parse text materials into important relationships. Students represent these relationships in the horizontal rows of a table. Further, vertical organization can show a hierarchy of ideas—what is most important and why. Often a third column allows students to keep track of questions they have from readings. Used in conjunction with talking strategies, organizing tables consistently increase students' ability to learn from text-based material (Block & Pressley, 2002). A variety of table types are put to use in this program: reading comprehension, prereading, analogy mapping, similarities and differences, and observation and interpretation.

Venn Diagrams and Concept Maps. Other types of spatial organization of text-based information also enhance student literacy. Venn diagrams are particularly effective at helping students sort ideas presented in readings into shared features and distinctive features (Moore, 2003). Such contrasts form the basis for students' association of concepts into a coherent mental structure that is consistent with experts in a field (Bromley, 1999). For example, in Chapter 10 students use a Venn diagram to express similarities and differences among human male and female reproductive systems.

Concept maps prompt students to arrange ideas from a reading passage or series of activities in a way to convey the most important concepts and how closely the concepts are related. This exercise helps students develop a sense of the big ideas in science—the ones that have the greatest explanatory power and form the foundation for future learning. Also, concept maps help teachers assess what kind of changes might be occurring in students' minds as a result of instruction. This is true since experts in a field tend to have similar concept maps. Thus, a teacher can monitor how closely related are student and expert concept maps. Combined with talking techniques, these literacy strategies help students distinguish one concept from another and place science concepts into a meaningful conceptual framework. When students' conceptual framework is more like experts', they tend to place important science content into long-term memory more successfully and are able to access and utilize that content information.

Highlight Comments and Captions. Graphs, tables, charts, and diagrams are not always easy for students to interpret. Explicit strategies to include these forms of information can help broaden students' scientific literacy. Highlight comments and captions represent two such strategies.

This program regularly asks students to interpret information from graphs and charts by answering two highlight questions: What do I see? and What does it mean? Students answer these questions *on their graphs* near a trend line or key information. In this way, students make physical and conceptual connections between graphical information and interpretation (Sweller, 1988). They accomplish this by linking highlight comments to graphical information, thus building cause-and-effect relationships. From these relationships, they are able to construct a meaningful caption.

For example, in chapter 2 students analyze graphs showing changes in the size of finches' beaks over time. Students generate highlight comments to make sense of finch populations' beak size in two different years of data collection. From their highlight comments, they write a caption of explanation and place it under their graph.

Captions help students assemble highlight comments into a coherent, short paragraph that explains what is important in the figure. In effect, the combination of highlight comments and captions is a reverse literacy strategy compared to organizing tables. That is, with organizing tables, students reconfigure what they know from text into organized structures or tables; with highlight comments and captions, students generate meaning by shifting from dimensional structures (graphs, charts, and tables) to text. The built-in back-and-forth process among these various strategies makes for more literate, intellectually flexible students.

Observation Skills. It is difficult for teachers to help students construct meaningful understandings and explanations if students do not have appropriate observation skills. Too often, students write down what they are *supposed* to see or simply do not notice the same things teachers notice. This program helps you teach students how to make accurate and meaningful observations from which they can draw well-reasoned conclusions.

A blend of sketching, writing, and designing data tables forms the foundation for collecting interpretable observations. Most science teachers are familiar with students placing experimental results in data table handouts. This program emphasizes students' *design* of data tables in collaborative teams. When students consider the format in which to record data *ahead* of data collection, they consider relationships among key experimental variables. Student-designed data tables precondition their minds for meaningful interpretations much the same way prereading does for reading comprehension.

Our experiences suggest that students who sketch and annotate their sketches make better observations. But many students don't do this unless given explicit instructions on when and how. Built into this program are *when* and *how*. For example, in chapter 8, we ask students to generate labeled diagrams of how a radio-labeled carbon atom would move from the atmosphere into a protein in a human arm muscle. Diagram labels serve a similar purpose to highlight comments in graphs and charts. They connect linguistic and spatial representations of knowledge to form a stronger memory input. When combined with talking strategies, these methods for improving observation skills increase the quality and meaningfulness of students' observations.

Metacognition Strategies. A hallmark of experts in a field is the way they monitor their own thinking—metacognition (Bransford, Brown, & Cocking, 2000). As noted by Beyer, "Thinking becomes more effective and efficient when we think about how we are thinking as we think!" (1987). Novices spend a lot of time guessing and checking. Experts use a *sense-making* feedback loop among observations, explanations, and new problems. Experts recognize when they don't know, and they understand what to do about it. As a result, they spend less time solving more problems. Several strategies work together to foster increased metacognitive capacity in students. You will notice a number of questions in the student book that ask students to explicitly reflect on their thinking or their prior work. This program also integrates two other strategies into activities: the student science notebook and multiple forms of representation.

Science Notebooks. Students use their science notebooks to increase their scientific literacy by recording the results of conversations about text readings, charts, graphs, activity experiences, text questions, and teacher demonstrations. Each literacy strategy depends on students' mindful reflection on each task and their record of the process. Science notebooks provide that record.

Science notebooks represent important evidence that you use to assess students' ongoing growth. Without this record, you're forced to use anecdote and impression to substantiate student metacognitive gains. The record of ongoing student thinking helps you pinpoint specific problem areas that might otherwise go undiagnosed. For example, students having difficulty with a reading about nucleic acids might not be able to construct a meaningful organizing table contrasting DNA and RNA, even after collaborative discussions. A quick walk around the room lets you identify these students *before* a major test. Student science notebooks enable you to conduct *formative assessments* of the dynamic changes inherent in each student's daily learning.

Multiple Forms of Representation. Not every student sees things the same way (Gardner, 1983; Eisner, 1982). We don't expect them to. But we do expect them to see the value of looking at ideas and concepts from multiple perspectives. It is a natural part of building a rich context around anything new. To encourage this, we help students learn from multiple perspectives.

Broadly, there are four ways to represent knowledge commonly encountered in school: linguistic, mathematical and logical, spatial, and performance. Students construct knowledge in these forms during activities such as investigations, readings, mathematical exercises, graph generation, and authentic assessments. They also encounter knowledge in these forms throughout the text. As they assimilate and process these experiences, they continue to construct a deeper understanding. Then students show what they know by representing knowledge in one of these forms.

Any overemphasis on one form over the other produces students with a narrow perspective on knowledge. Such narrowness limits students' ability to solve authentic problems, the ones they find in an increasingly complex work world. For example, a student who is asked to explain how populations grow when resources are unlimited might fail if he were to forget the only he represented this relationship, with a formula for exponential growth. But the student who could sketch a graph *and* include highlight comments with a caption (not necessarily with numbers) could pass even though she or he had no equation.

Good problem solvers exhibit a balanced ability to represent what they know (Eisner, 1982). That ability in turn leads to increased problem-solving capacity and transfer. On an ongoing basis, this program requires students to draw, sketch, chart, and *do* science in equal proportions to writing, formulating, and speaking. Moreover, it helps students connect the meaning of these multiple forms of representation into a coherent conceptual framework. That framework results in students with the intellectual flexibility requisite to solving today's problems.

Questioning Strategies. In addition to engaging students in these learning and critical thinking strategies, look for opportunities to use other teaching strategies that enhance constructivist learning and critical thinking. Teachers can make a major contribution to the learning environment by adopting research-based questioning strategies. Such strategies include using probing and open-ended questions and stimulating discussions. Remember, asking more questions and giving fewer answers is the fundamental nature of teaching for understanding. Students must be challenged continually to think about what they are seeing and doing and to seriously examine their present understandings.

During discussions, frame questions that provoke thoughtfulness in students. Avoid asking questions that can be answered in one or two words. When students give you such answers, encourage them to justify their answers; often a student can come up with the right answer but for the wrong reason. Ask them to provide examples that support their answers.

Try to ask questions that reflect on complex issues and have no simple answers. Let students debate among themselves as they try to respond to these questions. Challenge students to make connections between what they are doing in biology class and how it applies to other classes and to other aspects of their lives.

Figure TR1.5 Guidelines for Asking Effective Questions

The Teacher should:	The Teacher should not:
• prepare five or six pivotal questions for each class meeting • ask questions that are stimulating • ask questions that are appropriate for the students' abilities • ask questions that are personal and relevant to students • vary the length and difficulty of questions • ask questions that are clear and straightforward • encourage learners to ask questions of each other and to make comments • allow sufficient time for deliberation; include "wait time" of at least 10 seconds before having a student answer a question or rephrasing a question • follow up on incorrect answers; probe the learner's thinking to reveal possible misconceptions • follow up on correct answers; use a correct answer as a lead to another question • call on nonvolunteers as well as volunteers • move around the room while questioning students	• use yes or no questions or questions that allow a limited response; example: Are monkeys in the same taxonomic order as humans? What are the products of photosynthesis? If you find yourself asking this type of question, follow up with questions such as Why? or How? • use vague questions; for example: How does evolution relate to genetics? • ask suggestive or leading questions; example: Why is the population explosion such a threat to the earth's ecology? The question really calls for an opinion, but the answer is already stated. • ask "tugging" questions; example: What else? Who else? • call the name of the pupil before asking the question. This creates a situation in which one student is set up for failure or success and the remaining students can relax because they have been excluded from the exchange. • answer student-generated questions that learners should know; an appropriate response would be, Who can answer that question? • limit discussion to bright students or volunteers; if most of the discussion centers around a few students, the rest of the class will not be learning.

When a student asks you a question, resist the temptation to give the quick, knowledgeable answer. Instead, invite other students to help answer the question or try turning the question back to the inquirer. Use phrases such as, How could you find out more about that? or What do you already know that can help you answer that question? or How does what you know about xyz help you answer your question about abc? **Figure TR1.5** provides additional suggestions for promoting critical thinking in your classroom (adapted from Ornstein, 1988).

A simple way to assess your daily progress in implementing the 5Es and learning strategies embedded in *BSCS Biology: A Human Approach* is to refer to the actions listed in **figures TR1.3** and **TR1.4**. After each activity, do a quick check to determine whether you focused your instruction on the appropriate E and whether your students reached the intended outcomes of the activity (as stated in the teacher's edition). If not, you may wish to return to the activity the next time you meet and focus the students specifically on the major concepts and understandings.

Monitor the types of questions you are asking during class and team discussions. Try to increase the number of thought-provoking questions that you ask. Use **figure TR1.5** as a quick check. If you find yourself consistently following some of the "Don'ts" from the table, make a conscious effort to change one habit over the course of a week of classes. After each chapter, monitor your progress on the implementation charts for the BSCS 5E instructional model and for discussions (**figures TR1.6** and **TR1.7**).

Figure TR1.6 **Implementation Continuum for the BSCS 5E Instructional model for *BSCS Biology: A Human Approach***

No Implementation of Instructional Model	Beginning Implementation of Instructional Model	Partial Implementation of Instructional Model	Full Implementation of Instructional Model
The teacher ignores the 5E strategies in teacher's edition	The teacher uses some of the 5E strategies in the teacher's edition	The teacher uses the 5E strategies described in the teacher's edition. The teacher and students use the 5Es to describe lessons.	The teacher uses the 5E strategies described in the teacher's edition and uses the 5Es to organize extensions, daily lessons, new units, and non-program-specific activities.
Lecture is a common teaching strategy.	The teacher leads discussion in directions related to key ideas.	The teacher leads discussion in directions related to key ideas. The teacher asks questions of students as they are working.	Student discussions and explanations dominate class discussions.
The teacher tells students they are wrong and provides the right answer.	The teacher allows students to explore concepts but introduces additional concepts and skills before the elaborate phase.	The teacher allows students to explore key concepts and eventually to construct explanations of the concepts. Elaborations often are omitted.	The teacher allows students to explore key concepts and construct explanations of the basic concepts. Only then does the teacher introduce related concepts and skills for students to elaborate on their experiences.
The teacher leads students through investigations step-by-step.	The teacher directs most instructional activities but attempts to incorporate some student-centered strategies from the teacher's edition.	The teacher guides students and encourages them to rely on prior experience and data to make connections during lessons.	The teacher acts as facilitator.
Students follow the teacher's instructions but do not initiate questions, explanations, or solutions. Students seek "right" answers.	Students occasionally initiate questions or explanations but do not generate multiple solutions to questions. Students still seek "right" answers.	Students listen to the teacher's and peers' explanations critically. Students ask relevant questions that would imply future investigations.	Students are actively engaged in the pursuit of science.

Figure TR1.6 **Implementation Continuum for the BSCS 5E Instructional model for *BSCS Biology: A Human Approach (continued)***

No Implementation of Instructional Model	Beginning Implementation of Instructional Model	Partial Implementation of Instructional Model	Full Implementation of Instructional Model
The teacher creates tests with a majority of recall items.	The teacher uses assessment strategies as they are laid out in the teacher's edition but does not regularly use evaluate activities.	The teacher uses evaluate activities in addition to assessment strategies laid out in the teacher's edition.	The teacher seeks opportunities for embedded assessments beyond those specifically identified in the teacher's edition. Evaluate activities, portfolios, and science notebooks are featured prominently in student assessment and as a means for determining grades.

Figure TR1.7 **Implementation Continuum for Discussions in *BSCS Biology: A Human Approach***

No Implementation of Discussion	Beginning Implementation of Discussion	Partial Implementation of Discussion	Full Implementation of Discussion
Students work in teams with little sharing.	Students are encouraged to share their perceptions and observations with their teammates.	Students are encouraged to share their perceptions and observations within their teams.	Students begin lessons with the teacher or a learner posing a question.
There is little or no whole-class discussion.	There are seldom class discussions.	Brief class discussions are held at the end of a lesson.	Most lessons end with a class discussion in which students and teams share their perceptions and observations.
Most verbal exchanges in class are initiated by the teacher asking recall questions or explaining procedural problems.	Verbal exchanges include teacher-directed discussions in which students gain additional information from the teacher. These exchanges may be initiated by either the teacher or the students.	The teacher uses discussion as a way for the class to come to a consensus regarding what happened or what can be concluded from the lesson.	Discussions take the form of questions that solicit learner opinion and thought. Teacher and students often pursue a satisfying answer that neither possesses.

C. Assessment

Assessment refers to the process of collecting data about what the students know, understand, and are able to do. Data from a systematic assessment protocol should be analyzed and used to evaluate students periodically (summative assessment) and to modify instruction (formative assessment). The results of these evaluations then are reflected in student report cards and in changes in teaching strategies.

BSCS's Approach to Assessment in This Program

Students rightly interpret assessments as reflecting those things that the teacher or school considers most important to learn. Thus, if the assessments primarily emphasize recall of facts, students will try to remember facts. Alternatively, if the assessments emphasize conceptual understanding, reasoning, and inquiry, students will strive to master those tasks. Just as this curriculum promotes new emphases on what students should know, understand, and be able to do, our classroom assessments also reflect these new values.

In *BSCS Biology: A Human Approach*, we regard assessment as a process that should be ongoing throughout the program rather than a separate process that happens only at the end of a chapter or unit. When successfully implemented, the boundaries between assessment and instruction should blur so thoroughly that it is difficult to distinguish between the two.

We have developed an assessment package that presents the students with opportunities to apply what they have learned to situations that have meaning for them and to situations that they are likely to encounter in the world. In many cases, we have provided assessments that reflect the nature of science and the work that scientists do.

The assessments in this program also help students become more responsible for their own learning, and to some extent, that of their classmates. You will find opportunities for both individual and collaborative assessments. Collaborative assessments are included because collaborative learning complements our approach to assessment and promotes the skills necessary for reflective self-assessment as well as peer assessment.

One of the goals of *BSCS Biology: A Human Approach* is to develop a curriculum that is appropriate for all students; this applies to assessment as well. To accomplish this goal, we have included a variety and a balance of assessment strategies that represent alternatives to traditional tests and meet the varied strengths of students. The following assessment elements are integrated into *BSCS Biology: A Human Approach*.

- Embedded Assessment Opportunities
- Outcomes and Indicators of Success
- Evaluate Activities
- Model Chapter Assessment
- Unit Assessments
- Portfolio Option
- Evaluate Section

Using Alternative Assessment in Your Classroom

Implementation of alternative assessment needs to be a multistage process that coincides with your own professional development. Seek out literature regarding alternative and authentic assessment so that you can become more familiar with assessment theory, concerns that need to be addressed when developing assessments, and different models that can be used for assessing. Also, look for inservice workshops on assessment. If you cannot find local workshops, look for detailed guides that you can work through with your colleagues. (Refer to the following two references in Section

1.7 *Bibliography*: McCloskey and O'Sullivan, 1995, and Regional Educational Laboratory Network Program, 1994.) Focus your literature review and inservice training on what you need to do to design good assessments. If you are having problems getting started, try some of the following (McCloskey and O'Sullivan, 1995):

- For a given activity, articulate one very important desired student outcome.
- Draft a document for students that outlines the major chapter or unit goals you have for their performance and how their performance on these goals will be assessed.
- Develop a protocol for expanding the assessment tools you use, giving weight to each type of assessment tool.
- Keep a folder of assessment ideas that you come across as you read, attend inservices, and talk to colleagues.

Use the implementation continuum chart for alternative assessment (**figure TR1.8**) as a guide to monitor your progress in implementing new assessment strategies.

Figure TR1.8 **Implementation Continuum for Embedded, Alternative Assessment Strategies for *BSCS Biology: A Human Approach***

No Implementation of Assessment Strategies	Beginning Implementation of Assessment Strategies	Partial Implementation of Assessment Strategies	Full Implementation of Assessment Strategies
The teacher uses unit examinations as the only form of assessment. Examination questions tend to emphasize recall of factual information.	The teacher uses unit and chapter examinations as one of several forms of assessment. A few examination questions require students to analyze and evaluate data.	The teacher uses unit examinations as one form of assessment. Examinations include questions that require students to analyze and evaluate data and draw conclusions.	Assessment is an ongoing process. The teacher uses a wide array of tools to assess the students' skills and knowledge. The teacher assigns assessment tasks that require several days to complete.
Students do not use journals.	Students use journals during lectures to take notes.	Students use journals during investigations.	Students use journals daily and record a variety of types of information, including data, notes, and reflections.
The teacher relies heavily on test scores to assign grades.	The teacher assigns one or two long-term projects. Project grades are used in addition to test scores when assigning grades.	The teacher assigns at least one long-term project during the year. The teacher encourages the students to demonstrate their knowledge and skills with a variety of media. Grades are based on a combination of test scores, hands-on performance tasks, and long-term projects.	Students are allowed to demonstrate their knowledge with a variety of media (for example, drama, creative writing, debates, reports, posters). Grades reflect a balance of entries in many categories.

Figure TR1.8 **Implementation Continuum for Embedded, Alternative Assessment Strategies for *BSCS Biology: A Human Approach (continued)***

No Implementation of Assessment Strategies	Beginning Implementation of Assessment Strategies	Partial Implementation of Assessment Strategies	Full Implementation of Assessment Strategies
The teacher does not refer to the activities' outcomes and indicators.	The teacher occasionally uses the activities' outcomes and indicators as a guide for focusing activities.	The teacher frequently uses the activities' outcomes and indicators as a guide for focusing activities. The outcomes and indicators also are used occasionally as a tool for developing assessment strategies and informally assessing learner understanding.	The teacher routinely uses the activities' outcomes and indicators as a guide for focusing activities as well as a tool for developing assessment strategies and informally assessing learner understanding.
Assessment tools are completely objective.	Assessment tools require a paper-and-pencil strategy.	The teacher uses one or two hands-on performance tasks.	The teacher uses numerous hands-on performance tasks that require both group and individual effort.

D. Science as Inquiry

Using inquiry to teach science is a powerful way to promote conceptual learning. When implemented skillfully, inquiries result in deep understandings of concepts, and students use these understandings to develop mental frameworks for organizing and applying factual knowledge. Inquiry complements constructivism and the BSCS 5E instructional model by allowing students to develop their own understandings, and it allows for ample opportunities to assess students' thinking skills. Inquiry activities require students to manipulate materials and think critically about what they are doing. Students often become enthusiastic about these investigations because they perceive that they are doing real science.

Inquiry learning is highly student-centered, with the teacher acting as a coach or facilitator. If you find yourself consistently in charge of what occurs during inquiry activities, students are not likely receiving all the benefits of inquiry-based instruction. It often takes several years for teachers to transition to a style that is fully inquiry oriented. Reflecting on your daily practice and seeking support from colleagues over this time can help you to implement this innovation properly.

To inquire means to ask about or to investigate something. Use this definition as the primary focus of all your inquiry-based instruction. Constantly ask questions and encourage your students to seek answers. Reinforce the use of scientific attitudes such as seeking evidence for explanations, considering alternative ideas, and avoiding personal bias. Encourage students to question their own inferences, teammates' responses, and experimental results. Also, encourage them to be precise in their measurements and in their responses to questions.

Although inquiry can involve any number of processes that involve asking questions and seeking answers, most formal science inquiries focus on a few common processes. Students are exposed to these processes through the first three units, with certain activities focusing on one or a small number of processes until the students develop some expertise with them. Gradually, the students develop their abilities with all of the processes of scientific inquiry. The order in which we present these steps is shown in **figure TR1.9**.

Figure TR1.9 Processes Involved in Science as Inquiry

Processes Involved in Science as Inquiry
• Make observations and comparisons of natural phenomena.
• Ask a question that is testable.
• Formulate a tentative explanation, or hypothesis, that could answer the question.
• Gather information about the question/hypothesis.
• Design a controlled experiment to test the hypothesis.
• Carry out an experiment with controls and careful collection of data.
• Use data to formulate an explanation supported by evidence and reasoning.
• Draw conclusions supported by the data and based on other biological knowledge. Assess the hypothesis.
• Communicate the results and conclusions, including connections to other aspects of biology and science.

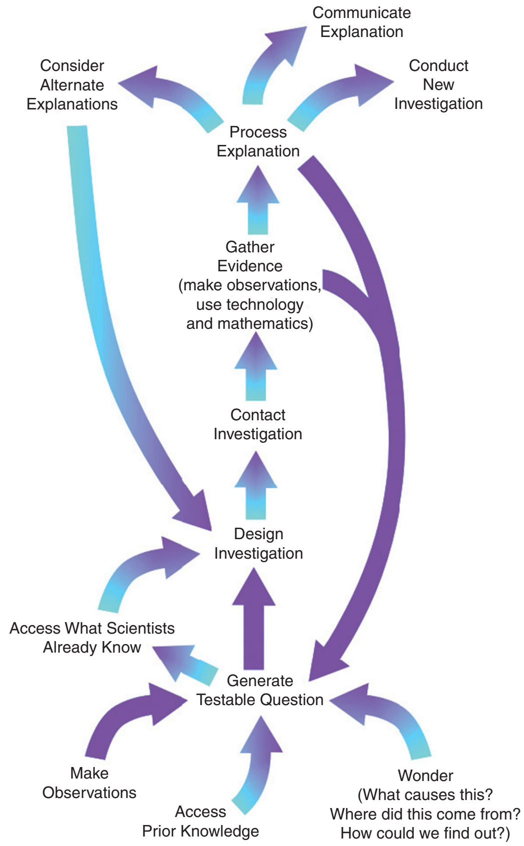
Of course, in many scientific investigations these processes do not flow in exactly this order or include all of these processes. For example, not all scientific studies involve controlled experimentation; many involve seeking patterns in observational data. Furthermore, in many activities *in BSCS Biology: A Human Approach*, students focus on only one or two of these processes. For these reasons, students frequently reflect on their inquiry experiences with the help of the Scientific Inquiry Diagram (**figure TR1.10**). Such reflection helps students develop perspective on the complex, flexible, and creative process of scientific inquiry.

The inquiry skills for each activity in this program are identified in the implementation charts in the teacher's edition. Early inquiries are more structured than later ones, allowing you and the students to focus sequentially on only a few of the steps outlined above. As you move through the chapters in order, you will notice that the inquiries become more open-ended and that the number of inquiry steps that students must complete on their own increases. Students are given frequent opportunities to design and conduct their own experiments. To emphasize the thinking aspect of experimental design, we treat technical aspects of laboratory work as Protocols. These Protocols give students some guidance for working in the lab, but do not constitute a full experimental procedure. Actually conducting experiments requires that the students design controls, data tables, and make choices about how to collect data. By the end of Unit 3, the students will have practiced using all of the steps of scientific inquiry. They then have the opportunity to complete the Explain section, in which they design and carry out an independent full inquiry, which may last several months and will allow you to assess all of the inquiry skills. If your school or district encourages or requires students to participate in local science fairs, the Explain section can be used to structure student science fair projects.

It is important that you continually reinforce and assess students as they undertake each step of the inquiry process. As the students formulate their questions and hypotheses, actively encourage them to use a wide range of resources beyond those found in this curriculum, such as libraries, local science-related organizations (for example, museums), and experts within the community. As students inquire, ask probing questions that will help you determine whether the student understands what he or she is doing during the process and why. Encourage students to be precise in their data collection. Promote critical thinking by framing your questions in such a way that students need to give reasons for what they are doing.

As students discuss results and conclusions, ask questions that require students to support ideas with evidence and push them to consider alternative explanations. Model the attitudes of science,

Figure TR1.10 **The Scientific Inquiry Diagram can Help Students Reflect on their Inquiry Experiences**



such as avoiding personal bias, considering all evidence, critically evaluating peers' work, and considering science to be a fluid, ever-developing body of knowledge. Encourage students to be precise in their explanations. Reassure students that it is all right to have experimental failures. Scientists can learn more from experiments that disprove an initial hypothesis than from experiments that confirm a hypothesis.

You can use the outline of the steps we recommend for the formal inquiries in the Explain Section (also refer to **figure TR1.9**) as a way to assess your progress in guiding students to become scientific inquirers. Students should gradually use more of these steps without direct guidance from you. Over time, much of what occurs during formal inquiries should be directed by individual student teams rather than by you. Discussions, whether they occur in teams or as a class, should become more thoughtful, with students making a conscious effort to justify their statements. Use the implementation continuum charts for *Science as Inquiry* (**figure TR1.11**) and implementation of student-centered learning (**figure TR1.12**) to help you assess your progress in implementing this innovation. Finally, check to see how closely you fit the following description taken from the first draft of the *National Science Education Standards* (National Research Council, 1994):

Teachers of science … support inquiries as they

- interact with their students.
- orchestrate discourse among students about scientific ideas.
- challenge students to take responsibility for their own learning and to work collaboratively.
- recognize and respond to student diversity and encourage all students to participate fully in science learning.
- encourage and model the skills of scientific inquiry as well as the curiosity, openness to new ideas, and skepticism that characterize science.

Figure TR1.11 Implementation Continuum for Science as Inquiry for *BSCS Biology: A Human Approach*

No Implementation of Science as Inquiry	Beginning Implementation of Science as Inquiry	Partial Implementation of Science as Inquiry	Full Implementation of Science as Inquiry
Students seldom conduct science investigations.	Students occasionally conduct investigations on questions defined by the teacher or the text.	Students frequently conduct investigations on testable questions they designed; questions frequently are not well defined.	Students frequently conduct investigations on well-defined testable questions of their own design.
Experiments in text are replaced by less open-ended activities in which students can predict the outcome without doing the experiment. Experimental procedures are not distinguished from true inquiry and are given to students by the teacher or the text.	Experimental procedures still are not distinguished from investigations and are given to students by the teacher or the text.	Students begin to design their own investigations and use available experimental procedures. Not all variables are controlled.	Students design their own investigations. They design their own experimental procedures or modify procedures that they have sought from other sources. All variables are controlled.
Students collect mostly qualitative measurements.	Students collect mostly qualitative measurements.	Students collect quantitative as well as qualitative measurements, but quantitative measurements often lack precision.	Students collect quantitative as well as qualitative measurements. Quantitative measurements are precise.
The teacher analyzes the data for the students.	Students do not analyze data well; students frequently are asked to recognize only general patterns.	Students analyze qualitative data for specific as well as general patterns. Quantitative data analysis frequently includes graphs. However, the type of graph used is not always the most appropriate to represent the data.	Students analyze qualitative data for specific as well as general patterns. Quantitative data analysis frequently includes graphs that are appropriate to represent the data. Statistical analyses may be used.
The teacher interprets data collected in the experiment.	Students do not interpret data in light of their original question.	Students interpret data in light of their original question but do not justify their ideas.	Students interpret data in light of their original question. They justify their interpretations using evidence to support inferences.

Figure TR1.11 **Implementation Continuum for Science as Inquiry for *BSCS Biology: A Human Approach* (continued)**

No Implementation of Science as Inquiry	Beginning Implementation of Science as Inquiry	Partial Implementation of Science as Inquiry	Full Implementation of Science as Inquiry
The teacher provides an explanation of the results.	Students develop a single explanation.	Students develop alternative explanations, but the explanations do not always adhere to the criteria of scientific explanations.	Students develop alternative explanations. Their explanations adhere to the criteria of scientific explanations.

Figure TR1.12 **Implementation Continuum for Student-centered Learning for *BSCS Biology: A Human Approach***

No Implementation of Student-centered Learning	Beginning Implementation of Student-centered Learning	Partial Implementation of Student-centered Learning	Full Implementation of Student-centered Learning
The teacher lectures and the students rarely pose questions. Most of the questions students do ask are logistical rather than inquisitive.	The teacher directs the students' progress through activities.	The teacher provides encouragement and suggestions for further inquiry but still is the primary director of the learning process.	The teacher is primarily a facilitator of learning while students determine the direction of their inquiries and other studies.
The teacher tends to use questions related to knowledge and comprehension to assess student understanding. Questions that synthesize or evaluate student understanding are asked infrequently.	The teacher frequently poses both knowledge (recall) questions and application or analysis questions to the students.	The teacher frequently poses both recall and application or analysis questions to the students. Students occasionally ask reflective questions.	Students frequently pose reflective questions. Questions in general tend to focus on higher-order thinking (application, analysis, evaluation).
The teacher's actions encourage students to rely on the teacher as their primary source of information. The teacher makes most decisions about what the students will study and how the information will be presented.	The teacher provides students with limited opportunities to decide what they want to pursue in more depth.	Students are encouraged to take more responsibility for their own learning.	Students initiate projects and take responsibility for their own learning.

Figure TR1.12 **Implementation Continuum for Student-centered Learning for *BSCS Biology: A Human Approach (continued)***

No Implementation of Student-centered Learning	Beginning Implementation of Student-centered Learning	Partial Implementation of Student-centered Learning	Full Implementation of Student-centered Learning
The teacher never uses interactive teams for student learning.	The teacher infrequently asks the students to share information and ideas with each other.	Students often work in teams and are willing to share information and ideas.	Students share information and ideas with each other. Students often work in teams and each person contributes to the task.
*You should observe a shift from a teacher-centered environment to a student-centered environment as the school year progresses.			

E. Science and Humanity

Awareness of and sensitivity to opportunities to incorporate the various elements of Science and Humanity will take you a long way toward implementing this important subtheme of *BSCS Biology: A Human Approach*. We use this subtheme to make science approachable and relevant to the diverse range of students found in American schools today. Remember that students construct understandings based on their previous experiences. Thus, not only do you need to provide common experiences to the students, you also need to be aware of the range of experiences your students have had in the past. In this program, we characterize Science and Humanity subthemes as connections between biology and culture, technology as a way of adapting, connections between biology and ethics, and the history of science.

One way to become aware of students' experiences is to use the cultural emphasis in an activity as a lead-in to discuss related experiences that students have had in their individual cultures. Culture refers to a broad range of social interactions and customs including ethnic cultures, age cultures, economic cultures, neighborhood cultures, and gender-based cultures. Thus, during discussions of performance and fitness in Chapter 7 of the student book, you might ask students to compare how some of these different cultures might affect one's diet and the types of physical activities he or she undertakes. Activities in Chapter 1 and Chapter 14 allow a broad range of culture-based discussions.

Activities that incorporate the history of scientific discoveries, another element of the Science and Humanity subtheme, offer opportunities for students to examine the human component of science. Students can read about the events surrounding the development of major ideas and about the people involved in these events. Again, look for additional opportunities to reinforce this subtheme. For example, following the primate activities in Chapter 1, you might encourage students to view the movie *Gorillas in the Mist*, which is about the research of Dian Fossey, or read some of Jane Goodall's books. *The Double Helix*, a book that describes Watson and Crick's race to become the first to discover the structure of DNA, is relevant to Unit 4 and provides fascinating insight into how, for some scientists, ambition can override courtesy and even ethics. Examples such as these provide rich grounds for highly motivating discussions regarding the nature of science and scientists.

Many of these same enhancements offer sources of material for examining the remaining two elements of Science and Humanity: ethics and technology as a way of adapting. For example, how does one balance the rights of the people of Rwanda (where Dr. Fossey's work took place) to use the resources of the forests that are home to the mountain gorilla against the possible extinction of the gorillas? How did the discovery of DNA's structure change science technology and medicine, and consequently, modern human society? These topics stimulate the enthusiasm of students as they research and debate some of these questions.

To prepare to implement Science and Humanity, examine the implementation charts in the teacher's edition and determine which activities have a Science and Humanity emphasis. Spend some time thinking of ways to enhance this subtheme based on your students' experiences and interests. Make notes of discussion questions or extension activities you might use to enhance this theme. Use some of the strategies that we have outlined above.

If you feel that you are not able to give adequate attention to this innovation, consider asking interested students to take the responsibility for incorporating the subtheme into activities. For each chapter, you could assign pairs of students to each of the four aspects of this topic—culture, history of science, technology as a way of adapting, and ethics. It then would be the students' responsibility to make sure that these subjects were broached in class during the appropriate activities. In this way, you would again be encouraging students to become responsible for their own learning.

A simple way to assess your progress in implementing Science and Humanity is to monitor the level of student interest and excitement in your classroom. To assess your implementation progress more rigorously, refer frequently to the implementation continuum chart in **figure TR1.13**.

F. Collaborative Learning

We have structured many activities in *BSCS Biology: A Human Approach* in ways that make it easy for students to use collaborative learning to complete the activities. Our model of collaborative learning is based primarily on the cooperative learning model of Johnson, Johnson, and Holubec (1986). For in-depth background about and strategies for implementing collaborative learning, please read section 2 of the *Teacher Resources*, *A Guide to Collaborative Learning*. Core ideas about implementing collaborative learning are summarized below.

One of the keys to making collaborative learning a highly successful strategy is to apply two factors consistently: a defined team goal and individual accountability. If these two elements are not present, the effectiveness of collaborative learning will greatly diminish. In fact, the students would be working in groups, not collaborative teams. To implement collaborative learning fully, we include the following list of elements essential to collaborative learning and a brief definition of each:

- **Use of roles**—all team members have a distinct and useful responsibility to the team in any given collaborative activity.
- **Heterogeneous grouping**—the students work with people who they would not necessarily choose as teammates or who may differ from themselves in learning style, background, or ability.
- **Group autonomy**—the team looks to its members rather than to the teacher to answer questions or solve problems that arise.
- **Positive interdependence**—the members of a team must rely on each other for critical pieces of information or to accomplish crucial jobs to finish a given assignment.
- **Use of working relationship skills**—the students learn how to cooperate, how to work with other people who might be completely different, and how to manage their teams.
- **Distributed leadership**—all students have the opportunity to function in some type of leadership capacity, thus calling on untapped strengths and talents.
- **Individual accountability**—each team member is held responsible for knowing all aspects of the lesson or activity that the team completed.
- **Team self-evaluation**—the team members evaluate themselves on their use of collaborative learning skills.

Figure TR1.13 Implementation Continuum for Science and Humanity in *BSCS Biology: A Human Approach*

No Implementation of Science and Humanity	Beginning Implementation of Science and Humanity	Partial Implementation of Science and Humanity	Full Implementation of Science and Humanity
The teacher makes occasional reference to how biology is applicable to students' daily lives.	The teacher makes frequent reference to how biology is applicable to students' daily lives.	The teacher makes reference whenever possible to how biology is applicable to students' daily lives. The teacher involves students in coming up with examples.	Students recognize on their own that biology is applicable to their daily lives and relevance is an integral focus of instruction. Students independently offer examples.
Technology as a way of adapting, culture, and history of biology are not part of the biology program.	Examination of technology as a way that humans adapt is part of instruction. Occasional historical vignettes and culture-related activities are included.	Technology in human society, culture, and history of science are addressed at the level they are included in the program. No particular emphasis is given to these threads.	Technology, culture, and history of science are freely incorporated into instruction. The teacher actively seeks opportunities to enhance those threads.
Ethical questions are avoided.	Ethical questions are acknowledged but not discussed.	Ethical questions related to biology are introduced by the teacher and students but are discussed only superficially.	Ethical questions are introduced by the teacher and students and are examined in depth.
Students see no connection between science and culture.	Students realize that science takes place within a culture.	Students not only realize that science takes place within a culture but also understand that one's culture influences what one sees and what questions one asks.	Students understand that one's culture influences what one sees and what questions one asks. They also understand that culture refers to a way of knowing, being, and doing.

Use of these elements will help the students achieve the program goals for the following reasons:

- Collaborative learning makes the students responsible for seeking information and achieving a particular task.
- Collaborative learning strategies model the collaborative nature of the scientific enterprise.
- Research has shown that collaborative learning is an effective technique for involving students from groups that are underrepresented in science, such as female and minority students.
- Collaborative learning can be a powerful way to interest and motivate students who otherwise might not excel or even be interested in science.

Using Collaborative Learning in Your Classroom

Before implementing collaborative learning, we recommend that you read *A Guide to Collaborative Learning*, Section 2 of the *Teacher Resources*. This section summarizes some of the research supporting collaborative learning (including Cohen, 1986; Cohen, 1994; Johnson and Johnson, 1991; Lundgren, 1993; Slavin, 1990), and provides detailed suggestions for how to use this effective teaching tool.

To help ensure detailed success in your classroom, begin implementing collaborative learning by using the ideas listed below:

- Use the activity, *Cooperating like a Scientist* in the *Engage* section (pages 6–7 in the student text), to initiate discussions with your students about the potential value of working collaboratively.
- Follow the recommended team sizes indicated in the teacher edition.
- Always hold individual students accountable for their own learning.
- Provide opportunities for self-evaluation.

As you develop your skill using collaborative learning strategies, you can assess your progress by using the implementation continuum (**figure TR1.14**). With time and patience, you will find yourself incorporating collaborative learning as a natural part of your teaching.

Figure TR1.14 **Implementation Continuum for Collaborative Learning for *BSCS Biology: A Human Approach***

No Implementation of Collaborative Learning	Beginning Implementation of Collaborative Learning	Partial Implementation of Collaborative Learning	Full Implementation of Collaborative Learning
Students sometimes work in small groups but do not use working-relationship skills or team jobs.	Students work in cooperative teams during some group activities, but the teams are self-selected.	Students work in cooperative teams during most group activities, and teams are teacher-selected.	Students always work in teacher-selected cooperative teams during all activities that are designed for groups.
Students working in groups do not have to cooperate to accomplish a common task.	Students are sometimes assigned team roles but do not appear to understand the nature of the role or job.	Students do not always have assigned team roles, but when they do, they understand the nature of the role.	Students always are assigned team roles and know their responsibilities.
Students working in groups do not share information.	Teammates share some of their information.	Although teammates share information, they do not take responsibility for being sure that every member understands all the information.	Students share information with their teammates and take responsibility for the entire team's understanding of the information.
Group members may change with each new group activity.	Students either stay with the same team all year or change too frequently to learn how to work together.	Students change teams at reasonable intervals, but team members tend to have the same role all the time.	Students change teams at reasonable intervals and rotate through team roles.
Students do not assess their progress in using working-relationship skills.	Students occasionally assess their progress in using working-relationship skills.	Students consistently assess their working-relationship skills.	Students not only assess their working-relationship skills, but also consistently apply them as they work together.

G. Differentiated Instruction

Each of your students will bring different talents and struggle with different challenges that this program brings. For some students, adopting differentiated instruction strategies will be necessary to help them maximize their learning. The program includes Further Challenges and Extensions ideas for students able to delve deeper into the material. For students with physical or learning disabilities, you will want to incorporate specific instructional strategies into your daily planning. For students with visual challenges, enlarge print materials and/or read aloud if needed. These students may need key visual information described for them when an activity asks students to look closely at an image, diagram, or graph, or view a video segment. In many cases, this might best be done prior to the class period when the activity is scheduled. With weekly or biweekly meetings, you may be able to train the paraprofessional assigned to your class or an advanced student in the class to take on this task.

When activities call for students to take on specific roles, you may wish to preselect roles for students with challenges that might hinder participation in a particular role. For example, when students need to use scissors and tape to manipulate materials, plan teams so that students with challenges will have a partner who will take those responsibilities and still encourage the partner to participate in decision making. Encourage teamwork that facilitates participation by all. Also, be certain that all students who need assistance communicating with teammates have the means necessary for teaching and learning from teammates when roles or jigsaws are employed.

Students reading below a ninth grade level may struggle with some of the readings. For these students, implementing literacy strategies embedded within the activities will be essential. You may wish to offer these students additional literacy strategies to choose from. If a substantial portion of the class struggles with reading, you may wish to have students summarize each paragraph of the reading and discuss any difficult terminology during class time.

Tangential conversations have a disproportionate distracting effect for students with attention disorders. While advanced students can handle tangential conversation during hands-on work, for others this makes it difficult to be both hands on and minds on. Tangential conversations should be limited to areas where students can benefit from relevant engagement, and before or after class.

Assessment opportunities vary throughout the program in order to allow all students to showcase their knowledge. Nevertheless, for any particular assessment some students may be better able to show their understanding in alternate formats. For example, when students present their Critters at several points in the program, some students may show enhanced performance if they are able to write about their Critters during class time, use a word processor, and/or present their Critter work to you orally.

1.5 Planning for Successful Implementation and Professional Development

Successful implementation requires planning, support, commitment, and time. It involves changing the way you approach teaching. You will need to receive logistical and emotional support from team members and administrators. In addition, as a team, you must coordinate training, equipment, and instruction.

The implementation planning process can be summarized by five steps:

1. With whom will you work to implement the program?
2. Where are you now and what do you need?
3. Where do you want to go?
4. How will you get there?
5. How will you know when you have arrived?

A. With Whom Will You Work to Implement the Program?

Choosing a Team

The first step is to identify team members for the implementation process. Implementing a program by yourself can be very difficult (Tobias, 1992). Implementation is most likely to be successful when you work with other teachers (Fullan, 1992). Your team members will serve as colleagues with whom you can discuss the implementation process as time goes by. Together you determine how *BSCS Biology: A Human Approach* can best be implemented in your classrooms.

If your school has several teachers who are using this program, you have a ready-made team. If you are the sole biology teacher in your school, you need to recruit some teammates. Science teachers would be best, but any teachers who are interested in innovative teaching strategies would make good teammates. Look for colleagues who enthusiastically seek to develop their teaching skills—those who go to professional meetings, volunteer for district programs focusing on teacher development and student learning, enjoy working with and mentoring student teachers, and seek opportunities to try innovations.

One way to recruit reluctant teachers is to encourage them to “shadow” a student for a day, following him or her to all classes. Generally, after experiencing firsthand how monotonous it is to sit through a day of conventional instruction, many teachers will be ready to discuss how to improve their individual teaching to be more interesting and more challenging to students.

Your principal also is an important team member. Successfully implemented programs have principals who provide leadership, help develop a plan for change, support the establishment of an implementation team, and support teachers’ efforts for change. Talk with your principal to determine how much support and encouragement she or he can provide during the next few years. Administrative support should include, at a minimum, funds to buy equipment and supplies for the program. Additional support by your principal might include arranging a common planning time for all the teachers using the program, participating in implementation team discussions, providing time and money to attend area or regional workshops on some of the innovations included in the program, and promoting the program to students, parents, and other teachers.

Sometimes the students can serve as implementation teammates. Experience has shown that including students as partners in new endeavors can increase their interest in what is happening in class and can increase their tolerance levels when the teacher is trying something new (Paulin, 1995).

Team Commitments

Implementing a new program involves a lot of time and hard work. Assume that full implementation will take up to 5 years to complete. You and your implementation team members, therefore, must make a long-term commitment. As members of the implementation team, you need to agree to

- support each other through a meaningful change. Support should include such actions as exchanging class schedules with other teammates, establishing a regular meeting time to identify and solve problems of the implementation process, observing and providing feedback about each others’ teaching, and arranging collaborative efforts with teammates.
- help negotiate for resources within both the school environment and the larger community, including parents. These resources include materials for the program, community support, and time for staff development.
- support and facilitate staff-development workshops, provide technical assistance to team members, and reinforce the efforts of both other teachers and the district administration as they make changes.

- support each other in efforts to obtain the necessary equipment and information needed to begin the new program.
- offer feedback to each other, share ideas, listen to others' concerns, provide encouragement, and lend support.

It will be natural to feel that sometimes things are not working. Implementation research (Fullan, 1992) indicates that when a teacher tries something new, his or her effectiveness will worsen before it improves. This is to be expected because at first you will be a novice at using the new strategies. Once you construct an understanding of the program and its innovations and gain skills in using the new strategies, you are likely to be more successful than you were before, and you will enjoy teaching more.

Examples of Successes and Problems during Implementation

Following are some examples of actual implementation successes and challenges that occurred during the field test of this curriculum. As you read these examples, keep in mind that implementing a field-test version of a developing, changing curriculum is an even greater challenge than implementing the final, published edition. Still, the experiences of these schools and teachers provide valuable lessons for all implementers of the curriculum. The examples include schools in a range of communities and educational climates. There does not appear to be any correlation between implementation success and the income level of students' families, learner ethnicity, or students' previous academic success. The primary differences are how familiar teachers are with the innovations that the program promotes, how committed teachers are to implementing the program, and how much support they receive from their administration and parents. Use these examples as lessons in how to succeed and how to avoid some of the problems that others have encountered.

Example A: The two biology teachers in this suburban school decided to use *BSCS Biology: A Human Approach*. One was a veteran teacher while the other had been teaching only a year. They approached their principal with the proposal to test this new curriculum, and he gave them enthusiastic support. Both of these teachers were familiar with many of the innovations incorporated into the curriculum and agreed that this was a better way to teach than the way they had been.

As they began using the program, they met frequently, planning all of their lessons together and discussing what worked and what needed to be changed. With the help of an individual from a nearby university, they were able to meet monthly with other teachers in the area who also had decided to try the curriculum. The university colleague also arranged several workshops in which teachers were able to become more familiar with the innovations that they found difficult to implement. After 2 years, these two teachers still were using the program and becoming more adept with the complex task of using all of its innovations. One of these teachers commented that her class of college-bound high achievers initially was disappointed in the program because it seemed to lack the emphasis on facts with which they were accustomed. After her students' scores on the Standardized Achievement Test in Biology (SATII) exceeded the scores of her previous year's traditionally taught class, however, this teacher was convinced that the conceptual approach of this program was superior to a traditional curriculum.

Example B: Two of the high schools that field tested *BSCS Biology: A Human Approach* are located in a town with a population of about 50,000. The town is about an hour's drive from a metropolitan area. A nearby middle school had implemented BSCS's middle school program, *BSCS Science & Technology*, a few years earlier. The middle school program promotes many of the same innovations as the new high school biology program, and the middle school teachers were very enthusiastic about the program. Their response motivated four biology teachers at the two high schools to consider field testing. With the encouragement of and monetary support from the district's science supervisor, two teachers from each of the high schools began implementing the new program. The principals were aware of the teachers' involvement in the field test but did not give them active support.

In the beginning, the teachers received professional help from several people at the university in the nearby city, but this help soon stopped. Two of the teachers, who were convinced of the merit of the program's approach, still were actively using the program after 6 months. One of these teachers found that telling his students at the beginning of the school year about the nature of the program and its innovations resulted in involved and excited students who were eager to evaluate the program and the implementation process.

The other two teachers were less successful. One discovered that her personal teaching style was very different from the BSCS approach and she had great difficulty switching to a new way of teaching. After struggling through two chapters trying to use the program, she decided to drop it and return to the one she had been using. The other teacher apparently lacked the strong motivation needed to follow through on implementing a new program and gradually returned to a more familiar, conventional curriculum.

By the end of the year, the remaining two teachers were becoming discouraged because they had no interactions with each other (they taught at two different high schools) or with other teachers using the program, and they received no support from outside professionals.

Example C: Four teachers in this inner-city school began using *BSCS Biology: A Human Approach* at the beginning of the school year. The school and the principal had been working actively for several years with individuals at a nearby university to improve science teaching and learning at the high school level.

After 2 months, only two teachers continued to use the program; the other two were unwilling to adapt their teaching styles to ones compatible with the program. The remaining two teachers collaborated strongly with each other and with an individual from the university. The university professional visited their school frequently, helped them obtain materials that their district could not afford, and offered assistance with innovations when the teachers had difficulties. The teachers were eager and willing to accept change and the challenge of trying a very different sort of biology curriculum. They felt that their students were much more enthusiastic than those in previous biology classes. As one of the teachers put it, "Kids are going home and talking about what they did in class." These two teachers are eager to continue with the program during the new school year and appear renewed by the accomplishments they have achieved.

Example D: This high school is located near the downtown area of a mid-sized city. The science supervisor for the school district had strongly recommended *BSCS Biology: A Human Approach* to the members of the biology department. While the principal gave verbal support to the field-test teachers, he did not have any resources to support them financially. The teachers were not happy with the program they were using, but they were not convinced that this was the program they needed. After long deliberation, they decided that the whole biology department would use the program. To begin with, three teachers initiated the program, but another was brought on board after class sizes became unwieldy due to unexpected growth in the student population.

The teacher who had been brought in after the school year started felt that he was coerced into using the program. It did not match his philosophy or teaching style, and he stopped using the curriculum after completing the first chapter. Another teacher had never been convinced that this program was appropriate for his students. He felt that he was quite successful with the previous program and that, while the BSCS program had some good activities, it was not as good as what he was doing. He picked and chose activities from the BSCS program during the first semester, then stopped using the curriculum during the second semester.

The remaining two teachers persevered. They met weekly to discuss their progress and shared their impressions of implementation throughout the year. One was not entirely comfortable with the program but perceived that her average to below-average students were more successful with the BSCS program than with the old one. Also, during parent-student-teacher conferences, some students and parents volunteered strong, positive comments about the program, telling how the students felt they were actually learning how to think, and how they were thinking about biology outside of class time. The teacher spent the year seeking to meld the program innovations with her own teaching style. She had mixed feelings about the program after the first year. The fourth teacher liked the program and followed it closely. However, like many teachers, he often added extras as the students expressed interest in certain aspects of the program. As a result, this teacher's classes only completed the program through Unit 3, and thus the students did not experience the breadth of biology that the program covers.

As you can see, each of the examples illustrates different successes and problems. It is never easy to undertake the task of implementing an innovative program, and total success is unlikely during the first few years. You need to build on your successes and reevaluate your failures. You are more likely to succeed if you are enthusiastic about tackling a new program, if you enjoy the challenge of expanding your teaching expertise, and if you receive support from others within the school or community.

B. Where Are You Now and What Do You Need?

Once you have identified your implementation team and made commitments to proceed, your team will carry through the remaining implementation steps. Your first team task is to become familiar with the entire curriculum. Each team member needs to understand the content and pedagogy of the curriculum. Kendall/Hunt, with the support of BSCS, offers workshops for lead teachers from schools or districts that adopt *BSCS Biology: A Human Approach*. These workshops range from 1-day inservice training on site to week-long summer institutes at BSCS in Colorado Springs, Colorado. Check with Kendall/Hunt personnel about the level of support at which your district is eligible by calling 800–258–5622. An alternative is to develop your own implementation workshop. A sample workshop outline is provided in Appendix A of the implementation guide.

If you have less than 1 week available to accomplish the initial implementation steps, you can condense the workshop by focusing intensely on the one or two components of the curriculum that the team decides to implement first. Use activities from the first unit to illustrate the innovations you have chosen. Give only a general introduction to each of the other components. Then hold additional workshops as your team nears the end of each unit or decides to implement additional innovations.

Analyze the Team's Strengths and Weaknesses

To identify the curriculum innovations of highest priority to your team, you must analyze your present situation and determine your implementation needs. We have provided a *Personal Implementation Questionnaire* and a *Needs Assessment Worksheet* (Copymasters IG.1 and IG.2) to help you. The *Personal Implementation Questionnaire* should be distributed to all members of the implementation team, including all teachers who will be using the new curriculum and anyone else affected by the changes. It is important to involve all these participants before making final decisions. This will avoid the risk of having individuals on the team who feel pressured to implement the program but who lack a commitment to do so.

Once each team member has completed the *Personal Implementation Questionnaire*, the implementation team should collate the results onto the *Needs Assessment Worksheet.* Although team members will have many of the same concerns, there also will be differences because each person brings a different background and different skills to an innovation. Discuss any comments, concerns, and actions that team members raise. Pay particular attention to weaknesses, threats, and concerns that are raised. You must first meet these basic needs of team members if they are to feel confident in the implementation process.

If any concerns arise that threaten the entire implementation process, take immediate action. Decide who can solve the problem and how to approach this person. Present your concerns and needs in terms of your goals and your school's or district's goals for students. Solutions that do not cost money are easiest to initiate. If cost is involved, be prepared to present options for how the costs can be covered.

Be Aware of the Nature of Your Community

The nature of your community also may affect your implementation process. For example, teachers in some schools may feel uncomfortable beginning the school year with the subject of evolution. We placed this subject first because evolution is the most fundamental principle, helping to explain and unite all other subdisciplines of biology. Learning this subject early in the school year allows for continuing opportunities to reinforce this theme through the entire curriculum. We strongly recommend that you proceed with this unit despite the fact that the topic may be controversial in your community. Most teachers field questions from parents and students about evolution at some point in the year, regardless of when the topic is introduced.

We have observed field-test schools handle the public controversy about evolution in a variety of ways. In one school, where students complained when they realized that evolution was being examined, the teacher took about 20 minutes of class time to conduct an open forum. All students were encouraged to respectfully present their points of view. This included limited discussion of whether the subject was a valid one for study in biology. Finally, the teacher brought the discussion to a close by stating why evolution was being studied in his biology class—it served as a strong example of a scientific theory that was formed and modified based on evidence, and it successfully explains the unity and diversity seen in the earth's living systems.

Indeed, the scientific community does not debate the validity of evolution. That evolution occurred in the past and continues to occur today is a fact; continuing research is focused on elaborating the details of the life's evolutionary history and the mechanisms by which evolution occurs. The theory of evolution is not unlike the theory of gravity. Physicists know that gravity exists, but the theory of gravity does not yet explain everything about attractive forces between and accelerations of matter, and scientists are working hard to develop more complete explanations.

Another approach that can be used to counter the plea for equal time for creationism is to make clear that science is a way of knowing that seeks natural explanations for phenomena. Thus, by definition, science cannot address issues of faith because they deal with the ***supernatural***. In nearly all field-test situations, a straightforward approach to teaching the Unifying Principle of evolution was met with very little resistance and controversy.

C. Where Do You Want to Go?

Using the data from the worksheet and input from discussions, develop a list of priorities and a flow chart that lays out what you want to accomplish and when you want to reach certain check points (see the sample in **figure TR1.15**). The flow chart should include a timeline of expected outcomes for the first year. As you develop your flow chart, set realistic timelines. Be sure to build in plenty of time to practice a new innovation. Include implementation of the BSCS 5E instructional model and conceptual teaching early on in your flow chart because they play important roles in organizing the curriculum.

Do not be overly ambitious. To ensure long-term success, you need to feel comfortable using one set of innovations before adding a new set. Allow sufficient time for mastery before introducing another level of complexity. We recommend emphasizing no more that two new innovations during the first year. Of course, other innovations still could be used, but place less emphasis on their implementation.

Keep in mind that the availability of time, money, and other resources may affect the rate at which implementation can proceed. If you perceive that this is the case in your school, look for assistance

Figure TR1.15 **Sample List of Priorities and Flow Chart for Implementation**

Priority List of the Implementation Team at ABC High

1. Learn about BSCS 5E model and constructivist teaching.
2. Begin implementation of BSCS 5E model.
3. Find money to order computer hardware and software, if needed.
4. In faculty meetings, begin to lobby for some form of flexible class scheduling to allow for blocks of time to complete activities.
5. Learn about alternative assessment.
6. Begin implementation of alternative assessment.
7. Other issues.

Flow Chart of the Implementation Team at ABC High

August	September	October	November	December	Etc.
Hold teacher workshop on the new program.	Inservice on constructivist teaching.	Bring in consultants as needed to aid implementation of the 5E model.			Etc.
Meet weekly to discuss implementation.	Continue meeting weekly to discuss implementation and to plan lessons.				Etc.
Find money for purchase of computers and software. Place order for equipment and supplies.	Begin discussions on setting up an inquiry into teaching using the 5E model.	Undertake first inquiry into teaching using the 5E model.	Collect assessment data on the inquiry into teaching using the 5E model.	Report results of the first inquiry into teaching using the 5E model.	Etc.
Prepare to teach the *Engage* section and Unit 1 using the 5E model.	Visit classrooms for the purpose of peer coaching each other as you teach the curriculum.	Prepare to teach Unit 2. Continue peer coaching.	Continue peer coaching.	Prepare to teach Unit 3 and the Explain Section. Continue peer coaching.	Etc.
	Begin lobbying for flexible scheduling.	Continue lobbying for flexible scheduling.			Etc.

from other sources. Depending on your community and district, you might check into using district Eisenhower funds, nearby university resources and teaching centers, or publisher support.

Before you begin to implement your plan for teaching this curriculum, take time out to check whether there is group approval for the plan. It might be useful to develop a two-stage plan. The first part could address the concerns and directions on which everyone agrees and that could be considered in the short term (1 year). The second part could address the concerns that the team presently is uncertain about how to approach and/or that need to be considered over a longer time during the implementation process (3 to 5 years).

D. How Will You Get There?

A variety of models and methods can help you get where you want to go. We describe several models of implementation in this section. Each can be used alone or combined with others, depending on the size and ambition of your implementation team.

Regardless of what model or process your implementation team uses, stay alert to problems in the early stages of implementation. Once a problem has been identified (perhaps students are discontented or parents are concerned that their children are not learning enough about specific topics), look for a solution immediately. Solving problems as they arise will keep them small. If you wait until a problem grows large, it may become intractable.

Also, with each model, you will need to assess your progress periodically. You can use the implementation continuum checklists that define points along a continuum from no implementation to full implementation (see **figures TR1.6, 1.7, 1.8, 1.11, 1.12, 1.13**, and **1.14**). These checklists will help you assess your progress based on observable behaviors that indicate the use of a program feature. Work with another teacher (or even with students) and ask him or her to observe your class for use of the behaviors on the checklist. To assess the level of implementation fairly, set up several observation times over a period of 2 or 3 weeks. These observations also might include notes about the behaviors of both students and teacher while they are using the program, interviews with students, and videotapes of the class.

As you implement learning-based innovations, you also will need to analyze the content of the curriculum. Arrange times for all team members to get together to become familiar with the biological concepts, work with the materials in upcoming units, and discuss ways to effectively facilitate the conceptual learning of biology. Your team might rotate among stations that are set up to match the activities from a particular chapter. This will help the team become familiar with materials and procedures. To keep each teacher's workload manageable, each teacher could bring the necessary materials for one activity.

If your team is small, schedule discussion times instead. Be sure each teacher has read the upcoming materials, then discuss common concerns. Work through difficult activities together during one of your regular planning times or after school. Having a common planning time to discuss such strategies or other concerns would be helpful to all teachers using the program. You also might want to prepare materials together so that you can share instructional ideas and classroom supplies.

Implementation Model 1: Start Small

Sometimes large, complex changes can fail because the implementers find it impossible to address all of the changes at one time. If you think that implementing *BSCS Biology: A Human Approach* seems overwhelming or is likely to cause a tremendous increase in your workload, break it into small pieces. Try using only one facet of the curriculum at a time. Do not try to include the other innovations until you feel that you have a good grasp of the one you have undertaken.

Yet be careful not to simplify too much, such as by limiting your implementation to only a portion of the BSCS 5E instructional model or an abbreviated version of inquiry-oriented activities. More challenging changes are more likely to keep you motivated and working toward success than simple changes. Some good ways to begin might be to focus solely on constructivist teaching or using the BSCS 5E model or designing alternative assessments. Each of these innovations can be undertaken long before you have a thorough understanding of how to implement them. You can improve your understanding and skill with the innovation as you gain experience using it. Also, each of these innovations can have far-reaching influences on teaching and learning, and as you gain expertise, you likely will find yourself naturally overlapping into other innovations.

Implementation Model 2: Use Learners as Partners in Innovation

You have a powerful group of innovators in every classroom. Being needed is a powerful incentive for students (Sizer, 1992), and most students will be eager to work with you as partners during implementation. Using students as partners during implementation also reinforces the goal of helping students take more responsibility for their own learning.

Recruit your students by describing the new curriculum and identifying your implementation goals. Ask them which of the new components of the curriculum they would most like to help you implement. Have them assist in setting up your implementation plan and assessment instruments. Ask them what role or roles they would like to undertake. Possible student roles include acting as resource people who will look for information regarding the component you are addressing, being assistants who are willing to take on the role of tutors or coaches for other class members, or serving as evaluators who will complete assessment instruments and work with you to analyze how the implementation is progressing.

You will find that students who are actively involved in the implementation process are more tolerant of your struggles to master the new strategies. You also may find that your students are much more motivated to attend class on a daily basis.

Implementation Model 3: Inquiring about Learning

> Teachers of science approach their teaching in a spirit of inquiry-assessing, reflecting on, and learning from their own practice. They seek to understand which plans, decisions, and actions are effective in helping students and which are not. They ask and answer such questions as, Why is this content important for this group of students at this stage of their development? Why did I select these particular learning activities? Did I choose good examples? How do the activities tie in with student needs and interests? How do they build on what students already know? Do they evoke the level of reasoning that I wanted? What evidence of effect on students do I expect? (National Research Council, 1994)

Just as your students are inquiring about science in this program, you can be inquiring about learning. This is a complex and ambitious implementation model. Yet you will find the rewards to be as great as the challenges involved in using it. Also, working as colleagues engaged in inquiry is likely to make team members more tolerant of the ups and downs of the implementation process and more open to feedback from students and other colleagues (Fullan and Hargreaves, 1992). It works best for schools that have a number of biology teachers using the program, but it also can work for schools with a single biology teacher.

Inquiring about how one's classroom operates can be a personally rewarding endeavor for any teacher. Our Inquiring about Learning model views the teacher as a reflective practitioner who seeks to understand how best to help students learn biology. This model uses the same steps to approach your inquiry into learning as the students are using to inquire about biology (see **figure TR1.16**). You can use this model to conduct hands-on research into learning in a manner analogous to the way your students are conducting hands-on research into biology. A detailed example of using the steps in **figure TR1.16** to conduct an inquiry is given in **figure TR1.17** Inquiring about Learning Scenario.

In this model, all members of the implementation team collaborate on inquiries and use their findings to determine the direction of continuing implementation. Teachers identify problems or questions based on the curriculum, its innovations, and their classroom situations. Then they locate

Figure TR1.16 Outline of Steps Involved in Inquiring about Learning

Science for Inquiring About Learning	Stage of the Instructional Model	Steps in Science as Inquiry
Identify a learning-based question. Use group discussions to identify general concerns or problems. Then use one of these concerns as the source for identifying a question such as, Are students participating equally? Develop tests that address your questions. This involves thinking about or making observations of your classroom to determine how your classroom situation compares with that required to achieve implementation of the program.	Engage	Ask a testable question and propose a hypothesis.
Gather information. This first may involve some background reading and/or training related to the question you are considering. At a minimum, you determine what the program has to say in relation to the question.	Explore	Gather information. Design an experiment to test the hypothesis.
Develop a plan for proceeding with your inquiry. A good plan will describe what you will do, how you will determine whether you are doing what you said you would, and take measurements to assess how what you are doing is affecting you and your class. Include a definite beginning point and end point.		
Set your plan in motion. Once you feel that you are proceeding according to the plan, you need to have someone come into your class to assess your progress. If you modify your plan based on the feedback you receive from an outsider, from your learners, or from your own perceptions of how it is proceeding, make detailed notes to help you track these changes as the inquiry proceeds.	Explain	Carry out the experiment, using appropriate controls. Follow your protocol. Collect and record data accurately.
Analyze the results of your inquiry using the assessment data you have collected.	Elaborate	Analyze your data.
Draw conclusions about your results using your data as evidence to support your conclusions and using preexisting knowledge about how children learn to help make your conclusions. Discuss your conclusions with your implementation team. The team should use this information to decide whether to continue the original implementation plan or to modify it as needed. They also should decide whether to develop new inquiries based on something that was revealed during this study, develop a new study based on another aspect of the same innovation, or move on to a new innovation as a source for inquiry studies.	Evaluate	Draw conclusions about your results using your data as evidence to support your conclusions and using preexisting biological knowledge to help make your conclusions. Assess your hypothesis. Communicate your results to colleagues.

resources to conduct the study (for example, consultants, workshops, supplies, coaches/evaluators, administrative support, and parent involvement), develop methodologies, collect and interpret data, discuss findings with collaborators, and use the results to modify classroom strategies. Teachers may conduct inquiries individually, perhaps using teammates only as outside evaluators who come into the classroom to collect data, or they may develop joint projects that use the resources of several classrooms and teachers to investigate a question.

The following guidelines will help your team develop its personalized version of the inquiry model:

1. **Propose and develop testable questions/problems that you want to answer regarding your implementation goals.** Decide which innovation will receive the most attention as you begin your school year. Identify a set of questions regarding how this innovation will affect learning in your classroom. Some teachers may feel that a particular innovation simply will not work in their classrooms. This model allows teachers to develop inquiries that test these assertions. Include these questions as they arise in your brainstorming session. (See **figure TR1.17**, Inquiring about Learning Scenario, for examples.)

Figure TR1.17 **Inquiring about Learning Scenario**

The implementation team members for *BSCS Biology: A Human Approach* at Midcity High School have received a great deal of support in their endeavors from their principal. One way she is supporting them is by scheduling a common planning period for all team members. The team members have gotten together during their planning period to discuss possible inquiry questions related to implementing the BSCS 5E instructional model.

Teacher A: "I think this model is unworkable. We won't cover nearly as much material, and the students won't do well on the standardized tests that we have to give at the end of the semester."

Teacher B: "In my classroom, this model might improve behavior. It's much more activity-intense than what I was doing before. My kids seem to stay on task more during activities than during lectures."

Teacher C: "I like the idea of using the 5E model, but I've used constructivist models before and the exploration phase always seems to take forever. I want to focus on setting up really strong explore activities that don't take so long to accomplish."

Teacher D: "I have a different point of view regarding Teacher A's concerns. I agree that we probably won't cover as much material, but I believe that the students will have a stronger, longer lasting understanding of the material that we do cover. Also, my guess is that students don't remember many of the details they learn long enough to make a difference on standardized tests. They probably pick the answers that sound most like things they might have heard somewhere and don't really understand the subject well."

As a result of this discussion, the teachers came up with the following inquiries:

Teacher A: Question: Will students using the BSCS 5E instructional model perform worse on standardized tests than students being taught using my old teaching methods? **Test:** I will use the 5E model to teach Unit 1, and then I will give students a standardized test using relevant test questions I have used before. I will compare student scores with my students who used the same test last year. I will have an evaluator visit my classroom to see how well I am implementing the 5E model.

Teacher B: Question: Will using the 5E model improve student behavior in my classroom? **Test:** I will record the number of instances of misbehavior over a 1-week period as I use my present teaching methods. Next, I will use the 5E model consistently and correctly for 1 month. Then I will again record the number of instances of misbehavior over a 1-week period as I use the 5E model.

Teacher C: Question: Can most explore activities be completed in no more than two class periods? **Test:** I will focus less on imparting detailed information and more on finding out what students' current understandings of a concept are. This will help me determine if I can complete Explore activities in 2 days or less.

Teacher D: Question: Will students being taught using the BSCS 5E instructional model have a stronger, longer lasting understanding of major biological concepts? Will they do as well on standardized tests as students being taught using my old way of teaching? **Test:** I will use the 5E model to teach Unit 1. Then I will use last year's evolution test and compare the results of this year's students with those of last year's students. I also will use some of these questions on the semester exam (as I did last year) and compare retention of learning between this year's students and last year's students.

Each teacher set up a plan based on his or her questions and tests. Teacher B's plan follows.

Teacher B's Plan

Mr. X, who teaches chemistry, has a planning period during one of my biology classes, and he has expressed an interest in some of the innovations we are trying to implement. I will ask him to be my evaluator. I expect that when I start using the 5E model, I will not do it very well. This is likely to be accompanied by just as many classroom problems as I experienced in the past. One good thing about this is that it will allow me to collect baseline data on my students' behavior.

I am going to write detailed lesson plans that pay particular attention to what I should be doing at each of the 5Es. I will use the charts *What the Teacher Does* and *What the Student Does* (**figures TR1.3** and **TR1.4**) as the guidelines for writing my lesson plans.

During the course of this inquiry, I will ask Mr. X to come into my class a number of times, maybe twice a month, to collect data. I will need two different kinds of information. The first set of data will detail how many students are off task, how frequently they are off task, and for how long. I will make a chart for Mr. X to use:

Student's name	Time student went off task	Time student returned to task

The second set of data will document how well I am implementing the 5Es. I will give Mr. X the same charts that I used as guidelines for constructing lesson plans. For each of the statements given under a particular E, I will ask him to rate me on a scale of 1 to 5 to indicate how well I am implementing that element. Based on his feedback, I will modify my lesson plans to better implement the 5Es. I expect to find a correlation between changes in learner behavior and the degree to which I am implementing the 5Es. I predict that after several months I will have greatly improved the degree to which I am implementing the 5Es and my students' time off task will have decreased considerably.

I will use these data to determine whether using the 5E approach at a beginning level had an effect on the amount of time students are on or off task in my classroom. I will share my results not only with the implementation team, but also with Mr. X.

Note: Teacher C is planning to recruit his students as co-inquirers. Before he begins his inquiry, he will tell his class what he is doing and what he hopes to accomplish. He will construct an assessment form for students to fill out. It will ask the students questions based on the explore activities' outcomes and indicators and on the major concepts that the activity is meant to address. He will have students complete the form before doing the explore so that he can try to determine the learners' current understanding of the concept. Then he will conduct the activity, pay attention to some of the misconceptions revealed by his assessment form, and ask the learners probing questions to get a better indication of their conceptions and whether they are adequate. After he has analyzed his results, he will share them with the students.

Limit the number of questions from the brainstorming list to the two or three that are most important to your team and that can be addressed by precisely constructed questions. If you have a large group of people, different teams may wish to tackle different but closely related questions. We strongly recommend, regardless of the size of the implementation team, that your first inquiries focus on implementing the BSCS 5E instructional model because of its central role in organizing the curriculum.

2. **Gather information.** Spend time reading and discussing literature related to your topic of inquiry. Changes that you want to implement should be supported in the education research literature. Also, reading the literature will provide you with new ideas and insights about how to proceed with implementation. Other sources of information include your students, self-reflection, fellow teachers, and staff.

   Because the program includes many innovations, you may need to solicit external consultants to present workshops that address an innovation. Decide as a team what information you need before you undertake your inquiries. Then identify key people in your school or district who can assist you or provide resources. Schedule workshops or consultations that address the team's concerns. As inquiries proceed, additional questions, problems, or needs may arise. Seek additional assistance as needed to meet these concerns. For instance, the assistance might take the form of a mentor teacher who teaches demonstration lessons or models other aspects of teaching the curriculum.

3. **Design the inquiry.** First, identify the roles of team members in specific inquiries. You should work with at least one other person to conduct your classroom inquiry. A minimum role for your partner is to act as your evaluator. In this situation, each teacher may have a separate but related inquiry, and each partner acts as the evaluator for his or her teammate. In other instances, teammates may decide to set up different variables and controls in different classrooms.

   Next, develop methodologies and a detailed timeline for conducting the inquiry. Set a realistic timeline for completing your inquiry. List the instruments or procedures you will use to collect information to answer each question (see examples in **figure TR1.16**). You should consider using multiple types of information to answer your questions because this provides stronger support for your conclusions. You might consider the following: paper-and-pencil instruments for students to complete, observation checklists, and interviews of selected students. It might be valuable to videotape each other in your classrooms and then, through peer coaching and positive feedback, help each other strengthen those strategies that work best. Feel free to ask other teammates for help locating an instrument or for information on a particular procedure.

   Use assessment tools periodically. Describe who (for example, you, a teammate as observer, or a student) will provide the input you need to assess your progress and analyze your results. Indicate when you will gather the data for each procedure or instrument, for example, after every lesson or at the end of the chapter. Set dates for implementation team meetings to discuss ongoing progress with the inquiries.

4. **Do the inquiry**. Once your plan is in place, carry out the inquiry that you have designed to answer your question. Remember to record data carefully and to use controls when appropriate.

   Schedule informal after-school sessions to share ideas, problems, and concerns that arise during the inquiries. Keep in mind that when changes in teaching strategies are made, your teaching first may feel awkward. Then it will improve as you gain competency in the new strategy.

5. **Analyze and report your results.** Determine what procedures you will use to analyze the information you gather. How will you summarize the data? What comparisons, graphs, or statistics might be useful? How will you report the data? For example, will you use data tables, quotes from interviews, or a narrative description?

Meanwhile, the implementation team should set a date for final reports on inquiries to be given. On this date, each teacher or inquiry team will report on the inquiry that was done and what conclusions can be drawn from the results. To successfully implement an innovative program such as *BSCS Biology: A Human Approach*, conducting learning-based inquiries and evaluating how the program is working in the classroom go hand-in-hand. Colleagues should be expected to ask thoughtful and critical questions about each inquiry and its conclusions. These questions should try to ferret out the strengths and weaknesses of the inquiry. Based on these reports and accompanying discussions, the implementation team should modify classroom practices and develop new inquiries. Teams or individuals may choose to formalize particularly good reports and present them to education journals, such as *The Science Teacher* or *The American Biology Teacher,* for possible publication.

An effective implementation team using the Inquiring about Learning model should be able to develop a "center of inquiry" within the school that promotes long-term professional development for teachers. Teachers in such centers continue in the role of reflective practitioners beyond the implementation period. They use their classes and classrooms as vehicles for inquiring about various innovations as they continue to implement new strategies that are beyond the scope of this curriculum.

E. How Will You Know When You Have Arrived?

During the 3- to 5-year implementation process, the concerns you and your implementation team members have will change. Therefore, as you continue the implementation process according to the plan your team developed, it is important occasionally to stop and reevaluate the process and your progress. Such evaluation should occur at the individual level as well as at the team level.

Individual Evaluation

As you initiate your individual program, be sure to build in ways to evaluate it. Undergoing successful change requires frequently analyzing your current practices and considering how you might move toward your goals. Constructing a table similar to **figure TR1.18** will help you analyze your personal progress. You may wish to use this table and complete the last column in a way that reflects your personal program, or you may wish to develop your own table. To develop a table for yourself, identify the components that you are trying to implement and evaluate your current use of each component. Next, ask yourself what you want your students to know, value, and be able to do at the end of your program in relation to their understanding of major biological concepts, unifying principles, and processes of inquiry. Finally, determine what changes you need to make in your teaching practices and how you are going to make these changes in order to reach your goals.

Be realistic in the number of changes you are willing to make immediately and in the near future. Resist the temptation to add content-dense activities that do not promote your instructional goals. This often means that some content has a priority over other content. Focus on content that promotes conceptual understanding of the unit or the chapter concept. If some part of the implementation plan is not working effectively for you, ask your team to address that aspect of the plan promptly, in other words, before you become discouraged.

Just as students' learning takes time and effort, so will your learning of a new way to teach biology. Keep in mind the following points about your progress as you begin to implement a new innovation (AAAS, 1989):

- Progression in learning is usually from the concrete to the abstract.

  At first, you probably will find yourself going through the motions of implementation with little concern about how well you are doing. This is normal. Once you feel comfortable with the mechanics, you will find yourself naturally paying more attention to how your students are responding and how you should adjust your strategies.

- People learn to do well only what they practice doing.

  Don't expect to have instant success with implementation. Just as your students need time to learn a new skill, such as how to do scientific inquiry, you also need time to learn how to teach in a different fashion.

- Effective learning requires feedback.

  Feedback from your implementation colleagues and your students is crucial. Without feedback, you will have no idea of what works and what does not in your attempts to implement a new innovation.

- Build on success.

  We all like to do things that we know we can do well. If something works, keep using it. Expand on your successes by using them as jumping-off points for implementing new innovations.

- Plan to gain experience as you use new strategies.

  As the old adage goes, "Practice makes perfect." (With practice, your areas of weakness can turn into successes.)

- Learning should extend beyond your classroom experiences.

  Try to apply some of the new strategies you are learning to out-of-class situations, such as during new experiences with your family, while teaching an inservice lesson, or when presenting at a professional meeting.

- Learning takes time.

  Expect that it will take several years before you feel completely adept at using some of the new innovations.

Figure TR1.18 **Example of How You Might Evaluate Your Current Program**

Program Innovation	Current	Long-term Changes in Practice	How Changes Will Be Made Short-term and Long-term Actions
Unifying principles	Don't use.	Organize biological content around six principles.	Point out to learners the unifying principle of the unit being studied. Make frequent reference to the principle throughout the unit of study. Make connections to unifying principles in past and future units.
Focus on biological concepts	Assemble a list of topics from last year's syllabus	Focus more on major biological concepts.	Add content only as needed for learners to complete the conceptual development required by an activity. Resist the temptation to add terms that are not directly relevant to the activity or to the learners. Minimize topics discussed in lecture, and increase the number of activities that introduce and reinforce major biological concepts. Note: Add your own intended actions in the spaces below.

Figure TR1.18 Example of How You Might Evaluate Your Current Program *(continued)*

Program Innovation	Current	Long-term Changes in Practice	How Changes Will Be Made Short-term and Long-term Actions
Instructional model	Don't use one. Mostly lecture on biological content.	Organize program around the 5E model. Focus on critical thinking and problem solving. Allow learners to construct their own understandings.	
Science as Inquiry	Not explicit or thoughtfully developed.	Add investigative experiences that develop learners' ability to use and articulate processes of scientific inquiry.	
Science and Humanity	Occasionally relate studies to situations relevant to students.	Increase the opportunities learners have to practice applying biology to personal and social decision making.	
Assessment strategies	Use multiple-choice and fill-in-the blank exams.	Provide varied assessments that match the learning goals.	
Cooperative learning	Partner students occasionally, to share lab materials.	Use frequently to integrate learning strategies, to conduct inquiry-oriented activities and to prepare students for class discussions.	

Team Evaluation

An important part of evaluation involves looking at the effectiveness of your entire biology course. This kind of evaluation focuses on the extent to which your course has achieved its stated goals or objectives for the program and its learning outcomes for the students. Discuss as a team the question, What do our students know and value, and what skills can they demonstrate at the end of our classes? How does the students' level of achieved knowledge and skills compare with the level of knowledge and skills that we sought to give them?

It is a good idea to reevaluate the strengths and weaknesses of the team and its members at the beginning of each new school year. The following questions will help your team establish an evaluation dialogue:

1. How effectively is our team monitoring the implementation process?
2. How open and effective are the channels of communication among the team members?
3. How effectively do the implementation team members respond to problems and concerns of the students, parents, teachers, and administrators?
4. What things could the team members learn from each other or with what things could they help each other?
5. What aspects of our implementation plan do we need to change so that we can implement the program more effectively?
6. In what areas have we made the most progress? Which of our goals are we closest to meeting?
7. What are some of the positive changes that we have seen in the students in our classrooms?

Also, at the beginning of each new school year, each team member should fill out a new *Personal Implementation Questionnaire* (copymaster IG.1) and check where he or she is on each of the implementation continuum sheets. It is likely that each team member will move along each continuum at different rates, depending on the students' personal learning styles, the teachers' particular teaching styles, and the novelty of each innovation. Next, as a team, complete a new *Needs Assessment Worksheet* (copymaster IG.2) to determine how far you have come and what still needs to be done.

Your team must continually monitor its progress at implementing the program; continue to adapt the program to meet the specific needs of your school community; find other ways to involve the parents, community, and school district in the new program; and find ways to help new teachers who join the staff. This reflective process should enable your implementation team to identify the areas of greatest success and the areas that need the most attention in the next phase of implementation. Then you can develop effective ways of responding to these areas of concern as well as ways to share successes throughout the next year.

1.6 Planning for Continuing Success

A. New Teachers Joining Staff

It is important that your implementation team establish a plan to help new teachers who come into the program after a school already has begun the implementation process. All of the work that you have accomplished to implement the program and to make it fit your needs should make teaching this program easier for new teachers. Nevertheless, new teachers will need to understand and be comfortable using the various print, technology, and pedagogical features of the program. New teachers also will need to become familiar with the personalities and working relationships of existing team members.

New teachers should become part of the implementation team immediately. Ask them to complete the *Personal Implementation Questionnaire* (copymaster IG.1) to evaluate themselves. Your team also may wish to complete a new *Needs Assessment Worksheet* (copymaster IG.2) to determine how the new teachers affect your team's implementation plan as a whole. This would provide both the new teachers and the implementation team with information that should help new teachers in the most effective and efficient ways. It also is important that the new teachers take advantage of the ongoing staff development that you designed to benefit the implementation process.

For the first unit or two, it might be valuable to rely on team teaching, pairing the new teacher with another who is experienced in teaching the program. When the new teacher is comfortable teaching alone in the classroom, he or she then should establish a mentor relationship with the experienced teacher. Even if it is not possible to arrange team teaching, each new teacher should be assigned an experienced mentor teacher.

B. Helping Substitute Teachers

Because of the many innovations in *BSCS Biology: A Human Approach*, it is important that you consider ways to help the substitutes who might come into the classroom for a day, a week, or an extended time. Encourage your district to identify the substitutes who are experienced in teaching biology. Suggest that these teachers attend as many of the staff-development workshops for this program as possible. These workshops will help them learn about the special features and overall philosophy of the program.

If this is beyond the scope of your district, a more practical solution is to assign one of your students to assist the substitute. Being chosen for such responsibility could be a reward for a student who exhibited outstanding effort in working with classmates collaboratively or in applying science process skills. Coach the student assistant ahead of time regarding potential trouble spots or difficulties that might arise during a particular activity.

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1.8 Appendix A: Sample Agenda for a Training Institute

Goals

The goals of this training institute are to

- provide teachers with enough knowledge and experience with *BSCS Biology: A Human Approach* to enable them to begin using the program effectively in their classrooms,
- encourage teachers to approach teaching differently, and
- help teachers focus on interacting with students as active participants in the learning process rather than as passive recipients of knowledge.

Outcomes and Indicators of Success

By the end of this institute, the participants should

1. be familiar with the components of the curriculum.

They will demonstrate their familiarity by

a. describing how to use the student activities and essays and the teacher's edition, and

b. being able to find information in their teacher's books.

2. be aware of the philosophy of the curriculum.

They will demonstrate their awareness by

a. identifying how to focus activities according to a particular stage of the BSCS 5E instructional model,

b. describing how they would help students conduct an open-ended scientific inquiry,

c. discussing the types of changes that teaching this curriculum implies for them, and

d. participating in the development of an alternative assessment.

3. be prepared to teach the first unit of the curriculum.

They will demonstrate their preparation by

a. constructing a 5E flow for Unit 1, and

b. developing a personal plan for teaching Unit 1.

Preparations

Read the outline of the training institute (**figure TR1.19**) and make modifications as necessary for your group. Make transparencies or copies of Copymasters IG.1 through IG.9 if you think they will assist you in the training. Assemble materials needed for small groups to carry out any activities you select to model from the *BSCS Biology: A Human Approach* program.

Figure TR1.19 Training Institute Overview

Day	Time	Goals
1	morning	Become familiar with components and philosophy of curriculum
1	afternoon	Become familiar with constructivism and the BSCS 5E model
2	morning	Practice using BSCS 5E model in planning Chapter 1 lessons
2	afternoon	Become familiar with Science as Inquiry subtheme and unifying principles
3	morning	Plan how to implement the Science as Inquiry subtheme
3	afternoon	Become familiar with embedded assessment and the Science as Humanity subtheme
4	morning	Become familiar with cooperative learning
4	afternoon	Prepare to implement the curriculum

Day 1: Morning Session

Purpose: By the end of this session, participants should have a general idea of the components and philosophy of the curriculum.

Engage

Hold a group discussion of the question, What is your perception of how this curriculum differs from others?

Explore

Have the group look at unit titles. Ask them, What do the titles suggest about the way the program is organized?

Do the *Engage* section activity *Thinking as a Scientist Thinks*.

- Read the termite scenario.
- Have the participants examine the Process and Procedures section.
- Ask the participants, What questions come to mind about this scenario? How would you proceed to get a more precise handle on the situation? Each group must report ideas orally.
- Refer to the strategies in *Thinking as a Scientist Thinks* in the *Engage* section of the teacher's edition for potential responses to the questions above.

Discuss with the group, What does this activity suggest about some major subthemes that are incorporated into the program? Refer to the activity *You and the Science of Biology* in the teacher's edition for potential answers.

Explain

Give a brief overview of the program that explains the unifying principles, conceptual approach to learning biology, and the two major subthemes. Copymasters IG.3 and IG.4 will help you structure your overview.

Elaborate

Have the participants work in teams to examine Chapter 1. Have them prepare to discuss what unifying principles are present, how conceptual teaching and learning are approached, how learning strategies are incorporated, and how Science as Inquiry and Science and Humanity are incorporated into this chapter.

Ask different teams to lead the discussion for each feature. Each discussion should take about 10 to 20 minutes.

Evaluate

Ask teachers to plan what additional content, if any, they are likely to add and how they will do this without making the chapter too lengthy to teach. Also, ask them to plan how they will ensure that the subthemes are emphasized during this chapter.

Day 1: Afternoon Session

Purpose: By the end of this session, the participants should be familiar with constructivism and the BSCS 5E instructional model, which forms the framework for teaching the curriculum.

This session should help participants see that everyone must deal with their previous understandings as they experience new learning situations. Use a situation that is not likely to fit anyone's current understanding and take them through to a new conceptual understanding using the BSCS 5E model. One possible activity is the *Burning Candle Experiment* (Appendix B in this implementation guide). It is a brief experiment that illustrates some processes that occur in a physical/chemical system. Most people will need to think through what is happening and test some hypotheses in order to construct an understanding of how the system works.

As you take the participants through the lesson, try to do two things simultaneously. First, try to help them construct an understanding of what is happening in the experimental system, thus modeling how the constructivist theory applies to teaching. (Do not tell what is happening.) Then try to have the participants construct an understanding of how they are learning, thus illustrating that adults as well as children construct their understanding by interacting with materials and by trying to fit what they are seeing and doing with how they presently perceive the world.

This session should cover the engage, explore, and explain stages of the constructivist BSCS 5E instructional model. In the following lesson, the facilitator's comments are given in quotes. Comments in italics are directions, expected effects, or possible answers.

Engage

"We are going to look at how people learn. To do this more realistically, we will move outside the field of biology and try to learn how a simple system works. But first, tell me, how do you think people learn something new? **(List comments.)** What is the process you or your students go through when you are learning?" ***(Make a list on the board as participants discuss.)***

Explore

Conduct the burning candle experiment (from Appendix B). "Observe the following setup. What do you think will happen when I place this beaker over the burning candle? Discuss this with your team and write down everything that you predict will happen and why you think so. **(Pause.)** Share some of your predictions with the class." ***(Likely answer: the candle will go out because all the oxygen will be used up.)***

Learning process: "How did you come up with your prediction(s)? **(Pause for responses.)** What did you use as the basis for making the predictions?" ***(Likely answer: previous experience)***

"Observe what happens when I put the beaker over the burning candle. What happened? ***(Candle went out and water rose in the beaker.)*** How did the actual event relate to your predictions?"

Learning process: "Discuss with your team: When the event did not match predictions, what did you feel? What did you think? How did this (unexpected) result (the water rising) affect your thinking about the event?" ***(Likely answers: I was surprised. I wanted to know why the event happened the way it did. I started thinking more about the science and how I could explain it.)*** Briefly discuss with the class.

"In your team, discuss this question: What are some possible reasons for why the events you observed occurred (the water rose and the candle went out)? Record your ideas. How can we test these hypotheses? What sorts of predictions can we make for each of the hypotheses you developed? Work in teams to develop some predictions for each hypothesis, then we will discuss them as a class." ***Record hypotheses and predictions on the board.***

"Now that you have come up with some ideas and predictions, let's test them." ***Participants begin experimenting. Go from group to group and continue asking probing questions about what they are doing and what results they get. Refer to the notes for the teacher given at the end of the experiment in*** **Appendix B.**

Learning process: In teams and then as a class: "What were you thinking and doing as you went through this process? What was I, the teacher, doing? How did I influence your thinking and actions? What kinds of science did you learn during this activity? ***(Possible answers: science processes, concepts about how air and water molecules interact in a small system, not too many facts or details.)*** Do you think you will remember what you discovered during this experiment? Why or why not?"

Explain

"What if instead of doing this activity, I diagrammed the setup and asked you what would happen. You probably would give the same answers that you first gave above. Then what if I told you that water will rise because of the heat—the heat of the candles makes the air expand and when the fire is extinguished, water rises as the air cools. Would you have believed me? Why? Did I give you a complete explanation?"

"If I came back to you 2 months after I ***told*** you what happened and asked you to explain what happens with this setup, what would you have been likely to respond? Your initial predictions? My explanation? Now that you have done some experimenting, what would you tell me 2 months from now if I ask you what happens with this setup?"

"The 'telling' scenario demonstrates how many of us did much of our teaching in the past. The experimentation is an example of what a teacher would do when teaching in accordance with constructivist theories of learning. Discuss with your group and write down what you think students might learn in each instance and how they might learn it. Also, discuss the tradeoffs involved between the time it takes to teach a concept and the level of understanding the students retain."

Go into a formal explanation of the 5Es. Include charts of what the teacher does at each stage of the model (copymasters IG.5–IG.9). Emphasize the need for students to take charge of their own learning in order to construct their own understanding. Ask participants to write down what each E means to them as a teacher and what they think it might mean to their students.

Engage: Catches student interest and attention; serves as a way to determine students' prior knowledge.

Explore: Provides a common experience (be sure to emphasize this point) and another chance to discover students' prior knowledge and conceptions. Ask yourself, How much do students already know? Where can I find opportunities to challenge their current ideas? Probe the depth of students' understanding. Use your assessment of student understanding at this point to guide remaining instruction.

Explain: Allows students to make meaning out of their common experiences and to formalize their understanding. Pushes students to construct their own explanations. Different students may require different lengths of time to develop adequate explanations.

Elaborate: Lets students apply new knowledge/conceptions to another situation to reinforce or expand their understanding. Helps you ascertain whether what you did to address misconceptions or incomplete understandings was effective. Multiple events may be occurring in a classroom at this stage: some students may need additional time in the explain phase while others continue to elaborate.

Evaluate: Permits students and the teacher to evaluate the progress students have made constructing and expanding their understanding.

Look at figures TR1.3 and TR1.4 (in the implementation guide), which explain what the teacher does and does not do and what the student does and does not do in the BSCS 5E model. Emphasize that the teacher's role involves monitoring students' current ideas and ways of thinking and guiding students into constructing more adequate knowledge.

Day 2: Morning Session

Purpose: By the end of this session, the participants should incorporate the BSCS 5E model in a set of lesson plans that they design.

Continue with additional explain as needed, but spend most of the time on the elaborate and evaluate portions of the lesson on 5Es.

Elaborate

Spend time examining how the BSCS 5E model is used in the *Engage* section. Have participants do some of the activities as you model how each stage of the BSCS 5E model is emphasized. Use the *Outcomes and Indicators of Success* for each activity as a guide for identifying what concepts to emphasize.

Note: Activities may need to be abridged to communicate their essence in a short amount of time.

Evaluate

Now have participants work in small teams to examine the chapter goals and the activities in Chapter 1. Each team should plan how to introduce and conduct each activity such that the chapter expresses a smooth conceptual flow as it moves through the 5Es.

Day 2: Afternoon Session

Purpose: By the end of this session, the participants should become familiar with how Science as Inquiry and the unifying principles are used to teach conceptual biology in this curriculum.

Use the BSCS 5E instructional model to present this session. This afternoon, you will present the engage, explore, and explain stages of Science as Inquiry and the conceptual teaching of biology.

Try to reinforce what was presented yesterday on constructivism and the 5Es. Keep the presentation interactive and moving at a good pace. This is the point in the institute where participants generally “settle in” for the duration, and it is essential that you keep them highly involved in what they are learning.

Engage

Ask participants to refer back to Day 1 and the termite activity. Discuss what they think makes the activity interesting and challenging for students. ***(Likely answer: They feel like they are doing real science and looking for answers to a real question.)***

Explore

Do one or more activities from Chapters 1 and 2 of the student book to explore Science as Inquiry. *Primates Exploring Primates, Exploring Change,* and *Evidence for Evolution* are particularly strong in inquiry skill development. After doing the activities, ask participants, What are the basic components involved in the process of “doing” science? How does this process aid in understanding concepts? facts? How does this process differ from didactic teaching approaches?

Explain

Use activities from Chapter 2 of the student book to help participants develop an explanation of how and why inquiry is such an important subtheme in *BSCS Biology: A Human Approach*. Bring in the importance of inquiry to developing lifelong problem-solving and critical-thinking skills and of conceptual understanding of biology to science literacy.

Homework

Ask participants to review Chapter 3 of the student book and develop a conceptual flow of the major concepts that manifest the unifying principle of evolution.

Day 3: Morning Session

Purpose: By the end of this session, the participants should construct a plan for systematically developing the Science as Inquiry subtheme for Unit 1.

This session consists of the elaborate and evaluate stages for the lesson on Science as Inquiry.

Elaborate

Use activities from Chapter 3 of the student book to elaborate on inquiry as more than the processes of experimentation. Ask participants to investigate how an information lesson can be taught as inquiry. Ask them to look for the inquiry components of asking questions, gathering information, and proposing explanations.

Evaluate

Have teachers develop lesson plans for Chapter 3 that reflect how they will introduce and conduct lessons to emphasize the Science as Inquiry theme. Also, make sure that teachers continue to focus on facilitating conceptual learning via the constructivist BSCS 5E model. Lesson plans should reflect an emphasis on the appropriate stage of the BSCS 5E model as well as a strong emphasis on Science as Inquiry.

Day 3: Afternoon Session

Purpose: By the end of this session, participants should become familiar with embedded, alternative assessments and the Science and Humanity subtheme of the curriculum. They will practice connecting assessment with teaching and learning and recognizing assessment activities that are embedded in the instruction.

Engage

To make teachers aware of their present conceptions about assessment, begin with a general discussion: What do teachers assess and why? What types of assessments do you use? What is the anticipated outcome of teaching this curriculum? How would the design of assessments need to change to match these outcomes? Why use alternative assessments?

Explore

Help participants examine how this curriculum deals with assessment in Unit 1. Ask the participants to identify what the curriculum developers expect students to know and be able to do and how the curriculum makes these expectations clear. Then ask the participants to identify tasks built into activities throughout the unit that might help teachers assess what the students know and are able to do.

Explain

Use some Science and Humanity activities from the unit to look at how the outcomes and indicators given in the teacher's edition can be used to identify what students should know and be able to do. *Portraying Humankind, A Long Childhood, Lucy, A Cold Hard Look at Culture,* and *Explaining the Zebra's Stripes* show a range of Science and Humanity treatment. Also, go through the activities in Chapter 3 and point out how each E can be used as an embedded assessment. Refer to the *Guide to Assessment,* where opportunities for summative and formative assessments are listed.

Return to *Portraying Humankind* in Chapter 1 of the student book and guide participants through the process of constructing a rubric from a set of clear criteria. Remember that the key to good rubric design is for the designers to be very clear about the goal of the learning experience, and thus the assessment, and the criteria used to judge completion of the assessment task.

Elaborate

Ask participants to review the Unit 1 Assessment from the *Guide to Assessment* to determine if they might want to modify it to more closely match the things they plan to emphasize in the unit.

Evaluate

Have the participants conduct a brainstorming session of ways that current grading practices could be expanded to better communicate a student's successes and needs for improvement to the student, the student's parents, and other teachers. Participants should include in their method an evaluation of the student's science process abilities as well as conceptual understandings.

Day 4: Morning Session

Purpose: By the end of this session, the participants should become familiar with how collaborative learning works, how it is incorporated into the curriculum, and how it can be extended.

Engage

Conduct the *Cooperating like a Scientist* activity, pages 6–7 in the student text, with the participants. Ask the participants to identify the elements that made this activity a collaborative learning activity. Try to elicit most, if not all, of the essential elements given in the Collaborative Learning section (Section 2 of the *Teacher Resources*).

Note: This activity is written as if teachers were doing it with their students. Redirect the discussion as necessary to make it more appropriate for your participants. Point out to the teachers that this activity provides a good way to introduce collaborative learning to a class.

Explore

Ask participants what evidence they have seen in the curriculum for the support of collaborative learning. Next, ask for examples of activities in which it could be incorporated and what makes these activities particularly good for collaborative learning.

Explain

Explain how collaborative learning has been included in the program. Refer as needed to the Collaborative Learning section in the *Teacher Resources* (Section 2).

Elaborate

Ask participants to choose at least one activity in each chapter of Unit 1 that they could make collaborative. Have them identify the working-relationship skills they might emphasize and the roles they might assign. Some of the figures in the Collaborative Learning section of the *Teacher Resources* will aid the participants in this task. Figure TR2.1, which lists working-relationship skills, and figure TR2.6, which gives the differences between collaborative and group work, might be especially useful to the participants at this point.

Evaluate

Ask the teachers to state at what level they plan to implement collaborative learning in the coming year, then over the next 3 to 5 years. Have them explain their rationale.

Day 4: Afternoon Session

Purpose: By the end of this session, the participants should have begun preparing to implement the curriculum.

Engage/Explore

Ask the participants to anticipate how they will approach implementation. Participants should identify their most pressing needs and how they plan to meet these needs.

Give the participants some basic guidelines regarding how to organize their teams and plan team meetings. Teams should include, at a minimum, all the teachers using the program and those decision-makers who can most strongly influence the program, for example, the principal, the science coordinator for the school or district, and perhaps the head of the purchasing department. Teams should meet frequently—once each week would be good; once every 2 weeks would be minimal. Meetings should focus on discussions of the most recent lessons, preparation for upcoming lessons, and implementation of the curriculum's pedagogical innovations.

Explain/Elaborate

Provide time for each participant to develop a personal plan for success with this program. Have them respond to these questions:

- What am I really looking forward to in the coming year?
- How will I prepare students for the program?
- What will parents want to know about the program? From whom will I seek support?
- How will I vent my frustrations?
- How will I obtain my materials?

Ask each team to spend time together preparing a plan for success. This plan should include immediate actions the team will take to enhance its ability to implement the program successfully. It also should incorporate some elements of group consensus regarding their responses to the questions above.

Evaluate

Have the participants evaluate the success of the institute in meeting the goals defined on Day 1 and evaluate the usefulness of the institute.

Note: During the first year of implementation, the teams should plan three to four additional inservice workshops to deal with upcoming unit content and components of the program with which team members may be having difficulty.

1.9 Appendix B: Burning Candle Experiment

Materials (per team)

6 small candles (birthday size)

transparent glass cylinder (beaker, jar, etc.)

putty or clay, enough to hold 6 candles upright in the tray

shallow tray

1 book of matches

metric ruler

water, enough to fill the tray about 1 inch deep

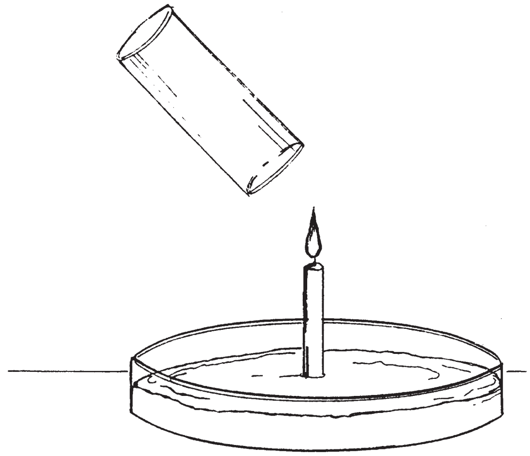
Process and Procedures

1. Working in teams, observe and record what happens when the cylinder is placed over a burning candle anchored in a tray of water. See **figure TR1.20** for a diagram of the setup.
2. Develop several explanations for what you have observed.
3. Test each explanation using any of the materials provided in any manner that the group wishes. Appoint a recorder to write down the steps followed and the observations made.
4. Analyze your data and present your conclusions to the class.

Analysis

Compare your methods and results with those of other groups. Come to a class consensus about what processes occurred when the cylinder was placed over the burning candle.

Figure TR1.20 Setup for the *Burning Candle Experiment*



Notes for the Facilitator

Instruct the participants to proceed by observing what happens when they place the cylinder over the burning candle (figure TR1.20). Let them explore the phenomena for several minutes. Then hold a brief discussion. Ask questions such as, Why did the candle go out? and What caused the water to rise?

Write these on the board, and then ask for possible explanations. Most participants will know that the candle went out because it ran out of oxygen. Ask them how they know this. In response to the question about what caused the water to rise, they may suggest that the water rose to fill the space left when the oxygen is used up. Or, they may suggest that the carbon dioxide produced has a lower partial pressure than the oxygen used. Continue to record their suggestions and explanations on the board.

Instruct the groups to design ways of testing their explanations for why the water rose in the cylinder. One method for testing the oxygen replacement hypothesis is to burn more candles. If this hypothesis is true, then five candles should go out more rapidly than one candle because the same amount of oxygen is present while more candles are using it. Also, the water should rise to the same level.

The participants will find that while the candles do extinguish more rapidly, the water actually rises to a higher level; thus, their hypothesis is not supported. This result may lead the students to wonder about the heat generated by the candles—more candles mean more heat and thus the water can rise higher. You should suggest this possibility if the participants do not generate it.

Eventually, teams should conclude that while the candle went out because the oxygen was used up, the lack of oxygen is not the primary reason that the water rose. They may come to the conclusion that heat caused the water to rise. Ask them how heat might have done it. If air expands when heated, shouldn't it only shrink back to where it started? In this case, the cylinder ended up with less air (the water rose). Why? Shouldn't we have seen the water level in the beaker being pushed down as the air took up more space during expansion? (Possible answer: Maybe the air molecules went into the water. How can you test this hypothesis?)

Once the participants begin to consider that heat may somehow have caused the water to rise, they must envision a mechanism to explain how this happened. Eventually, participants will realize that heat might cause the gases in the cylinder to expand and then to exit the cylinder as it is placed over the candles. Then as the gases in the cylinder cool, a partial vacuum is formed and water is literally pushed up the cylinder by external air pressure. The prediction that arises from this explanation is that, as the cylinder is put over the candle and the flame extinguishes, bubbles should emerge from the water as gases escape. Participants indeed will see bubbles if they watch for them.

Personal Implementation Questionnaire

1. Describe your best hopes regarding implementing *BSCS Biology: A Human Approach* this year.

2. Describe your worst fears regarding implementing *BSCS Biology: A Human Approach* this year.

3. Please rank your knowledge, experience, and comfort level for each of the following components of the curriculum. A "1" means that, in general, you are very knowledgeable, experienced, or comfortable in a particular area. A "5" means that you are not knowledgeable or experienced, or do not have a high comfort level in this area.

	Knowledge	**Experience**	**Comfort**
a. Conceptual nature of the curriculum	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
b. The BSCS 5E instructional model	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
c. Learning strategies	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
d. Science as inquiry	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
e. Activity-based learning	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
f. Alternative assessment	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
g. Collaborative learning	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

4. Please rank the above features of the curriculum in order of importance for your own professional development. List the most important first and the least important last.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

7. ______________________________

Needs Assessment Worksheet

Staff Development

Using the results from the Personal Implementation Questionnaires, rate your implementation team by circling a number on the scale of 1 to 5. A "1" means that your team members are very knowledgeable, experienced, or comfortable in a particular area. A "5" means they are not knowledgeable or experienced, or do not have a high comfort level in this area.

	Knowledge	Experience	Comfort
1. Conceptual nature of the curriculum	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
2. The BSCS 5E instructional model	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
3. Learning strategies	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
4. Science as inquiry	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
5. Activity-based learning	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
6. Alternative assessment	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
7. Collaborative learning	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Resources and Facilities

Rate your school resources and facilities from 1 to 5. A "1" means very good, while a "5" indicates a serious deficiency.

1. Availability of science resources and supplies	1	2	3	4	5
2. Media resources and computers	1	2	3	4	5
3. Science room facilities	1	2	3	4	5
4. School or building facilities	1	2	3	4	5
5. Budget appropriations	1	2	3	4	5
6. Class schedules are flexible enough to offer sufficient laboratory/inquiry time	1	2	3	4	5

Participants in the Implementation Process

Rate the following groups on their interest/involvement in the change process for science learning. A "1" indicates extensive involvement, while a "5" indicates minimal involvement.

1. School administrators	1	2	3	4	5
2. Other teachers	1	2	3	4	5
3. Parents	1	2	3	4	5

Distinguishing Characteristics of *BSCS Biology: A Human Approach*

1. Unifying themes provide the structure for the biological content.

2. Two subthemes are used as threads for communicating the role and importance of biology to humans: Science as Inquiry and Science and Humanity (culture, history, ethics, technology).

3. The instruction of major concepts is organized around the BSCS 5E instructional model based on the constructivist theory of learning. Learning strategies are embedded throughout each cycle of the instructional model.

4. Collaborative learning is used as a strategy to model the process scientists use when collaborating and to increase classroom manageability.

5. Assessment strategies, including scoring rubrics, are embedded and varied and are based on the philosophy that assessment itself should be a learning experience.

6. Educational technology is integral to the program, although nontechnological alternatives are offered. The program includes videos, computer simulations, and microcomputer-based laboratories.

7. Students use a science notebook throughout the course to develop conceptual continuity.

Organization of Content around Six Unifying Principles of Biology

Engage Section Introduction to the science of biology, the nature of science, and the structure of the program

Unit 1 Evolution: Change in Living Systems

Unit 2 Homeostasis: Maintaining Dynamic Equilibrium in Living Systems

Unit 3 Energy, Matter, and Organization: Relationships in Living Systems

Explain Section Full and independent student inquiry

Unit 4 Continuity: Reproduction and Inheritance in Living Systems

Unit 5 Development: Growth and Differentiation in Living Systems

Unit 6 Ecology: Interaction and Interdependence in Living Systems

Evaluate Section Complete program assessment

What the Teacher Does

ENGAGE

What the teacher does	
that is **consistent** with the BSCS 5Es	that is **inconsistent** with the BSCS 5Es
• Creates interest • Generates curiosity • Raises questions • Elicits responses that uncover what the students know or think about the concept/topic	• Explains concepts • Provides definitions and answers • States conclusions • Provides closure • Lectures

What the Teacher Does

EXPLORE

What the teacher does	
that is **consistent** with the BSCS 5Es	that is **inconsistent** with the BSCS 5Es
• Encourages the students to work together without direct instruction from the teacher • Observes and listens to the students as they interact • Asks probing questions to redirect the students' investigations when necessary • Provides time for the students to puzzle through problems • Acts as a consultant for the students	• Provides answers • Tells or explains how to work through the problem • Provides closure • Tells the students that they are wrong • Gives information or facts that solve the problem • Leads the students step-by-step to a solution

What the Teacher Does

EXPLAIN

What the teacher does	
that is **consistent** with the BSCS 5Es	that is **inconsistent** with the BSCS 5Es
• Encourages the students to explain concepts and definitions in their own words • Asks for justification (evidence) and clarification from the students • Formally provides definitions, explanations, and new labels • Uses students' previous experiences as the basis	• Accepts explanations that have no justification • Neglects to solicit the students' explanations • Introduces unrelated concepts or skills

What the Teacher Does

ELABORATE

What the teacher does	
that is **consistent** with the BSCS 5Es	that is **inconsistent** with the BSCS 5Es
• Expects the students to use formal labels, definitions, and explanations provided previously • Encourages the students to apply or extend the concepts and skills in new situations • Reminds the students of alternative explanations • Refers the students to existing data and evidence and asks: What do you already know? What do you think? (strategies from explore apply here also)	• Provides definitive answers • Tells the students that they are wrong • Lectures most of the time • Leads the students step-by-step to a solution • Explains how to work through the problem

What the Teacher Does

EVALUATE

What the teacher does	
that is **consistent** with the BSCS 5Es	that is **inconsistent** with the BSCS 5Es
• Observes students as they apply new concepts and skills • Assesses students' knowledge and/or skills • Looks for evidence that the students have changed their thinking or behaviors • Allows the students to assess their own learning and group-processing skills • Asks open-ended questions such as, Why do you think ...? What evidence do you have? What do you know about x? How would you explain x?	• Tests vocabulary words, terms, and isolated facts • Introduces new ideas or concepts • Creates ambiguity • Promotes open-ended discussion unrelated to the concept or skill