

Teacher Scenario A: Mr. Coles

Background

Mr. Coles teaches middle school science at the same school as Ms. Rivera. The district has developed a K-12 scope and sequence, a pacing guide, and has recommended a textbook for teachers to use to plan for instruction. The school is focused on using best practices in teaching that support improved learning and achievement for all students. Since the school is also asking teachers to use data to inform instruction, the science department has agreed to give common assessments – end-of-unit chapter tests that all students in the same course take no matter which teacher they have – so that teachers can learn from the data.

Mr. Coles attended a summer professional development institute along with other teachers from his school. The teachers are working together through their school-based professional learning community to implement the ideas and strategies learned during the institute. Mr. Coles and Ms. Rivera attended different institutes and are part of different working groups.

Lesson 1

On the first day of the new chapter on Interdependent Relationships in Ecosystems, Mr. Coles starts the class as he does every new topic: with a question posted on the SmartBoard linked to the district’s state test. After a quick review of students’ written responses and the correct answer, students are asked to take out the key vocabulary terms that they had defined as part of their homework to prepare for their new chapter. Students had defined the following Tier 3 vocabulary terms: *ecosystems*, *communities*, *populations*, *biotic*, and *abiotic*. He reviews the definitions with students and writes the terms on the Word Wall that will remain there throughout the chapter. Mr. Coles introduces the chapter by giving a short PowerPoint presentation on biotic and abiotic factors and how they can affect populations within ecosystems, while students fill in their guided notes, a strategy they used in a previous chapter. After the presentation Mr. Coles does a read-aloud from the textbook on biotic and abiotic factors. As students read, Mr. Coles has them stop at the end of each paragraph and paraphrase what they read on sticky notes. Then he has them work in pairs to take turns verbally summarizing the paragraphs using their sticky notes as a reference. At the end of the class, he has students write down two biotic and two abiotic factors using a nearby park as an example. For homework, students are assigned four “Connect Questions” from the chapter in their textbook that they covered in class.

Lesson 2

After reviewing homework, Mr. Coles shows students samples of lichen he had collected on the school grounds. He explains that lichen is an example of *symbiosis*, where two organisms live in close association with each other. He then does a mini-lesson on *symbiosis* and explains the difference between *mutualism*, *commensalism* and *parasitism*. Students copy the four definitions into their notebooks and the terms are added to the Word Wall. Mr. Coles shows students a brief video called *Symbiosis: Mutualism, Commensalism, and Parasitism* by Mark Drollinger. After the video, students are given questions to discuss with their partners: What is the difference between Mutualism and Commensalism? How does Parasitism affect the parasite and how does it affect the host? Then Mr. Coles passes out a graphic organizer with three columns for the three types of symbiotic relationships. He models filling out the first column (mutualism) using the example of the lichen he has brought in. For the second column (commensalism) he plays a short video of a leopard shark swimming with remora on its back. He tells students that the shark is not harmed by remora, but that remora get a “free ride,” making this an example of commensalism. He has students to complete the second column with a partner. For the third column (parasitism), he plays the HHMI Biointeractive video *Malaria, Human Host*, pausing the video several times to review the main ideas with students and allowing them to record

information in their graphic organizer. After the students have completed their graphic organizers Mr. Coles discusses the homework assignment. The assignment is a five paragraph explanatory essay on symbiosis describing the three types of relationships with real world examples. Students receive a checklist and a rubric, and are allowed to use the remainder of the class time to start working on their essays that will be due in two class periods.

Lesson 3

Mr. Coles opens the third lesson with a “Do Now” with two questions from the state test. After a short discussion and review of the correct answers, he passes out a news article titled “When Lions Abound, Hyenas pick a new menu” which describes a real-world example of competition between lions and hyenas. He reads the article out loud with students and has them annotate, paraphrase, and summarize in the margins. He gives them two follow up questions: 1) According to the author why did the competition between lions and hyenas increase between 2005 and 2008?, and 2) Explain what the author means by his concluding sentence: “Hyenas’ magnificent jaws offered them another option, giving them plenty of reason to laugh at those pushy lions.” Students discuss their answers in pairs and then have a class discussion led by Mr. Coles. In the discussion they collectively come up with a definition of *competition* which is added to the Word Wall. As an exit ticket, Mr. Coles has the students compare and contrast symbiosis and competition.

Lesson 4

After collecting the essays assigned in Lesson 2, Mr. Coles begins the class with a “Do Now” in which students explain “predator-prey”, and list of three examples of predator-prey relationships in the wild. Students share their responses with the class. Mr. Coles has prepared three stations on predator-prey interactions which the students rotate through during the lesson. One station had vocabulary terms that students copy in their notebooks and use in a sentence. A second station has various photos with captions showing examples of predator-prey interactions that Mr. Coles got from nature magazines. Students are asked to identify predator and prey in each photo and write a short description of the interaction. A third station is a small group lesson taught by Mr. Coles, in which he explains the idea that populations grow and change over time and that predation is one of the main forces influencing population size. He shows students graphs of predator and prey populations and explains how they can use the graphs to answer questions about both populations such as “What happens to the algae population as the number of daphnia increases?” While he is explaining, the students are filling in the guided notes worksheet and are encouraged to ask questions. After students complete all the stations and are back in their seats, Mr. Coles added *predator-prey* to the Word Wall. Next he projects an image of a snowshoe hare and bobcat and asked the students to identify which is the predator and which is the prey. He asks the students to work in pairs and use large sheets of chart paper to brainstorm and list factors that affect the bobcat and snowshoe hare populations. When they were done, Mr. Coles has the partner groups pair up to briefly compare their posters and exchange ideas. At the end of the class Mr. Coles assigns homework: worksheets with population data for deer and wolves on an island for students to graph and answer follow up questions.

Lesson 5

Mr. Coles reserves time in the school’s computer lab to do a virtual predator-prey modeling lab about Canadian lynx and snowshoe hare that he found on eduweb.com. Before starting the lab, Mr. Coles reviews the homework assignment and answers students’ questions. He reviews some of the concepts from the previous class and explains the virtual lab. He also brings their attention to a prominently displayed poster detailing the steps of the scientific method and directs them to follow these steps during the lab. Then Mr. Coles explains the lab in detail: what parameters students will follow, and what data will be obtained and analyzed during the lab. Students work in pairs to develop a hypothesis for

their lab and identify the variables in the simulation. Students then follow the written procedure to complete the lab which has them manipulate variables such as the number of hares that each lynx must catch in order to survive and reproduce. They also produce graphs that serve as their results. For homework students were asked to complete the analysis and conclusion sections of their lab reports. All work is due in two days.

Lesson 6

As part of the preparation for the upcoming test, Mr. Coles starts the sixth day by taking down the Word Wall temporarily and giving a clicker-quiz on the vocabulary words covered thus far in the chapter. He asks students who get the correct answers to explain their answers to the rest of the class. After the quiz, Mr. Coles projects a picture of a human surrounded by different organisms (tomato, bacteria, malaria protozoan, cow, grizzly bear, and another human). Students identify the types of relationships humans have with each of the other organisms. Then Mr. Coles divides the class into two groups; each group receives a different reading. One group gets an article on the negative impact of humans on animal populations, titled "Human Impact on Animal Wildlife & Their Habitat," and the second group receives an article on the positive impact of humans on animal populations, titled "12 Innovative Ways Technology is Saving Endangered Species." Mr. Coles prepares his students for an "accountable talk" discussion where they debate the question "Humans: predatory parasites or mutualistic helpers?" Students are expected to use evidence from their readings, data collected during the lab, and science concepts covered in the class to support their reasoning. For their exit tickets students receive two sticky notes: one blue and one yellow. On the blue note students write their "Gots" (what they learned/understood), and on the yellow notes their "Needs" (questions, concerns, concepts they are still confused about). As students leave the classroom they post the notes on two sheets of chart paper hanging by the door. Mr. Coles reminds students that their lab reports are due the next day and that they should come prepared with questions regarding the approaching unit test.

Lesson 7

Mr. Coles begins class by collecting the students' lab reports. He reminds them that they will spend the whole period reviewing for the chapter test (the grade-level common assessment for the unit), which will be given during the next class. During the first half of the period, Mr. Coles has students work on group projects. Each group gets a large poster board and colored markers to construct a mind map of "Interdependent Relationships in Ecosystems" (students are familiar with mind maps as a result of Mr. Coles collaboration with the ELA teacher). The students have 25 minutes to complete their maps. During this time Mr. Coles circulates among groups and answers questions. When the maps are completed, students did a quick gallery walk of the posters. Next, Mr. Coles distributes the review sheets for the chapter test with all the important ideas from the unit along with the vocabulary from the Word Wall. Students are told that the test will be a performance task in which they will be presented with a scenario and data, and will have to apply their science knowledge to answer a series of questions. Mr. Coles goes over the review sheets, answers questions, and reviews specific concepts as necessary.

Teacher Scenario B: Ms. Rivera

Background

Ms. Rivera teaches middle school science at the same school as Mr. Coles. The district has developed a K-12 scope and sequence, a pacing guide, and has recommended a textbook for teachers to use to plan for instruction. The school is focused on using best practices in teaching that support improved learning and achievement for all students. Since the school is also asking teachers to use data to inform instruction, the science department has agreed to give common assessments – end-of-unit chapter tests that all students in the same course take no matter which teacher they have – so that teachers can learn from the data.

Ms. Rivera attended a summer professional development institute along with other teachers from her school. The teachers are working together through their school-based professional learning community to implement the ideas and strategies learned during the institute. Ms. Rivera and Mr. Coles attended different institutes and are part of different working groups.

Lesson 1

Ms. Rivera starts the lesson by asking students to briefly describe what animals and plants need in order to live and grow. This was something they had already learned in elementary school. After students list food, air and water, Ms. Rivera presents them with the guiding question for the lesson: “How do living things, including humans, interact with each other and with non-living things in an environment?” To generate interest in the topic, she invites students to think about a local environment near their school (such as a playground, park, or garden) and to list the possible interactions among the living and non-living things in that area. Students chart their responses, and compare their lists to other groups’ lists. Ms. Rivera then shows a video about the wolves in Yellowstone National Park. Students learn that all the wolves were gone from the park by 1930 due to overhunting, but that these animals were reintroduced into the park in 1995. In pairs, students discuss how reintroducing the wolves might affect the park and the tourists, cattle ranchers, and local residents who live nearby. Ms. Rivera asks students if they think the wolves stay within park boundaries. As a class they list other animals that live in Yellowstone based on what they saw in the video, and discuss how the wolf presence might affect the numbers and distribution of these other animals. Lastly, Ms. Rivera asks students to consider whether people should be allowed to hunt wolves, and whether people should act to restore wild ecosystems. She concludes the lesson by charting students’ questions about the interactions between animals and people in Yellowstone, and tells them that in their next lesson, they will start thinking about the kinds of patterns there might be in the ways that organisms interact.

Lesson 2

To begin the lesson, Ms. Rivera asks students to review the list of Yellowstone organisms they had generated in the previous lesson. She has them describe how the animals interact, and begins to construct a simple model of these interactions--a food web--based on student ideas. Ms. Rivera tells them that today they will be exploring the effect of the reintroduction of wolves on the food web in Yellowstone National Park. She shares the guiding question, “What impact can an organism have on the interactions between other organisms in a food web?” Students receive Yellowstone Food Web cards for certain organisms and are asked to put the cards into groups and explain their groupings. Next they arrange the cards into a food web and record it in their science notebooks. They compare their food webs with those of other groups and reflect on similarities and differences. Then Ms. Rivera gives students an information sheet that lists what the various organisms in the food web eat. Students revise their food webs according to the new information and record their revisions. In their groups they discuss

the patterns of interaction among the organisms in the food web. Ms. Rivera asks: “Which organisms play a similar role?” “What do you predict would happen to the food web if all the plants died?” Finally, she gives students the Gray Wolf food web card, and has them revise their models again and predict how the wolf might affect the food web. Bacteria, humans and cattle are also added to the food web. At the end of class, Ms. Rivera gives students reflection questions and asks them to describe the patterns of interactions in the food web: “Which animals eat other animals for food?” “Which animals compete for the same food?” “What is an example of a helpful relationship between two animals?” In the last few minutes, students revisit their local ecosystem from the first lesson to reflect on how the food web there might be similar or different from the Yellowstone food web. Their homework is to record their ideas.

Lesson 3

After checking homework, Ms. Rivera tells students that today’s lesson, like the previous lesson, will focus on the patterns of interactions among organisms. She has students share some examples of Yellowstone food web interactions from the previous lesson and tells students that now they will be learning scientific terms for some of these interactions. She shares the guiding question “What types of interactions occur between organisms?” Students watch three videos about patterns of interactions between organisms: one about *predator-prey*, one about *competition*, and the last about *symbiosis* (including *mutualism*, *commensalism* and *parasitism*). After each video, students record definitions of the terms onto a note-taking sheet, and list the organisms from the video. Ms. Rivera gives them a reading with information similar to what was in the videos, and students revise their definitions and list additional examples of organisms that follow each pattern of interaction. During the remaining part of the lesson, students work on identifying the patterns of relationships from the Yellowstone food web using the new scientific terms. Ms. Rivera asks students to explain how humans interact with other organisms in predator-prey, competitive, and mutualistic relationships. At the end of class, Ms. Rivera engages students in a discussion comparing the impact of humans on the Yellowstone food web before and after 1994, asking them to use their new terms.

Lesson 4

Ms. Rivera tells students that they will shift from thinking about individual organisms to thinking about populations of organisms. She shares the guiding question for the lesson, “How do living *and* non-living factors affect populations?” In the first part of the lesson, Ms. Rivera asks students to reflect on the interactions among organisms in Yellowstone. Students turn-and-talk with a partner about what kinds of data might help them learn more about the patterns of interactions they were studying in the previous lesson. Students identify wolves and elk as a predator-prey interaction and ask for more information about the quantity of each species in the park over time. They predict that the data will show an increase in wolves and a decrease in the elk since 1994. Ms. Rivera provides students with data, which they plot on graph paper. As students look at their graphs, Ms. Rivera suggest they think about what may have caused the fluctuations they were observing (the *overall* pattern does show the trend they predicted, but the data is more complex than they expected). She reminds them of the guiding question, and suggests they look at another factor that might have affected the elk population--snow accumulation. Students briefly discuss what they expect to see in the data and then graph the snow data with the elk population data. Ms. Rivera encourages her students to make sense of the data through discussion, asking what may have caused these patterns and trends to occur. She concludes the lesson by telling them that they will continue to think about the wolves in Yellowstone in the next lesson. For homework they have to write a paragraph summarizing how their graphs helped them answer that day’s guiding question.

Lesson 5

Ms. Rivera begins the lesson by asking students to summarize the story of the wolves in Yellowstone. Students recount that humans killed the wolves due to concerns about their effect on wildlife, pets and human safety; that after the wolves were reintroduced they increased in number; and that their predator-prey relationship with the elk caused an overall decrease in the elk population. Next Ms. Rivera shares a reading about the growing population of wolves in the greater Yellowstone region, and the concern about the wolves eating not just elk but also deer, moose, bison and sometimes even livestock and pets. The reading introduces the terms *ecosystem*, *biotic* and *abiotic*. Ms. Rivera has students consider the guiding question, “Does reducing a predator population have a positive or negative impact on an ecosystem?” Students discuss what additional data would be helpful to address this question. Ms. Rivera provides them with data that show the increase in population of some of the other organisms in the Yellowstone food web (birds, plants, etc.). Students say that they think this was due to the decrease in the elk they had observed in the data from their previous lesson. Ms. Rivera then shares a graph that displays four sets of data: the estimated wolf population from 2004-2014, the wolf population at the end of each year, the total number of wolf deaths caused by humans, and the total number of livestock and pets killed by wolves. An argument question is then posted on the wall: “Did wolf deaths caused by humans (ranchers, hunters and park rangers) have a positive or negative impact on the greater Yellowstone ecosystem?” Ms. Rivera posts the positive claim on one side of the room and the negative claim on the other, and students participate in a walking debate in which they move to the side of the room with the claim they think is best supported by the evidence; they are allowed to switch sides at any time. Ms. Rivera had previously introduced accountable talk to her class and has students discuss why their evidence best supports their side of the argument. The homework that night is for students to summarize the best lines of evidence they heard during the walking argument activity.

Lesson 6

Ms. Rivera begins the lesson by telling students that people are considering reintroducing the wolf into the northeastern United States. She shares the guiding question for the day: “What is the impact of reintroducing a predator in an ecosystem that also includes humans?” and asks students to identify the information they will need to answer this question. Students respond that they would need background knowledge about the ecosystem, data about existing populations including humans, and more information about the patterns of interactions among those factors. Ms. Rivera tells students that the focus of the lesson is to construct scientific explanations about how the reintroduction of wolves might affect the ecosystem in the Adirondacks. To support their investigation, she gives them a graphic organizer called the Explanation Tool and reviews the components of the Tool. Students gather in pairs to discuss a reading about populations of white-tail deer over time in the U.S., how humans have affected the population, and the variety of negative impacts that increased populations of deer are having on the ecosystem (both biotic and abiotic factors). The first part of the task has students construct an explanation about the effect of large populations of deer on the forest ecosystem in the Adirondacks using quantitative evidence from the reading. The second part has them construct an explanation that predicts the impact that the reintroduction of wolves in the Adirondacks might have on an ecosystem that includes humans, using their knowledge about patterns in ecosystems that they learned from studying the organisms in Yellowstone. Students are able to identify patterns of interaction in the Adirondack ecosystem using the reading and the data, and to identify the cause and effect relationships that help them predict the impact wolves might have on the deer *and* human populations in the Adirondack ecosystem.

Lesson 7

Ms. Rivera explains that the lesson will be divided into two parts. In Part 1, she shares the guiding question: “What are the patterns of interactions between biotic and abiotic factors that affect ecosystems?” Students work in groups to identify the patterns of interaction in a variety of scenarios to explain the impact of one population on another (including predator-prey, competition and symbiosis), and the impact of abiotic factors on a population. In Part 2 students are presented with the claim “Humans impact ecosystems,” and Ms. Rivera has them construct an argument using evidence and reasoning from their previous lessons to support or refute this claim. After the discussion, Ms. Rivera has students reflect with a partner on how their thinking about ecosystems has changed since the first lesson. She concludes the class by reminding students that they would be given a grade-level common assessment for the unit during the following class period. Students are told that the test will be a performance task in which they will be presented with a scenario and data, and will have to apply their science knowledge to answer a series of questions. She suggests they review what they had written in their science notebooks and scaffolds throughout the lessons, as well as what they had recorded from the various activities done during the unit.



5E Instructional Model

Engage. The engage activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of activating in the instructional sequence

Explore. Experiences in the explore phase provide students with a common base of activities within which students wrestle with their current conceptions about a natural phenomenon through the science and engineering practices in the performance expectation. Learners may complete activities that help them use prior knowledge to generate new ideas, explore questions, design and conduct investigations, analyze and interpret data, and/or develop and use models.

Explain. During the explain phase students are provided opportunities to demonstrate their conceptual understandings and use of science and engineering practices. In this phase teachers or instructional materials employ sense-making strategies and introduce academic language. An explanation from the teacher or other resources may guide learners toward a deeper understanding, which is a critical part of this phase.

Elaborate. Teachers or instructional materials challenge and extend students' conceptual understanding and use of science and engineering practices during the elaborate phase. Through new experiences, the students develop deeper or broader understanding by applying their understanding and practice in a new context. During the elaborate phase teachers may emphasize the crosscutting concept in the foreground of the instructional sequence.

Evaluate. Experiences in the evaluate phase encourage students to assess their conceptual understanding and use of the practices. The experiences allow teachers to evaluate student progress toward achieving the performance expectation(s).

The BSCS 5E Instructional Model: Personal Reflections and Contemporary Implications

By Rodger W. Bybee

More than 25 years ago, a team of colleagues and I created the BSCS 5Es instructional model.¹ At the time, we were developing a new program for elementary science and health and needed an instructional model. With an awareness of the long history of instructional models, the BSCS team adapted the learning cycle described by J. Myron Atkin and Robert Karplus (1962). Their model was used in the elementary school program Science Curriculum Improvement Study (SCIS) developed at the Lawrence Hall of Science in Berkeley, California.

At the time, we only had the proposed BSCS program in mind. We had no idea that in the decades that followed, the instructional model would be widely applied, commonly modified, and frequently used without reference or recognition of its origins. So, almost three decades later, I appreciate this opportunity to reflect on the instructional model and describe some contemporary implications, particularly in the era of *Next Generation Science Standards* (NGSS).

Before a detailed discussion of the instructional model, a few words of background and context seem appropriate. In developing the instructional model, we did take several things into consideration. First, to the degree possible, we wanted to begin with an instructional model that was research-based. Hence, we began with the SCIS Learning Cycle because it had substantial evidence supporting the phases and sequence. The BSCS additions and modifications to the Learning Cycle also had a research base. For example, we integrated cooperative learning (Johnson and Johnson 1987) as a complement to the original model for the SCIS program.

Second, we realized that the constructivist view of

learning required experiences to challenge students' current conceptions (i.e., misconceptions) and ample time and activities that facilitated the reconstruction of their ideas and abilities.

Third, we wanted to provide perspective for teachers that was grounded in research and had an orientation for individual lessons. We asked—what perspective should teachers have for a particular lesson or activity? Common terms such as engage, explore, explain, elaborate, and evaluate signaled the perspectives. In addition, we wanted to express a coherence for lessons within an instructional sequence. How does one lesson contribute to the next, and what was the point of the sequence of lessons?

Finally, we tried to describe the model in a manner that would be understandable, usable, and memorable for teachers. This was the origin of 5Es for the different phases of the model.

This editorial continues with a brief review of the five phases and some personal reflections about each phase. This summary is followed with a broader discussion of the model and its contemporary implications.

The BSCS 5Es Instructional Model *Engaging Learners*

The goal of this phase is to capture the students' attention and interest. Get the students focused on a situation, event, demonstration, or problem that involves the content and abilities that are the aims of instruction. From a teaching point of view, asking a question, posing a problem, or presenting a discrepant event are all examples of strategies to engage learners. If students look puzzled, expressing "How did that happen?" or "I have wondered about that," and "I want to know more about that," they likely are engaged in a learning situation. Students have some ideas, but the expression of concepts and use of their

¹ The BSCS team included: Nancy Landes, Jim Ellis, Janet Carlson, Deborah Muscella, William Robertson, Susan Wooley, Stephen Cowdrey, and Gail Foster.

abilities may not be scientifically accurate and productive.

Over the decades, I have come to realize two things about this phase. The engagement need not be a full lesson, but usually it is because of the need to surface and assess students' prior knowledge. It might be as brief as a question or a short demonstration. Teachers might, for example, provide a brief description of natural phenomenon and ask students how they would explain the situation. The main point is that the students are puzzled and thinking about content related to the learning outcomes of the instructional sequence. The second point about this phase is that it presents opportunities for teachers to informally determine misconceptions expressed by the students. I emphasize the informal nature of these observations. The engage phase is not a preassessment.

Exploring Phenomena

In the exploration phase, students have activities with time and opportunities to resolve the disequilibrium of the engagement experience. The exploration lesson or lessons provide concrete, hands-on experiences where students express their current conceptions and demonstrate their abilities as they try to clarify puzzling elements of the engage phase.

Exploration experiences should be designed for later introduction and description of the concepts, practices, and skills of the instructional sequence. Students should have experiences and the occasion to formulate explanations, investigate phenomena, observe patterns, and develop their cognitive and physical abilities.

The teacher's role in the exploration phase is to initiate the activity, describe appropriate background, provide adequate materials and equipment, and to counter any misconceptions. After this, the teacher steps back and becomes a coach with the tasks of listening, observing, and guiding students as they clarify their understanding and begin reconstructing scientific concepts and developing their abilities.

Explaining Phenomena

The scientific explanation for phenomena is prominent in this phase. The concepts, practices, and abilities with which students were originally engaged and subsequently explored, now are made clear and comprehensible. The teacher directs students' attention to key aspects of the prior phases and first asks students for their explanations.

Using students' explanations and experiences, the teacher introduces scientific or technological concepts briefly and explicitly. Here, using an NGSS example, the disciplinary core ideas including vocabulary, science or engineering practice, and crosscutting concept are presented, clearly and simply. Prior experiences should be used as contexts of the explanation.

I would make the point that verbal explanations are common in this phase. However, use of video, the web, or software also may provide excellent explanations.

Elaborating Scientific Concepts and Abilities

The students are involved in learning experiences that extend, expand, and enrich the concepts and abilities developed in the prior phases. The intention is to facilitate the transfer of concepts and abilities to related, but new situations. A key point for this phase—use activities that are a challenge but achievable by the students.

In the elaboration phase, the teacher challenges students with a new situation and encourages interactions among students and with other sources such as written material, databases, simulations, and web-based searches.

Evaluating Learners

At some point, students should receive feedback on the adequacy of their explanations and abilities. Clearly, informal, formative evaluations will occur from the initial phase of the instructional sequence. But, as a practical matter, teachers must assess and report on educational outcomes; hence, the evaluate phase that addresses the issue of assessment.

In the evaluate phase, the teacher should involve students in experiences that are understandable and consistent with those of prior phases and congruent with the explanations. The teacher should determine the evidence for student learning and means of obtaining that evidence, as part of the evaluate phase. Figure 1 summarizes the BSCS 5Es instructional model.

Questions, Recommendations, and Implications

Across the years, I have seen and been asked many questions about the BSCS 5Es instructional model. This section addresses some of the issues raised by curriculum developers and classroom teachers applying the 5Es model to materials and instruction. The 5Es model is based on the psychology of learning (NRC 1999a) and the observation that students need time and opportunities to formulate or reconstruct concepts and abilities. These two factors justify the perspective for each phase and the sequence of 5Es.

What Is the Appropriate Use of the Instructional Model?

More specifically, should the instructional model be the basis for one lesson? A unit of study? An entire program? My experience suggests that the optimal use of the model is a unit of two to three weeks where each phase is used as

the basis for one or more lessons (with the exception of the engage phase, which should be less than a lesson). In this recommendation, I assume some cycling of lessons within a phase; for example, there might be two lessons in the explore phase and three lessons in the elaborate phase.

Using the 5Es model as the basis for a single lesson decreases the effectiveness of the individual phases due to shortening the time and opportunities for challenging and restructuring of concepts and abilities—for learning. On the other hand, using the model for an entire program so increases the time and experience of the individual phases that the perspective for the phase loses its effectiveness. For example, teachers may have too much exploration time allotted, or multiple explanations may be concentrated.

Can a Phase Be Omitted?

My recommendation: Do not omit a phase. Earlier research on the SCIS Learning Cycle found a decreased effectiveness when phases were omitted or their position shifted (Lawson, Abraham, and Renner 1989). From a contemporary understanding of how students learn, there is integrity to each phase and the sum of the phases, as originally designed (Taylor, Van Scotter, and Coulson 2007). This question is often based on prior ideas about teaching that would omit engage or exploration and go immediately to explain. Alternatively, some suggest

omitting elaborate. Here the important point centers on the transfer of learning combined with the application of knowledge.

Can the Sequence of Phases Be Shifted?

My response is similar to the prior one on omitting a phase. What would be shifted? Would one have explain precede explore? The original sequence was designed to enhance students' learning and subsequently supported by research (NRC 1999a and 1999b; Bybee et al. 2006; and Wilson et al. 2010). There also is earlier research on the learning cycle that specifically investigated the question about changing the sequence (Renner, Abraham, and Bernie 1988; Marek and Cavallo 1997). That research indicated reduced effectiveness when the sequence was changed. So, I do not recommend shifting the phases' order.

Can a Phase or Phases Be Added?

My colleague, Arthur Eisenkraft, added two phases by splitting engage to elicit and engage and adding an extend after evaluate, in order to underscore the importance of knowledge transfer (Eisenkraft 2003). In principle, I do not have a problem with adding a phase (or two) if the justification is grounded in research on learning, which was the case for Eisenkraft's modification.

Although there is no research support, I believe there is

FIGURE 1.

Summary of the BSCS 5Es instructional model.

Engagement

The teacher or a curriculum task helps students become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.

Exploration

Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions, and design and conduct an investigation.

Explanation

The explanation phase focuses students' attention on a

particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. In this phase teachers directly introduce a concept, process, or skill. An explanation from the teacher or other resources may guide learners toward a deeper understanding, which is a critical part of this phase.

Elaboration

Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept and abilities by conducting additional activities.

Evaluation

The evaluation phase encourages students to assess their understanding and abilities and allows teachers to evaluate student progress toward achieving the learning outcomes.

the practical issue of recalling titles, establishing criteria, and differentiating strategies for more phases. I have found three to five to be the optimum number of total phases.

Can Phases Be Repeated?

Yes, it is sometimes necessary to repeat a phase. This change should be based on the curriculum developer or teachers' judgement relative to students' need for time and experiences to learn a concept or develop an ability. To be clear, an example of repeating a phase would be engage, explore, explore ... not necessarily placing an explore before the evaluate.

Shouldn't Evaluation Be Continuous?

Effective teachers continuously evaluate their students' understanding. In the instructional model, the evaluate phase is intended as a summative assessment conducted at the end of a unit. Certainly, some evaluation ought to be informal and continuous. But, there also is need for an evaluation at the end of the unit.

What If I Need to Explain an Idea Before (or After) the Explanation Phase?

This may be necessary as some ideas are prerequisites to students understanding the primary concepts of a unit. Teachers will have to make a judgement about the priority and prerequisite nature of the concepts. One should maintain an emphasis on the primary or major concepts and abilities of the unit and not digress with less-than-essential explanations.

Can the 5Es Be Used for NGSS and the Integration of Multidimensions?

Yes. I have actually found the 5Es to help solve the challenge of incorporating the multidimensions of NGSS in the classroom. The phases of instruction certainly can include activities that afford opportunities for students to experience the science and engineering practices, disciplinary core ideas, and crosscutting concepts. In *Translating the NGSS for Classroom Instruction* (Bybee 2013), I used the 5Es for examples of the integration of multidimensions of NGSS.

Conclusion

My early association with the BSCS 5Es instructional model was to design an instructional sequence that would help teachers approach instruction in a meaningful way, one that enhanced student learning. I still hold this goal. At the time of its origin, I had no idea of the potential wide use. Many within the science education community have recognized the model's practical value and incorporated

it into school programs, state frameworks, and national guidelines. There is something to the model that has held the community's interest during the decades, and this has touched me deeply.

To conclude, I encourage the continued use of the model with the full recognition that classroom teachers will bring appropriate adaptations based on the unique circumstances of their students. ■

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