The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications

Executive Summary

by

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This review centers on the BSCS 5E Instructional Model. That model consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. Table 1 summarizes the instructional emphasis for the different phases.

Table 1. Summary of the BSCS 5E Instructional Model

Phase	Summary
Engagement	The teacher or a curriculum task accesses the learners' prior knowledge and helps them 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 possibilities, and design and conduct a preliminary 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. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them 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 by conducting additional activities.
Evaluation	The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

Since the late 1980s this instructional model has been used in the design of BSCS curriculum materials. The model describes a teaching sequence that can be used for entire programs, specific units, and individual lessons. The BSCS 5E Instructional Model plays a significant role in the curriculum development process as well as the enactment of curricular materials in science classrooms.

Origins

Origins of the BSCS 5E Instructional Model can be traced to the philosophy and psychology of the early 20th century and Johann Herbart. His psychology of learning can be synthesized into an instructional model that begins with students' current knowledge and their new ideas that relate to the current knowledge. The connections between prior knowledge and new ideas slowly form concepts. According to Herbart, the best pedagogy allows students to discover relationships among their experiences. The next step involves direct instruction where the teacher systematically explains ideas that the student could not be expected to discover. Finally, the teacher provides opportunities for the student to demonstrate their understanding.

In the 1930s an instructional model based on John Dewey's "complete act of thought" philosophy gained popularity. The instructional model includes: sense a perplexing situation, clarify the problem, formulate a hypothesis, test the hypothesis, revise tests, and act on solutions.

The primary purpose of the review of instructional models proposed by individuals such as Herbart and Dewey is to point out that the fact that such teaching models are not new; there were earlier models similar in philosophy and psychology to the BSCS 5E Instructional Model.

The BSCS model is a direct descendant of the Atkin and Karplus learning cycle proposed in the early 1960s and used in the Science Curriculum Improvement Study (SCIS). The Atkin and Karplus learning cycle used the terms *exploration*, *invention*, and *discovery*. These terms were later modified to: *exploration*, *term introduction*, and *concept application*. At BSCS we added an initial phase designed to engage the learner's prior knowledge and a final phase to evaluate the student's understanding. Table 2 shows the common phases of the SCIS and BSCS models and the additional phases for the BSCS model.

Table 2. Comparison of SCIS and BSCS Instructional Models

SCIS Model	BSCS 5E Instructional Model
	Engagement (new phase)
Exploration	Exploration (modified from SCIS)
Invention (Term Introduction)	Explanation (modified from SCIS)
Discovery (Concept Application)	Elaboration (modified from SCIS)
	Evaluation (new phase)

Since the 1980s BSCS has used the 5E model as a central innovation in elementary, middle, and high school biology and integrated science programs. In addition, BSCS has completed a series of supplemental modules for the National Institutes of Health (NIH). The BSCS 5E model is the central organizing element for these models.

Effectiveness

The BSCS 5E Instructional Model rests on a foundation of contemporary research on student learning, particularly in science. Several reports from the National Research Council (NRC) form that foundation. The first NRC report, *How People Learn* (NRC, 1999) synthesized research results on learning and presented various perspectives for applying those findings to practice. Three statements summarize the NRC synthesis of research:

1. Students come to the classroom with preconceptions about how the world works.

2. Developing competence in an area of inquiry requires: a) a foundation of factual knowledge, b) understanding facts and ideas in the context of a conceptual framework, and c) organizing knowledge for retrieval and application.

3. Helping students learn to take control of their own learning by defining goals and monitoring their progress in achieving them.

Relative to this review the NRC synthesis of research, one quotation from *How People Learn* seems especially germane.

> An alternative to simply progressing through a series of exercises that derive from a scope and sequence chart is to expose students to the major patterns of a subject domain as they arise naturally in problem situations. Activities can be structured so that students are able to explore, explain, extend, and evaluate their progress. Ideas are best introduced when students see a need or a reason for their use—this helps them see relevant uses of the knowledge to make sense of what they are learning. (p. 127)

This quotation directs attention to a research-based recommendation for a structure and sequence of instruction that exposes students to problem situations (i.e., engage their thinking) and then provides opportunities to *explore, explain, extend*, and *evaluate* their learning. The National Research Council summary supports the design and sequence of the BSCS 5E Instructional Model.

In 2006 the NRC published another report that examined the status, significance and role of laboratories in high school science education. *America's Lab Report: Investigations in High School Sciences* (NRC, 2006) further supports instructional models in general, including the BSCS model.

The NRC committee was very clear that science education includes both learning about the methods of scientific inquiry and the knowledge derived from those processes. The learning goals that should be attained as a result of laboratory experiences include the following:

- Enhancing mastery of subject matter
- Developing scientific reasoning
- Understanding the complexity and ambiguity of empirical work
- Developing practical skills
- Understanding the nature of science
- Cultivating interest in science and interest in learning science
- Developing teamwork abilities (NRC, 2006, p. 76-77)

In the analysis of laboratory experiences, the committee applied results from the large and growing body of cognitive research. Some researchers have investigated the sequence of science instruction, including the role of laboratory experiences, as these sequences enhance student achievement of the aforementioned learning goals. The NRC committee (NRC, 2006) proposed the phrase “integrated instructional units”:

> Integrated instructional units interweave laboratory experiences with other types of science learning activities, including lectures, reading, and discussion. Students are engaged in forming research questions, designing and executing experiments, gathering and analyzing data, and constructing arguments and conclusions as they carry out investigations. Diagnostic, formative assessments are embedded into the instructional sequence and can be used to gauge the students’ developing understanding and to promote their self-reflection on their thinking. (p. 82)

Integrated instructional units have two key features; first, laboratory and other experiences are carefully designed or selected on the basis of what students should learn from them. And second, the experience is explicitly linked to and integrated with other learning activities in the unit.

The features of integrated instructional units map to the BSCS instructional model. Stated another way, the BSCS model is a specific example of the general idea of integrated instructional units. According to the NRC committee’s report, integrated instructional units connect laboratory experience with other types of science learning activities including reading, discussions, and lectures.

Typical (or traditional) laboratory experiences differ from the integrated instructional units in their effectiveness in attaining several of the aforementioned goals of science education. Although the studies are still preliminary, research indicates that integrated instructional units are more effective than typical laboratory research for improving mastery of subject matter, developing scientific reasoning, and cultivating interest in science. In addition, integrated instructional units appear to be effective for helping diverse groups of students progress toward these three goals.

Results described in *America’s Lab Report* provide further support for the organizational sequence of the BSCS 5E Instructional Model. The BSCS model meets the stated criteria for integrated instructional units. This synthesis by the NRC suggests the need for focused research on the use of the BSCS model and other learning cycles that represent integrated instructional units of different orientations, disciplines, and lengths.

The present review included an extensive search for research on the original SCIS learning cycle, the modified learning cycle, and the BSCS 5E Instructional Model.

Lawson (1995) completed a comprehensive review of more than 50 research studies on the learning cycle that were conducted through the 1980s. The earliest studies investigated the effectiveness of the Science Curriculum Improvement Study (SCIS) program developed in the 1960s for teaching elementary science. Results of studies about SCIS provide some evidence about the effectiveness of instruction based on the learning cycle. Later studies focused specifically on the learning cycle model. Several studies focused on the impact of omitting one or more phases of the learning cycle, changing the sequence of the phases, or using different instructional formats within the phases. The focus of these studies was the effectiveness of different instructional interventions, including the learning cycle, for addressing student misconceptions in science. The following sections summarize what these studies reveal about the learning cycle’s effectiveness for improving students’ mastery of subject matter, scientific reasoning, and interest and attitudes about science.

Enhancing mastery of subject matter: Ten studies cited by Lawson investigated the impact of the learning cycle approach on subject matter knowledge of elementary through undergraduate students. Six of the studies (Bishop, 1980; Bowyer, 1976; Nussbaum, 1979; Renner & Paske, 1977; Saunders & Shepardson, 1987; Schneider & Renner, 1980) found that students who were taught using the learning cycle had greater gains in subject matter knowledge than students taught using more traditional approaches. Generally, in these studies and others, “traditional” approaches are described as a lecture followed by a verification lab or activity. Two of the studies (Bishop, 1980; Schneider & Renner, 1980) found that the achievement gains among students who experienced learning cycle instruction persisted in delayed post-tests of students’ understanding of science concepts. The other four studies found no differences in achievement between students who experienced learning cycles and those who received traditional instructional formats (Campbell, 1977; Horn, 1980; Davis, 1978; Vermont, 1984).

A review by Guzzetti, Snyder, Glass, & Gamas (1993) used cluster analysis to identify instructional approaches that had the largest effects on conceptual change. They concluded that: “Meta-analysis of research testing the success of the Learning Cycle and its modifications in eradicating misconceptions provides support for the approach.” Specifically, they found that the average effect of the learning cycle on conceptual change was about one-quarter of a standard deviation unit, with larger effects when additional strategies (such as prediction laboratories) were included as part of the learning cycle. They further noted that when a learning cycle that included laboratory work was compared with a one that did not include a laboratory, the differential effect was about one and one-half standard deviations. When a laboratory was combined with other forms of traditional instruction (i.e., lecture, demonstration, and nonrefutational text not in a learning cycle format), however, it was much less effective. Comparison of a prediction laboratory–learning cycle combination with traditional instruction showed positive results in favor of the former, by one-third of a standard deviation.

Developing scientific reasoning: Many of the studies reviewed by Lawson investigated the impact of learning cycle instruction on students’ scientific reasoning abilities. This instructional model consistently showed superior results over more traditional instructional approaches for cultivating the development of these abilities: 17 of 18 studies had positive results. We divided the studies into two categories. The first category contains studies that address scientific inquiry abilities (e.g., asking questions, designing experiments, developing and communicating scientific explanations), which are the cornerstones of how scientific reasoning is defined in *America’s Lab Report*.

Studies reviewed by Lawson assessing general reasoning skills all showed that instruction based on the learning cycle was more effective than traditional instruction. Renner, et al. (1973) concluded that first graders who used the SCIS materials had greater gains in reasoning skills, as measured by Piagetian conservation tasks, than first graders who used a textbook. Linn & Thier (1975) found that fifth graders who were taught using the SCIS materials performed better than those who did not on tasks that required identification and compensation of variables. Several studies noted general gains in reasoning skills and in proportional reasoning for students who experienced instruction using the learning cycle model (McKinnon & Renner, 1971; Renner & Lawson, 1975; Wollman & Lawson, 1978). Finally, a number of studies assessed the development of formal thinking skills among students who experienced either learning cycle or traditional instruction. These studies also found greater gains for students who were taught science using a learning cycle format (Carlson, 1975; Schneider & Renner, 1980; Saunders & Shepardson, 1987).

Cultivating interest and attitudes about science: Instruction that uses a learning cycle approach consistently results in more positive attitudes about science. Lawson reviewed 12 publications that reported the impact of learning cycle instruction on students' attitudes. Eight of the studies found more positive attitudes for students who experienced learning cycle instruction than for those who did not. Four studies that did not do this comparison also reported positive attitudes about science among students in learning cycle classes. Lawson commented that finding a positive relationship between the use of learning cycle programs and student attitudes is typical; he noted only one study that found no relationship between attitudes and the SCIS program (presented at a meeting of the National Science Teachers Association in 1977).

Hendricks (1978) found general affective domain gains for students in a SCIS program, and Allen (1973a) reported slightly better motivation for students in a SCIS program. Others who reported positive attitudes about science following exposure to the SCIS program include Brown (1973); Brown, Weber, and Renner (1975); Krockover and Malcolm (1976); Haan (1978); and Lowery, Bowyer, and Padilla (1980). Lawson (1995) reviewed four studies that focused specifically on the impact of the learning cycle approach (as opposed to the entire SCIS program) on student attitudes toward science. All reported a positive relationship. Campbell (1977) found not only more positive attitudes toward laboratory work in a physics course, but also a decreased likelihood of withdrawing from the course among college students in the learning cycle sections of the course as compared with those in the traditional sections. Another study found that college students enrolled in learning cycle sections of a nonmajor physics course enjoyed their instruction more than those enrolled in the traditional sections (Renner & Paske, 1977). Middle school students taught science using a learning cycle approach also had more positive attitudes about science than those taught using a traditional approach (Davis, 1978; Bishop, 1980).

Research by Renner and his colleagues (Renner, Abraham, & Birnie, 1984; Abraham & Renner, 1984; Abraham & Renner, 1986; Renner, Abraham, & Birnie, 1985, 1988) investigated efficacy of learning cycles' sequence. Specifically, they researched the notion that the learning cycle is most effective when used as originally designed:

- All three phases of the model must be included in instruction, and the exploration phase must precede the term introduction phase.
- The specific instructional format may be less important than including all phases of the model, but laboratory work (typical in the exploration phase) is more effective for many students, provided it is followed by discussion (term introduction).
- Finally, student attitudes toward science instruction are more positive when they are allowed to explore concepts through experimentation or other activities before discussing them.

The effectiveness of the learning cycle and variations including the BSCS 5E Instructional Model are indirectly supported by research reports that review contemporary perspectives on learning and directly supported by studies that link use of the respective models to changes in important goals of science education. Table 3 presents a view of those goals and a summary of research support.

Based on evidence for the effectiveness of the learning cycle, BSCS used that cycle as the foundation for a new instructional model. BSCS first developed *Science for Life and Living* (BSCS, 1988) a comprehensive K-6 program that spanned the science disciplines and incorporated health and technology. During the design of that program, BSCS conceived the BSCS 5E Instructional Model. The use and refinement of the BSCS 5E model continued as we developed three more comprehensive programs: *Middle School Science & Technology* (BSCS, 1994, 1999, 2005); *BSCS Biology: A Human Approach* (BSCS, 1997, 2003, 2006); and *BSCS Science: An Inquiry Approach* (BSCS, 2006).

In each program, the BSCS 5E Instructional Model is the explicit pedagogical principle. The 5Es are expressed on several levels, with the most concrete at the unit level in the elementary program and at the chapter level in the middle and high school programs. As the students explore each unit or chapter, they experience a 5E cycle that carefully structures their learning. To differing degrees, the 5Es are also expressed at the lesson level and at the program level, but the most explicit use occurs at the unit or chapter level.

Table 3. Effectiveness of the Learning Cycle and BSCS 5E Instructional Model

Goal	Support Reported in America's Lab Report (NRC, 2006)	Learning Cycle (SCIS)	Learning Cycle (Other)	BSCS 5E Instructional Model*
Mastery of Subject Matter	Is no better or worse than other modes of instruction	Has inadequate evidence	Has strong evidence of increased mastery compared with other modes of instruction	Shows some evidence of increased mastery compared with other modes of instruction
Scientific Reasoning	Aids the development of some aspects	Has strong evidence of the development of more-sophisticated aspects	Has adequate evidence of the development of more-sophisticated aspects	Shows some evidence of the development of more-sophisticated aspects
Understanding of the Nature of Science	Shows little improvement	Has inadequate evidence	Has inadequate evidence	Has inadequate evidence
Interest in Science	Shows some evidence of increased interest	Has greater evidence of increased interest	Has greater evidence of increased interest	Has greater evidence of increased interest
Understanding of the Complexity and Ambiguity of Empirical work	Has inadequate evidence	Has inadequate evidence	Has inadequate evidence	Has inadequate evidence
Development of Practical Skills	Has inadequate evidence	Has inadequate evidence	Has inadequate evidence	Has inadequate evidence
Development of Teamwork Skills	Has inadequate evidence	Has inadequate evidence	Has inadequate evidence	Has inadequate evidence

In addition to comprehensive programs, BSCS also uses the 5Es in content areas other than science and in supplementary materials, such as our middle school health series *Making Healthy Decisions* (BSCS, 2000) and the 16 modules that BSCS developed for the Office of Science Education at the National Institutes of Health. The NIH modules, each comprising a 5E cycle, span the grade levels, and each is designed to take five to 10 days of classroom time.

In the development process, every BSCS program is field-tested nationwide to ensure that the activities work well in the classroom and improve students' understanding of the concepts. The results of the field tests inform a careful revision of the program before it is published. A detailed description and discussion of these results follows.

***Science for Life and Living*:** Student cognitive outcomes were measured in four areas. Science content outcomes in grades five and six included general energy concepts and general ecology concepts. Health content was measured at grades three through five, and scientific inquiry understandings were assessed at all grade levels. Students in grade two were given an oral scale that combined scientific processes and content. Of the eight significant differences found in the cognitive scales, seven were in favor of the treatment group (students using *Science for Life and Living*). (See Table 4)

Table 4. Evaluation of the BSCS Program Science for Life and Living

Grade Level	Cognitive Area Tested	Standard Deviation
2	Change and Measurement	–0.19*
3	Health Patterns and Predictions	No significant difference No significant difference
4	Health: Substance Avoidance Skills Systems	0.20** 0.30***
5	Energy Health: Fitness, Safety, Interpretation of Ads Process Skills: Observation, Measurement, Experimental Design, Interpretation	0.57*** 0.24** 0.21**
6	Ecology Subscale for Ecosystems Decision-Making Skills	0.46** 0.64** No significant difference

*Statistically significant difference < 0.05.
**Statistically significant difference is in favor of the control group.
***Statistically significant difference < 0.001.

An additional study conducted in North Carolina compared the student outcomes in fifth grade on the end-of-grade test for students who used *Science for Life and Living* (*SFLL*) and students who used an activity-centered, but traditional, science program (ACTS) for a full academic year (Maidon & Wheatley, 2001). Students taking *SFLL* outscored the students in ACTS on the overall measure and all subscales. The results are summarized in Table 5.

Table 5. Comparison of Test Results for Students in *SFLL* and ACTS

Fifth-Grade End-of-Grade Test	*SFLL* Number	*SFLL* Mean	ACTS Number	ACTS Mean	p Value
Overall	191	31.21	215	26.10	0.0000
Process Skills Subscale	191	14.63	215	12.20	0.0001
Conceptual Knowledge Subscale	191	12.80	215	10.83	0.0000
Nature of Science Subscale	191	2.63	215	2.22	0.0001
Manipulative Skills Subscale	191	1.15	215	0.84	0.0004
Lower-Order Thinking Skills	191	16.45	215	13.91	0.0000
Higher-Order Thinking Skills	191	18.10	204	15.51	0.0001

These results are significant. Both programs were activity centered, but *Science for Life and Living* used the BSCS 5E Instructional Model, while ACTS used a more traditional approach to instruction in which students received content information first and then did an activity to reinforce the information the teacher had provided. These results indicate that the use of an instructional model has a positive effect on the learning and doing of science as well as on thinking skills.

***Middle School Science & Technology*: **The formative evaluation conducted during the development and field-testing of *Middle School Science & Technology* (*MSST*) provided valuable data about student learning and attitudes. BSCS administered pre- and post-tests to students that covered concepts from the grade level of the program the students were experiencing. There were always positive gains in these scores. In one district in Ohio, project staff administered a content test to a group of students using the program that was twice as large as a group that was not using the program. The results showed statistically significant differences ($p < 0.01$) for the treatment group. The students using *MSST* had higher raw scores and answered more questions. On open-ended questions, the treatment group used more scientific vocabulary words correctly and had higher-quality responses (BSCS, 1994).

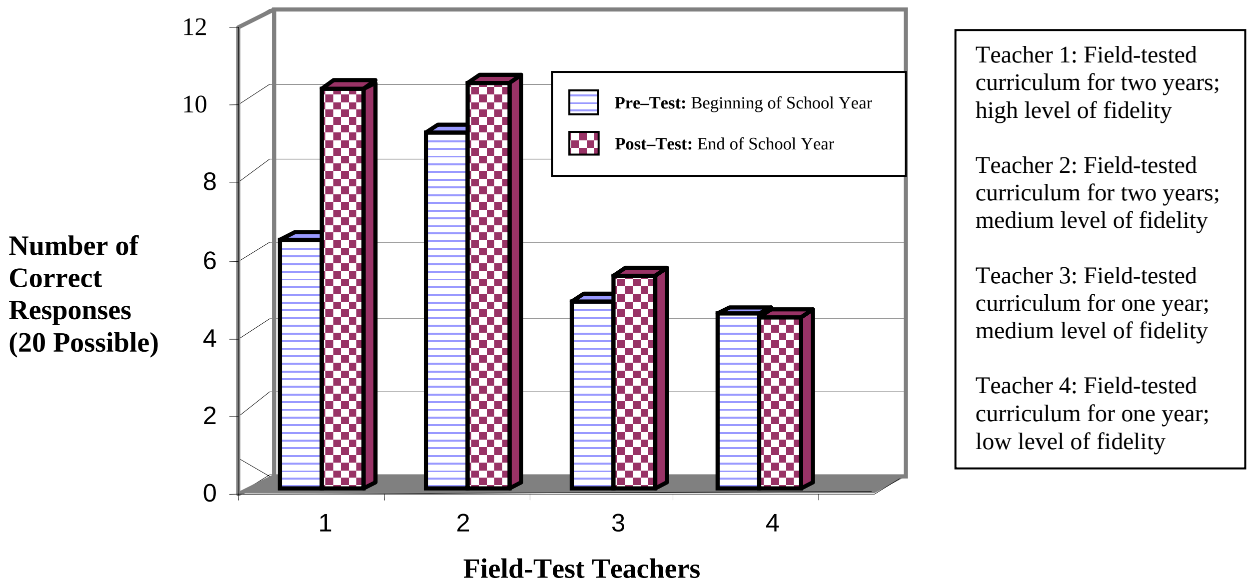
Three field-test sites in three different states compared the scores of students in the treatment group with other students on the state assessments and found that students using *MSST* scored equal to or above other students. A site in North Carolina reported gains of one-half to one full grade level on the California Achievement Test. Tests of thinking skills showed gains of two to eight percentile points after one year of use of the program.

***BSCS Biology: A Human Approach*: **In a comparison study that looked at the results of 76 students using *BSCS Biology: A Human Approach* (*BB: AHA*, the treatment condition) and 49 students using another biology program (the comparison condition), there was an overall improvement in mean post-test scores. When a more detailed study was conducted to examine the relationship between the teachers' fidelity of use of the program and student learning, more interesting results emerged. One preliminary study found distinct differences in the learning gains of students whose teachers implemented the program as designed as opposed to the gains of students whose teachers implemented the program with considerably less fidelity. Student learning was measured using a 20-item subset of questions from the NABT/NSTA biology exam. This test was used because, at the time of the study, it was considered a difficult test that was independent of a particular curriculum. Fidelity was measured through classroom observations. These findings are illustrated in Table 6 and Figure 1.

Table 6. Student Learning Gains by Teacher

Teacher	Pre-Test Average	Post-Test Average	Average Gain
1	6.4	10.3	3.9
2	9.2	10.4	1.2
3	4.8	5.5	0.7
4	4.5	4.4	0

Figure 1. Pre- and Post-Test Results for NSTA/NABT Biology Exam



***BSCS Science: An Inquiry Approach*:** The field test of the instructional materials developed during Phase 1 of *BSCS Science: An Inquiry Approach* comprised urban, suburban, and rural classrooms across 10 states, 31 teachers, 64 classes, and nearly 2,000 students. Assessment instruments included student surveys, teacher surveys, pre- and post-tests, an end-of-field-test survey, and classroom observations by an external evaluator and BSCS project staff. Among the findings, several stand out with respect to the quality and effectiveness of instructional materials and student achievement. The key findings are illustrated in Figures 2 and 3.

Figure 2. Student Test Gains by Grade Level

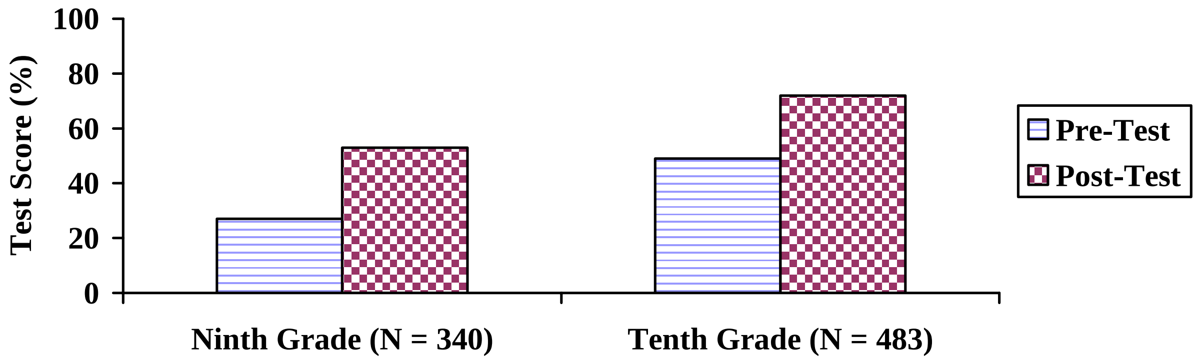
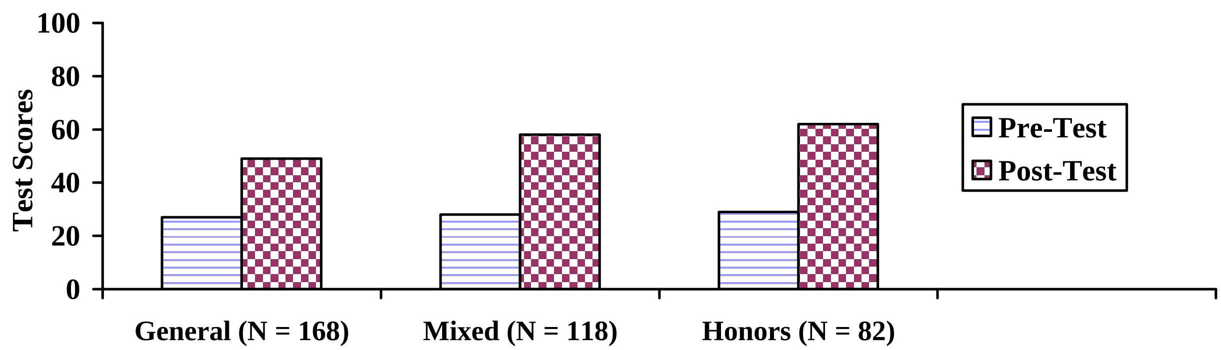


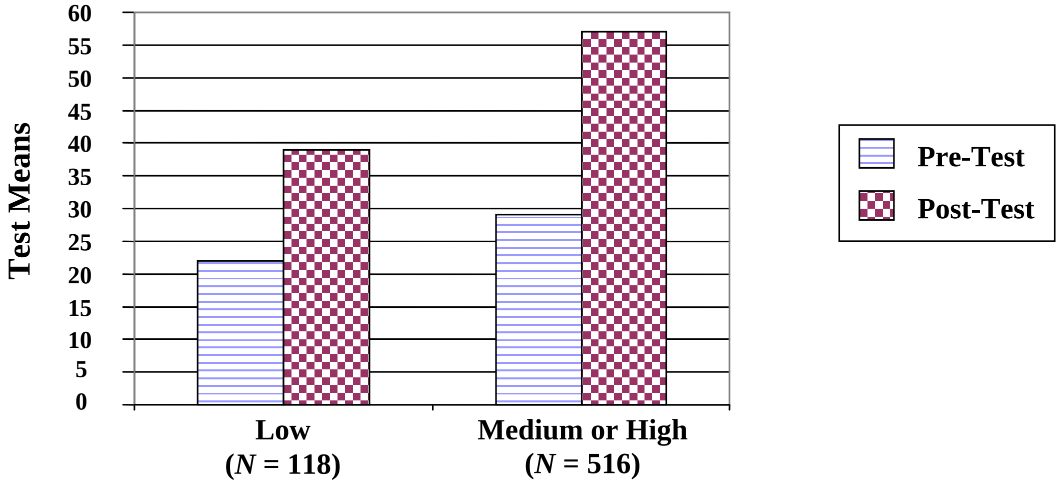
Figure 3. Ninth-Grade Test Gains by Ability Level



As mentioned above, Coulson (2002) also conducted a study examining the relationship between fidelity of use and student learning for *BSCS Science: An Inquiry Approach*. In this study, the learning gains of 634 ninth-grade students were determined by administering an identical chapter test before and after instruction. Implementation fidelity was measured by external evaluation staff and the curriculum development staff using an observation protocol adapted from the *Horizon, Inc. Classroom Observational Protocol* (HRI, 2001). This protocol allowed researchers to classify each teacher's fidelity of use as either "low," "medium," or "high." For each classroom study, three observers were in the classroom: two curriculum developers and the external evaluator. Each observer rated the teacher separately. Post-observation analysis indicated high inter-rater reliability. It is important to note that researchers operationally defined "fidelity" as teachers implementing the program as designed or in the spirit of the program's instructional model (i.e., the 5Es), not necessarily as rigid adherence to specific steps of the procedure.

The major finding of this study is the establishment of a strong relationship between student learning gains and implementation fidelity. Specifically, the data in this study suggest that when teachers implemented the program with a medium or high level of fidelity, the learning gains experienced by their students were significantly greater than the learning gains of teachers who did not adhere closely to the program (see Figure 4).

Figure 4. Ninth-Grade Test Gains by Levels of Implementation



NIH Modules: BSCS has developed 16 NIH-funded curriculum modules. Each module closely follows the 5E structure and is intended to immerse students in a special topic for one to two weeks. During the development phase of the modules, a field test takes place in which teachers and students provide feedback to BSCS about how the module works in the real-world classroom environment. In order to obtain data on student learning, a pretest-posttest design is used. Before the materials are covered in the classroom, a pretest is administered to the students. At the conclusion of the unit, the students complete the same test, as a posttest. Table 7 illustrated the changes in the mean student score, as well as the results of a t-test for each module.

Table 7. Effectiveness of NIH Modules Using the BSCS 5E Instructional Model

Module	Mean Pre-Test Score	Mean Post-Test Score	t-Test, Degrees of Freedom, and p Value
The Brain: Our Sense of Self (29 Possible Points)	15.74	18.85	t = 13.83, df = 426, p < 0.001
The Science of Energy Balance: Calorie Intake and Physical Activity (21 Possible Points)	9.73	13.51	t = 20.01, df = 400, p < 0.001
Using Technology to Study Cellular and Molecular Biology (15 Possible Points)	6.51	9.57	t = 27.77, df = 517, p < 0.001
The Science of Mental Illness (13 Possible Points)	6.88	9.84	t = 44.58, df = 1,249, p < 0.001
Looking Good, Feeling Good: From the Inside Out (22 Possible Points)	12.12	16.39	t = 22.60, df = 309, p < 0.001
Doing Science: The Process of Scientific Inquiry (19 Possible Points)	11.23	13.52	t = 18.03, df = 597, p < 0.001
The Science of Health Behaviors (21 Possible Points)	12.07	14.29	t = 19.71, df = 929, p < 0.001

Each of the BSCS modules listed in Table 7 shows significant gains in student knowledge from pre-test to post-test. The observed gain in student knowledge may be at least partially attributed to the use of a BSCS 5E instructional model.

Applications

This section of the report documents the application of the BSCS 5E Instructional Model in a number of domains:

- State science frameworks
- School district science frameworks
- Institutes of higher education—general courses
- Institutes of higher education—teacher education
- Curriculum (e.g. textbooks, units, modules)
- Specific lesson plans
- Informal education (e.g., museums, media)
- Professional development opportunities
- Non-science disciplines

State Science Frameworks

State science frameworks are the official documents (print and Web based) that outline the expectations for student achievement in science for a particular state. Such a document will usually include content standards and benchmarks by grade level or grade-level band (e.g., K through two, three through five, six through eight, and nine through 12); the role of assessment; models of instruction; the role of professional development; and the role of technology. At least three states strongly endorse the BSCS 5Es, including Connecticut, Maryland, and Texas. Other states, including Louisiana and Missouri, provide information about the 5E Instructional Model on the state's department of education Web site.

School District Science Frameworks

School district science frameworks are usually derived from the related state science framework and include similar sections related to the teaching and learning of science. Most district frameworks outline specific content objectives or benchmarks to be met by specific grade levels, incorporate expectations and a philosophy of what good science instruction should look like, and describe the district's approaches to the assessment of student learning.

Institutes of Higher Education

General courses: This category includes college and university courses that are designed for students who are not necessarily teacher education majors. Our search of the World Wide Web revealed over 97,000 discrete examples of universities using the BSCS 5E Instructional Model.

Teacher education: This category includes courses and programs specifically designed for students who are enrolled in a teacher education program. Our World Wide Web search found over 131,000 discrete examples of the 5Es used in teacher education programs or resources for teacher education.

Informal Science Education

Informal science education is generally described as that which takes place outside of the domain of traditional K–12 schooling. Informal learning experiences are designed to increase interest, engagement, and understanding of science, technology, engineering, and mathematics (STEM) by individuals of all ages and backgrounds. Informal education includes after-school programs and those provided by nontraditional organizations, such as museums; outdoor education and nature centers; government agencies, such as NASA; and online vendors. Many organizations and institutions in the informal sector have implemented the 5E model.

Curriculum

Textbooks, units, and modules: This category includes materials, both print and Web based, that provide instruction or instructional guidelines for teachers. Curriculum can be in the form of textbooks, stand-alone units or modules, or other packaged materials designed for use in formal or informal educational settings. Our search of the World Wide Web revealed over 73,000 examples of curriculum that incorporate the 5Es in their designs.

Specific lesson plans: Lesson plans are documents that provide teachers with an instructional sequence that guides a learning experience for students. Usually, teachers use lesson plans to guide daily instruction; multiple lesson plans can make up a chapter or unit of instruction if those lesson plans are designed to be used in sequence. Our World Wide Web search found over 235,000 lesson plans that incorporate the BSCS 5E Instructional Model.

Professional Development Programs

Teachers need to continuously update their knowledge of both content and pedagogy. A number of courses taught through universities as short-term workshops or offered online help teachers understand the BSCS 5E Instructional Model or are developed using the model.

Using the BSCS 5E Model in Other Disciplines

Although BSCS developed the 5E instructional model for improving science education, it is now being adapted and used to improve instruction in other area, including technology education and mathematics.

Impact of the BSCS 5E Instructional Model on Science Education

The range of applications of the BSCS 5E Instructional Model is one way to gauge the impact of the model. In addition, it serves as an indicator of its success as an instructional model in science education. The BSCS 5E Instructional Model has become the foundation for an incredible amount of curriculum materials used in science education and, consequently, has had a vast impact on the teaching and learning of science throughout the United States and internationally. The genius of the model is related to its alliterative nature. Every stage of the model begins with the same letter—in this case, an *E*. When we compare this model of 5Es with earlier instructional models, such as preparation, presentation, generalization, and application (Herbart, 1901), or exploration, invention, and discovery (Atkin & Karplus, 1962), it becomes apparent why those models did not “catch on.” The stages are not easy to remember or to understand without a graduate course in learning theory. A danger, of course, is that something that is catchy and easy to remember might be misused as often as it is used effectively; however, something that cannot be remembered or understood is less likely to have any sustainable effect. The effectiveness data in this report substantiate the potential of the BSCS 5Es when the model is used as intended.

Conclusion

The BSCS 5E Instructional Model is grounded in sound educational theory, has a growing base of research to support its effectiveness, and has had a significant impact on science education. While encouraging, these conclusions indicate that it is important to conduct research on the effectiveness of the model, including when and how it is used, and continue to refine the model based on direct research and related research on learning.

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