The BSCS 5E Instructional Model: Origins and Effectiveness

A Report Prepared for the
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National Institutes of Health

by

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Introduction

Science teachers continuously strive to improve their instructional practices to enhance student learning. Complementing the aims of science teachers, curriculum developers systematically attempt to identify research findings they can incorporate in materials that will facilitate connections between teachers, the curriculum, and students. Recently, the use of coordinated and coherent sequencing of lessons—learning cycles and instructional models—has gained popularity in the science education community.

Recent research reports, such as *How People Learn: Brain, Mind, Experience, and School* (Bransford, Brown & Cocking, 2000) and its companion, *How Students Learn: Science in the Classroom* (Donovan & Bransford, 2005), have confirmed what educators have asserted for many years: **The sustained use of an effective, research-based instructional model can help students learn fundamental concepts in science and other domains.** If we accept that premise, then an instructional model must be effective, supported with relevant research and it must be implemented consistently and widely to have the desired effect on teaching and learning.

Since the late 1980s, BSCS has used one instructional model extensively in the development of new curriculum materials and professional development experiences. That model is commonly referred to as the BSCS 5E Instructional Model, or the 5Es, and consists of the following phases: engagement, exploration, explanation, elaboration, and evaluation. Each phase has a specific function and contributes to the teacher’s coherent instruction and to the learners’ formulation of a better understanding of scientific and technological knowledge, attitudes, and skills. The model frames a sequence and organization of programs, units, and lessons. Once internalized, it also can inform the many instantaneous decisions that science teachers must make in classroom situations. See Table 1 for a summary of the BSCS 5E Instructional Model.

This report summarizes recent research on the sequencing of science instruction, including laboratory experiences, in order to facilitate student learning. Specifically, the report provides a rationale and empirical support for the BSCS 5E Instructional Model.

One reason for reviewing the historical development and research base for the BSCS 5E Instructional Model is its ubiquitous use in education today. This widespread use falls into three primary categories of use: 1) documents that frame larger pieces of work such as curriculum frameworks, assessment guidelines, or course outlines; 2) curriculum materials of various lengths and sizes; and 3) adaptations for teacher professional development, informal education settings, and disciplines other than science. A simple internet search, using a popular search engine such as Google, reveals the wide and varied applications of the 5E model. In spring 2006, this type of search showed the following range of uses:

- more than 235,000 lesson plans developed and implemented using the BSCS 5E Instructional Model;
- more than 97,000 posted and discrete examples of universities using the 5E model in their course syllabi;
- more than 73,000 examples of curriculum materials developed using the 5E model;
- more than 131,000 posted and discrete examples of teacher education programs or resources that use the 5Es; and
• at least three states that strongly endorse the 5E model, including Texas, Connecticut, and Maryland.

The first section of this report provides a brief history of instructional models and discusses the Science Curriculum Improvement Study (SCIS) learning cycle (Karplus & Thier, 1967), the predecessor to the BSCS 5Es. After that discussion, the same section summarizes research supporting contemporary views of learning and the effectiveness of different instructional models, with emphasis on the SCIS learning cycle and the BSCS 5E model.

Table 1. Summary of the BSCS 5E Instructional Model

<table>
<thead>
<tr>
<th>Phase</th>
<th>Summary</th>
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<tbody>
<tr>
<td>Engagement</td>
<td>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.</td>
</tr>
<tr>
<td>Exploration</td>
<td>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.</td>
</tr>
<tr>
<td>Explanation</td>
<td>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.</td>
</tr>
<tr>
<td>Elaboration</td>
<td>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.</td>
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<tr>
<td>Evaluation</td>
<td>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.</td>
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Summary and 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. Although encouraging, these conclusions indicate the need 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.

The uniqueness of the BSCS 5E Instructional 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 Herbart’s (1901) models of preparation, presentation, generalization, and application or Atkin & Karplus’ (1962) model of exploration, invention, and discovery, it becomes apparent why those models did not “catch on.” 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 widespread sustainable effects.

The five phases of the BSCS 5E Instructional Model are designed to facilitate the process of conceptual change. The use of this model brings coherence to different teaching strategies, provides connections among educational activities, and helps science teachers make decisions about interactions with students. The 5E model had its origins with the work of others especially the SCIS learning cycle. The research reinforced the effectiveness of the learning cycle:

- 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.

Using a learning-cycle approach to teaching and learning continues to be supported in significant reports, such as How People Learn (Bransford, Brown & Cocking, 1999). Bridging theory and practice can be accomplished by implementing the three major findings from this report through curriculum materials and professional development sessions designed on the instructional sequence to 5Es.

Findings from How People Learn can be implemented by curriculum developers and professional development providers by following these principles:

1. Learners preconceptions about how the world works will be engaged so that they may grasp new concepts and information in a meaningful manner.
2. Learners will develop a deep foundation of factual knowledge that is understood in the context of a conceptual framework and they will know how to organize that information in ways that facilitate retrieval and application.

3. Learners will be in control of their own learning by defining goals and monitoring their progress in achieving them.

Following the original work of Bransford, Brown, and Cocking, the National Research Council published *America’s Lab Report: Investigations in High School Sciences* (2006). In their examination of the status of science laboratories the committee was very clear that science education should include both learning about the methods and processes of scientific research and the knowledge derived from those processes. They developed a vision for the future of high school science education that includes laboratory experiences that emphasize the following:

- Enhanced mastery of subject matter
- Development of scientific reasoning
- Understanding of the complexity and ambiguity of empirical work
- Development of practical skills
- Understanding of the nature of science
- Interest in science and interest in learning science
- Development of teamwork abilities

As mentioned earlier in this paper, the authors of America’s Lab Report also support the concept of “integrated instructional units.” These units are carefully designed to integrate laboratory activities and other experiences into units focused on student learning.

Table 13 emphasizes the relationship between the evidence from lines of research about the BSCS 5E Instructional Model and the goals for integrated instructional units from *America’s Lab Report*.

### Table 13. Comparison of the Effectiveness of the BSCS 5E Instructional Models with Integrated Instructional Units

<table>
<thead>
<tr>
<th>Goal of America’s Lab Report</th>
<th>Integrated Instructional Units</th>
<th>BSCS 5E Instructional Model</th>
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<tbody>
<tr>
<td>Mastery of Subject Matter</td>
<td>Increases mastery compared with other modes of instruction</td>
<td>Shows some evidence of increased mastery compared with other modes of instruction</td>
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<tr>
<td>Scientific Reasoning</td>
<td>Aids the development of more-sophisticated aspects</td>
<td>Shows some evidence of the development of more-sophisticated aspects</td>
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<tr>
<td>Understanding of the Nature of Science</td>
<td>Shows some improvement when explicitly targeted at this goal</td>
<td>Has inadequate evidence</td>
</tr>
<tr>
<td>Interest in Science</td>
<td>Has greater evidence of increased interest</td>
<td>Has greater evidence of increased interest</td>
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</tr>
<tr>
<td>Understanding of the Complexity and Ambiguity of Empirical work</td>
<td>Has inadequate evidence</td>
<td>Has inadequate evidence</td>
</tr>
<tr>
<td>Development of Practical Skills</td>
<td>Has inadequate evidence</td>
<td>Has inadequate evidence</td>
</tr>
<tr>
<td>Development of Teamwork Skills</td>
<td>Has inadequate evidence</td>
<td>Has inadequate evidence</td>
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</table>

Studies of the 5E model conducted by the internal and external evaluators conducted showed positive trends for student mastery of subject matter and interest in science. The most significant finding, however, is that there is a relationship between fidelity of use and student achievement. In other words, the BSCS 5E Instructional Model is more effective for improving student achievement when the teacher uses the curriculum materials the way they were developed. Without fidelity of use, the potential results of the program are greatly diminished. This is a line of research that should be pursued. In addition, the research base around the BSCS 5E Instructional Model should be elaborated on through additional studies that compare its effect on mastery of subject matter, scientific reasoning, and interest and attitudes with other modes of instruction. The widespread use of the BSCS 5E Instructional Model warrants a commitment to a line of research that rivals that of the learning cycle.

While earlier sections of this paper indicated that there is compelling research on the learning cycle suggesting that it can have a positive impact on mastery of subject matter, scientific reasoning, and interest and attitudes toward science there are still many areas need further research to fully understand how to most effectively use learning cycles and instructional models to maximize student learning. The most noticeable void in the literature is research exploring the utility of both the learning cycle and BSCS 5E approach in helping students develop an understanding of the nature of science and the complexity and ambiguity of empirical work, as well as practical and teamwork skills.

The range of applications of the BSCS 5E Instructional Model is one way to gauge the impact of the model. (See Appendix D for details on areas of impact.) 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 a vast number of curriculum materials used in science education and, consequently, has had a large impact on the teaching and learning of science throughout the United States and internationally.