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SEPUP and the 5-E Learning Cycle

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Key Questions

- *What is a "learning cycle?*
- *What is the 5-E model?*
- *What is the SEPUP Learning Cycle?*
- *How does SEPUP's learning cycle model compare with the 5-E model?*

1. The Learning Cycle

In this information age, finding an entry for the learning cycle on Wikipedia (as I did when preparing to write this short paper in August of 2011) represents a certain popular awareness of the importance of the topic, even though the article is a wiki "stub," and only the 5-E model is represented, and further still, the description of the 5-E model is not entirely faithful to the language of Bybee (2006) and his staff at the Biological Science Curriculum Study (BSCS).

In the early 1960's, Robert Karplus and his colleagues proposed and used an instructional model based on the work of Jean Piaget. This model would eventually be called the Learning Cycle. (Atkin & Karplus, 1962). The early learning cycle model had 3 stages -- exploration, invention, and discovery. Using the learning cycle approach, the teacher "invents" the science concept of the lesson in the 2nd stage, rather than defining it at the outset of the lesson as in the traditional approach. The introduced concept subsequently enables students to incorporate their exploration in the 3rd stage and apply it to new examples. The learning cycle was first used as an inquiry lesson planning model in the Science Curriculum Improvement Study (SCIS) program, a K-6 science program in the early 1960s (e.g., Karplus and Thier, 1967).

Many examples of learning cycles have been described in the literature (Barman, 1989; Ramsey, 1993). The 5E Learning Cycle (Bybee, 1989, 2006) is used in the new BSCS

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science programs as well as in other texts and materials, and there is a 7E variant (Eisenkraft, 2003).

Since the 1970s, there has been a growing research base on the effectiveness of the learning cycle, though much of this work has been carried out within the context of research around the effectiveness of the science curriculum using the learning cycle as a prominent design element. It has come to be seen as a model for organizing instruction rather than a tool for reflecting on science teachers' instructional practice. Renner (1988) examined the relative importance of each of the phases in the learning cycle. Abraham (1989) found that the learning cycle was more effective than traditional methods in teaching certain chemistry concepts. Good (1989) and Lavoie (1992) explored the effectiveness of adding student prediction to the learning cycle elements. In a study involving student understanding of the life cycle of flowering plants, Scharmann (1992) showed the value of going beyond the "hands-on" to what is called the "minds on" phase, using analogies, opinion statements, decision making, etc.

Lawson (1995) completed a comprehensive review of more than 50 research studies on the learning cycle that were conducted through the 1980s. The focus of these studies was the effectiveness of different instructional interventions, including the learning cycle, for addressing student misconceptions in science. Lawson found that the use of the learning cycle was valuable in a number of important areas: enhancing mastery of the subject matter; developing scientific reasoning; and, increasing interest in, and positive attitudes toward, science.

2. The 5E Learning Cycle

This model, developed in 1989 (Bybee et. al., 2006, is summarized in Table 1. Since the late 1980s this instructional model has been used in the design of BSCS curriculum materials. The model describes a teaching sequence used for entire programs, units, and individual lessons.

Table 1. Summary of the 5E Model

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.

According to Bybee, et. al. (2006), origins of the 5E 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."*

Bybee also links the origins of the 5E model with John Dewey's "complete act of thought" instructional model, which includes: sense a perplexing situation, clarify the problem, formulate a hypothesis, test the hypothesis, revise tests, and act on solutions.

He then states the 5E model to be "direct descendant" (2006, p. 2) of the Atkin & Karplus SCIS model (1967). 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 an initial phase designed to engage the learner's prior knowledge and a final phase to evaluate the student's understanding were added. 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)

Bybee (2006) also provides an annotated summary of research to determine the effectiveness of the 5E approach in BSCS curriculum programs and applications of the use of the 5E model in various aspects of curriculum design and professional development.

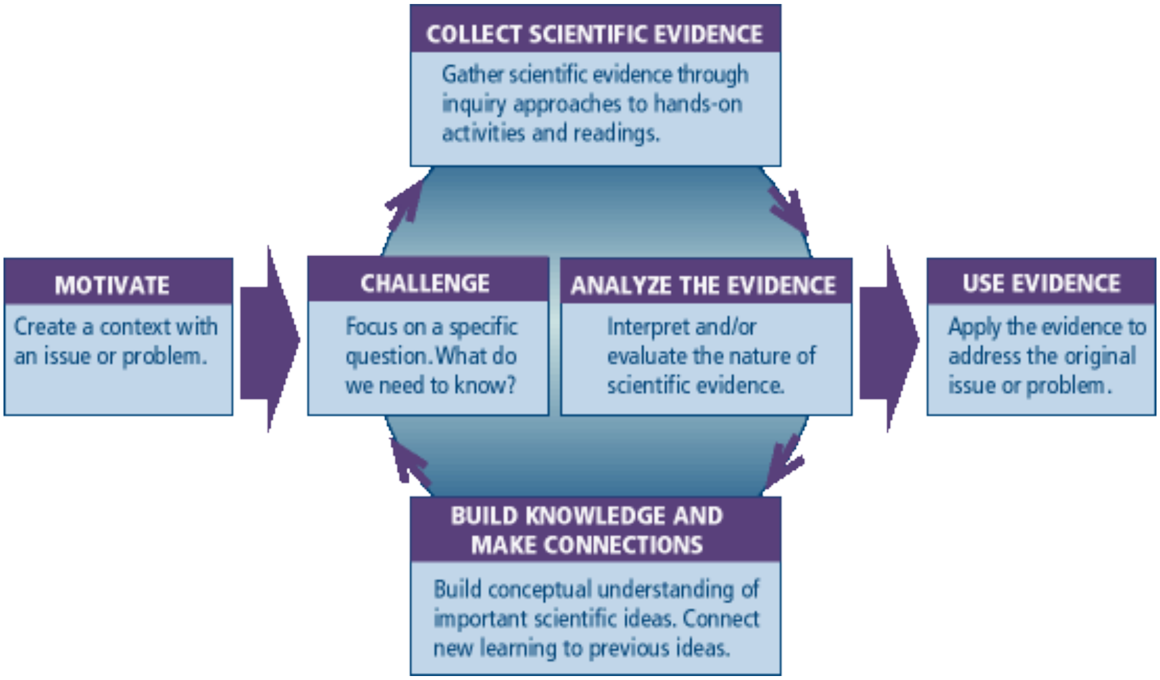
3. The SEPUP Learning Cycle

The Science Education for Public Understanding Program is based at the Lawrence Hall of Science at the University of California, Berkeley. Since 1987, the program has used development grants from institutions like the National Science Foundation (NSF) and others to develop supplementary and core science instructional materials, for students in grades 6-12. The materials are inquiry- and issue-oriented, and form a core component of the middle or high school science programs in large urban school systems such as those in San Diego, Denver, New York, Chicago, Baltimore, Phoenix, Winston-Salem, Hartford (CT), Portland (OR), as well as smaller suburban and rural districts like Tacoma (WA), Elkhart (IN), Stamford (CT) and others. SEPUP Founding Director Herbert Thier is generally credited with co-developing the original learning cycle model (Thier & Karplus, 1970), so the learning cycle in SEPUP is robust and backed by years of development.

A developmental model that emphasizes feedback from teachers and students in every stage is used. Through classroom trials, SEPUP tests the instructional materials to ensure that they work in a range of classrooms, to obtain feedback from teachers and students, and to ensure the materials contribute to the desired learning goals. Preliminary versions of all print materials and kit equipment are field-tested over a period of two years, typically by 50-100 teachers and nearly 5,000 students at different urban, suburban, and rural sites across the United States. Feedback from teachers and administrators (verbal and written), SEPUP staff's observations during field-testing, scientific review comments, and students' performance on assessment tasks and day-to-day work are used to guide the revision of all materials.

SEPUP's approach to science education includes an instructional model that integrates scientific inquiry with a thematic approach for teaching science in the context of personal and social issues. The phases of the model are illustrated in the following diagram.

Diagram 1. SEPUP Learning Cycle Model.



- To motivate students, a personal or societal issue provides a framework for each SEPUP unit, and students' questions are addressed in the subsequent series of activities. This issue then provides a context for the activities to follow.

- Each activity begins with a challenge, a specific question or goal. To tackle the challenge, students collect evidence in guided or open-ended investigations. Reading activities provide background information, extend investigations, and help students make connections. Students also run experiments, collect data, and analyze their evidence, all of which builds scientific knowledge to help them address the central issue.

Issue-oriented science helps students see that science is connected to their lives and communities in many ways. Students investigate such questions as:

- What is a safe yet effective window cleaner to use?
- What is the environmental impact of the life cycle computer?
- Where is the safest and most suitable water source for a community?
- How can a family reduce their energy costs?
- How can a motor vehicle be made safer?

In SEPUP curricula, these kinds of issues furnish a framework for students' work and reflection. The activities and investigations also require students to apply scientific evidence and the concept of trade-offs to personal and societal decisions. SEPUP does not advocate acceptance of specific positions. Instead, it provides students with knowledge, skills, and understanding that will help them make their own informed decisions.

SEPUP selects issues that:

- require an understanding of important scientific concepts and processes.
- require an application of evidence.
- engage diverse groups of students.
- are complex enough to foster discussion and debate.

Inquiry-based instructional strategies that give students experience with scientific processes and natural phenomena. SEPUP's instructional activities follow an inquiry continuum, from more guided to more open-ended. Guided inquiry introduces students to important ideas and gives students a model for scientific approaches. More open-ended-inquiry experiences encourage students to develop their ability to ask and investigate questions, to understand how to apply science to new problems, and to think critically about scientific evidence. Inquiry in SEPUP takes many forms, including hands-on investigations, analysis of data from other sources, use of physical and computer models, discussion of information and evidence gathered from readings, and role-plays and presentations.

At the end of a unit, students use their evidence and new knowledge in a culminating activity or activities that require them to reach a decision or to solve the original problem. Through these activities, they learn how science affects peoples' lives.

In an example from a middle level physical science unit *Force & Motion*, students first read a story about a family that has just survived a serious automobile accident. All family members are uninjured, but definitely in the market for a safer car! Students then work through a variety of hands-on activities to determine how to measure speed at its relationship in car accidents, the effect of mass in collisions, braking distance, acceleration around a curve (using carts with a high center of mass to simulate so-called "SUV rollover" accidents), design of crash test dummies (how do we design cars to minimize energy transfer in a collision?), finally applying this acquired knowledge and skill set to investigate policy issues in the design of safer cars.

Research on the effectiveness of the SEPUP model and impact of the program on student achievement and other variables can be found at www.sepuplhs.org/research and http://www.lab-aidsinstitute.com/institute_evidence_of_impact.php. In general, pre-post studies of SEPUP materials show medium- to high-effect sizes, and SEPUP students also outperform other non-SEPUP students on measures such as state end-of-course tests, although this data does include small samples and is generally regarded as formative feedback.

4. Comparison of SEPUP's Learning Cycle with the 5E Model

Table 3 summarizes a comparison of the design elements in the SEPUP Learning Cycle (Diagram 1) and the BSCS 5E model (Table 1), below:

Table 3. Comparison of SEPUP and 5E models

SEPUP Model	*SEPUP Assessment Focus*	*BSCS 5E Instructional Model*
Challenge		Engagement
Collect evidence	DI (Design investigations) OD (Organizing data)	Exploration
Analyze evidence	AD (Analyzing data) CS (Communication skills)	Explanation
Build knowledge/make connections	UC (Understanding concepts) SI (Organizing scientific ideas)	Elaboration
Use evidence (to make decisions)	RE (Recognizing evidence) ET (Evidence and TradeOffs)	Evaluation

The middle column makes reference to the embedded, rubric-driven assessment system designed to track what students know and are able to do as a result of their experiences with SEPUP. This feature provides powerful, formative feedback useful for teachers in planning additional lessons or re-teaching. For more information see Classroom Assessment and the National Science Education Standards (NRC, 2001, p. 65-69) or any of the SEPUP Teacher Guides.

The following are annotated scenarios from selected SEPUP middle and high school programs to show how the 5E model is supported by the SEPUP instructional design. Not all unit activities are shown, and the intent of this approach is to show the broad alignment of activities over a unit; it would be very easy to show the 5E architecture in full over a much smaller unit of instructional time, say 2-4 lessons.

4.1 Middle school programs

Issues & Earth Science, Unit C, Erosion and Deposition
Students learn about erosion and deposition to guide the redevelopment plans for the imaginary coastal town of Boomtown.

SEPUP Model	*IAPS Force & Motion Content by activity*	*BSCS 5E Instructional Model*
Challenge	24 Where Shall We Build?	Engagement
Collect evidence	25 Making Topographic Maps 26 Boomtown's Topography 28 Cutting Canyons and Building Deltas	Exploration
Analyze evidence	30 Challenges of the Mississippi Delta 31 Resistance to Erosion	Explanation
Build knowledge/make	32 Investigating a Cliff Model	Elaboration

connections	33 Earth Processes and Boomtown's Coast	
Use evidence (to make decisions)	34 Preparing the Geologist's Report 35 Building in Boomtown	Evaluation

Issues & Life Science, Unit E, Ecology
Students learn core ecological concepts through their study of introduced species.

SEPUP Model	*IALS Ecology Content by activity*	*BSCS 5E Instructional Model*
Challenge	72 The Miracle Fish? 73 Introduced Species	Engagement
Collect evidence	74 Observing Organisms 75 Classifying Animals 76 People, Birds, and Bats	Exploration
Analyze evidence	77 Ups and downs 78 Coughing up Clues (owl pellet dissection)	Explanation
Build knowledge/make connections	80 Nature's Recyclers 82 The Cells of Producers 83 A Suitable Habitat	Elaboration
Use evidence (to make decisions)	86 Taking a Look Outside 88 Presenting the Facts	Evaluation

Issues & Physical Science, Unit E, Force and Motion
Students learn about Newton's Laws in the context of motor vehicle safety.

SEPUP Model	*IAPS Force & Motion Content by activity*	*BSCS 5E Instructional Model*
Challenge	73 Choosing a Safe Vehicle	Engagement
Collect evidence	74 Measuring Speed 75 Interpreting Motion Graphs 76-77 Speed and Mass in Collisions	Exploration
Analyze evidence	78 Force, Acceleration, and Mass 80 Newton's Laws of Motion	Explanation
Build knowledge/make connections	82 Braking distance 83 Coming to a stop 85 Crash Testing 86 Investigating Center of Mass	Elaboration
Use evidence (to make decisions)	87 Fatal Accidents 88 Safety for All	Evaluation

4.2 High school programs

Science and Global Issues: Biology, Unit E, Evolution
Students learn core evolution concepts for application to a case study of the management of an island ecosystem.

SEPUP Model	*SGI Biology Evolution Content by activity*	*BSCS 5E Instructional Model*
Challenge	1 Biodiversity game – How are the biodiversity of ecosystems related to stability of human communities?	Engagement
Collect evidence	2 Human Activities & Biodiversity 3 Geologic Time 4 Darwin's Theory	Exploration
Analyze evidence	5-9 Evidence from the Fossil Record	Explanation
Build knowledge/make connections	10 What is a Species? 11 Natural Selection 12 Genetic Basis of Adaptation	Elaboration
Use evidence (to make decisions)	14 Ideas About Evolution 15 Conservation of an Island Biodiversity Hotspot – Which of four island areas should receive priority for conservation?	Evaluation

References

Abraham, M. R. (1989). Research and teaching: Research on instructional strategies. *Journal of College Science Teaching*, 18, 185-187.

Atkin, J. M. & Karplus, R. (1962). Discovery or Invention? *Science Teacher* 29, 45.

Barman, C. (1989). Making it work. *Science Scope, 12*(5), 28-31.

Bybee, R.W. et al. (1989). *Science and technology education for the elementary years: Frameworks for curriculum and instruction.* Washington, D.C.: The National Center for Improving Instruction.

Bybee, Rodger W., et. al., (2006). *The BSCS 5E Instructional Model: Origins, Effectiveness and Applications, Executive Summary.* Colorado Springs, CO: BSCS.

Eiskenkraft, A. (2003). Expanding the 5E Model. *The Science Teacher*, 70, 6, 56-59. Washington, D.C.: National Science Teachers Association.

Good, R. (1989). *Toward a unified conception of thinking: Prediction with a cognitive science perspective*. Paper presented an the annual meeting of the National Association for Research in Science Teaching (NARST), San Francisco.

Karplus, R., Thier, H., Lawson, C., Knoll, R., & Montgomery, M. (1967). *Science curriculum improvement study.* Chicago, IL: Rand McNally.

Lawson, A. E. (1995). *Science teaching and the development of thinking.* Belmont, CA: Wadsworth Publishing Company.

Lovie, D. (1989). *Enhancing the learning cycle with prediction and level three interactive videodisc lessons in science.* Paper presented an the annual meeting of the National Association for Research in Science Teaching (NARST), San Francisco.

National Research Council (2001). Classroom Assessment and the National Science Education Standards. Washington DC: National Academy Press.

Ramsey, J. (1993). Developing conceptual storylines with the learning cycle. *Journal of Elementary Science Education, 5*(2), 1-20.

Renner, J. and Marek, E. (1988). *The learning cycle and elementary school science teaching*. Portsmouth, NH: Heinemann.

Scharman, L. (1992). *Teaching evolution: The influence of peer instructional modeling.* Paper presented an the annual meeting of the National Association for Research in Science Teaching (NARST), Boston.

Thier, H., Karplus, R., Lawson, C., Knoll, R., & Montgomery, M. (1970). *Science curriculum improvement study.* Chicago, IL: Rand McNally

Wikipedia (2011). The Learning Cycle. Accessed at http://en.wikipedia.org/wiki/Learning_cycle on 23 August 2011.