SAVVAS LEARNING COMPANY

Research into Practice

Contemporary Science Teaching: Origins of the 5E, NGSS, and Phenomena

By Jesse Wilcox, Ph.D.

Jesse Wilcox, Ph.D.
Assistant Professor of Biology and Science Education, University of Northern Iowa, Savvas Author

Jesse Wilcox, Ph.D., is an Assistant Professor in Biology and Science Education at the University of Northern Iowa. He was a former high school general science and biology teacher prior to becoming a professor. Jesse has won numerous teaching awards, has presented nearly 200 times at science and STEM education conferences, and has published 45 articles in science and STEM education journals. Jesse is passionate about working with science teachers and helping them strive toward improving their practice.

Introduction

Savvas Learning Company has created *Experience Science* based on reforms-based teaching and the latest in science education research. In the reformed-based, contemporary science classroom, science teachers often use the 5E and phenomena to align their teaching with the Next Generation Science Standards (NGSS). Specifically, science teachers often structure their lessons using the 5E model (Bybee et al., 2015). The Engage phase of the 5E provides the opportunity for science teachers to generate interest and curiosity by using a phenomenon. These 5E lessons engage students in Science and Engineering Practices (SEPs), and teachers help scaffold students' learning to understand the Disciplinary Core Ideas (DCIs) and make connections to the Crosscutting Concepts (CCCs), thereby working towards the Performance Expectations (PE). While combining the 5E and phenomena to help scaffold students toward the three dimensions of the NGSS is powerful, where did all of these elements of contemporary science teaching come from? This white paper will explore reform efforts dating back to the Cold War era and how these reforms added elements to our contemporary understanding of effective science teaching that lay the foundation of the *Experience Science* Program.

> "... combining the 5E and phenomena to help scaffold students toward the three dimensions of the NGSS is powerful."

The Learning Cycle and the 5E

Contemporary science education reform efforts are often traced back to *Sputnik*, the artificial satellite launched by the Soviet Union in 1957 (DeBoer, 2019). As a response to Sputnik and the space race, the United States invested resources in science education through the National Science Foundation and many other efforts (Rudolph, 2002; Wissehr et al., 2011). One result of these efforts became known as "the Alphabet Soup" science education curricular projects of the 1960s, so named because most of the curricular projects were acronyms (e.g., SCIS, BSCS, ESCP, CHEM study) (Kyle et al., 1982).

In the late 1950s, theoretical physicist Robert Karplus became interested in science education. Karplus used the work of Jean Piaget in developmental psychology to help children better understand science (Fuller, 2003; Fuller & Hairline, 2013). His collaboration with J. Mryon Atkin (1962) resulted in the first iteration of the learning cycle (Bybee et al., 2006; Fuller, 2003). Karplus, along with his colleague Hebert Thier, later wrote: “The plan of a unit may be seen, therefore, to consist of this sequence: preliminary exploration, invention, and discovery” (Karplus & Thier, 1967, p. 40). This approach was later named “The Learning Cycle” (Fuller & Hairline, 2013). Science Curricular Improvement Study (SCIS), one of the alphabet soup projects, used the learning cycle to structure the lessons in that program and was extensively studied by Karplus, Thier, and their colleagues (Fuller & Hartline, 2013; Lawson, 2013). In the mid-1970s, Karplus noticed teachers were having a difficult time understanding what “invention” and “discovery” meant and changed the names of the phases (Fuller & Hartline, 2013). The learning cycle was further refined by Lawson (1988) and others.

Today, the three phases of the learning cycle are often described as exploration, concept development (or concept introduction), and application (or concept application) (Brown & Abell, 2007; Maier & Marek, 2006). The exploration phase is where students often engage in a hands-on experience with the phenomenon. In the concept development phases, the teacher guides students, through questioning, to help them make sense of the concepts (Olson, 2009). In the application phase, students use what they have learned in a new situation (Brown & Abell, 2007).

The Biological Science Curriculum Study (BSCS), another “alphabet soup” curricular project, received a grant from IBM in the mid-1980s (Bybee et al., 2015). Their charge was to design a new science and health curriculum for elementary schools (Bybee et al., 2015). A result of this project was the modification of the learning cycle by adding two new phases—the engage and the evaluate (Figure 1) (Bybee, 2006; Bybee et al., 2015). The revised learning cycle was called the 5E. As the name suggests, the 5E consists of five phases that all start with the letter *e*. In the engage phase, the teacher strives to engage students in the learning task to create interest, generate curiosity, and raise questions (Bybee et al., 2006;

“. . . the purpose is to help *students* develop explanations of the scientific phenomenon.”

Bybee et al., 2015). The explore phase is where the teacher uses concrete experiences so students can interact with the phenomenon and examine their ideas (Bybee et al., 2015). In the explain phase, the teacher helps students make sense of the exploratory experiences by directing students’ attention to significant aspects of the experience and scaffolds students’ thinking through the use of open-ended questions. Importantly, while the explain phase can include some teacher explanations (Bybee et al., 2015), the purpose is to help students develop explanations of the scientific phenomenon. The purpose of the elaboration phase is to help students transfer concepts and skills to a new context (Bybee et al., 2015). Finally, the evaluation phase is where teachers assess students’ level of understanding (Bybee, et al., 2006; Bybee et al., 2015). The *Experience Science* program from Savvas Learning Company uses the 5E in each experience, so students start with a hands-on, heads-on experience that provides the foundation for three-dimensional science learning as outlined in the NGSS.

Figure 1: The Learning Cycle and the 5E

The Learning Cycle		The 5E	
Phase	**Purpose**	**Phase**	**Purpose**
		Engage	Set context of the lesson, generate curiosity, raise questions, identify misconceptions
Exploration	Provide concrete experiences with a phenomenon, test ideas	Explore	Provide concrete experiences with a phenomenon, test ideas
Concept Development	Seeks student sense-making from experience, provides new concepts when students are ready, rich discussion of ideas, uses evidence to support conclusions	Explain	Seeks student sense-making from experience, provides new concepts when students are ready, rich discussion of ideas, uses evidence to support conclusions
Application	Use new concept in a more complex situation	Elaborate	Use new concept in a more complex situation
		Evaluate	Observes students as they apply new knowledge, assessment

A Nation At Risk and the Standards Movement

The standards movement is often traced back to a 1983 report by the National Commission of Educational Excellence entitled "A Nation at Risk." ANAR was often viewed as a response to the political and economic perception that the United States was no longer dominating the global marketplace (Kahle, 2007). The document was broadly influential within education and the general public because of the direct, yet colorful language (Kahle, 2007; Ravitch, 2010). For example, the report opened with,

> *"Our Nation is at risk ... the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people. What was unimaginable a generation ago has begun to occur—others are matching and surpassing our educational attainments. If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war."* (National Commission of Education Excellence, 1983, p.1)

ANAR resulted in two major changes. First, more than 700 new policies were legislated in two years, many of which were aimed at increasing high school graduation standards. Second, a greater emphasis on competencies or what students should know when they graduate which led to the standards movement.

As a response to ANAR, the standards movement began in order to develop "clear-cut descriptions of what to teach" in each subject area (Zemelman et al., 2005). In 1985, the year Halley's Comet was visible from Earth, Project 2061 was created to reform science education by the time the comet returned in 2061. Project 2061's goal was to "focus on what is essential to science literacy and to teach [fundamental science ideas] more effectively" by defining scientific literacy and producing a set of standards for all students to achieve scientific literacy (Rutherford & Algren, 1991, p. xvi).

Building on Project 2061, the National Research Council created the National Science Education Standards (NSES) (1996), which outlined standards in four areas of science education: teaching, professional development of teachers, assessment, and science content. The NSES states, "The intent of the Standards can be expressed in a single phrase: science standards for all students" (NRC, 1996, p. 2). The NSES strived to place more emphasis on teaching science through inquiry and guide students to understand fundamental science concepts and move away from verification activities and memorizing scientific facts (1996).

> "Each experience is aligned with all three dimensions of the NGSS."

In 2012, the National Academy of Sciences released "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas". This document served as the foundation for the Next Generation Science Standards (NGSS). The shift to the NGSS had three major differences from the previous standards documents. First, the NGSS has much more emphasis on engineering. Second, the NGSS has a set of performance expectations (PEs) that embeds three dimensions: science and engineering practices (SEPs), disciplinary core ideas (DCIs), and crosscutting concepts (CCC). The SEPs refer to practices scientists use when they investigate the natural world and the practices engineers use when they design systems (National Research Council, 2012). The CCCs refer to concepts that have applications across all disciplines of science (National Research Council, 2012). While previous iterations of the standards do include, what we would call today, the SEPs, DCIs, and CCCs, the integration of the three into three-dimensional learning was a significant shift. Finally, the NGSS standards are fewer in number and more broadly phrased than previous science standards (Fulmer et al., 2018). The *Experience Science* program was built with the NGSS in mind. Each experience is aligned with all three dimensions of the NGSS and each experience has explicit connections to the SEPs, CCCs, and DCIs so that students not only understand science but are able to do science and apply what they have learned.

Phenomena

Phenomena refers to observable events in the natural or designed world (Lowell & McNeill, 2019). Since the NGSS, phenomena-based learning has become an increasing emphasis in science education; however, it has been a part of education since Dewey (1938/1997) and Rousseau (1762/2023). For example, in Emile, or On Education, Rousseau (1762/2023) wrote,

> "Let us transform our sensations into ideas, but do not let us jump all at once from the objects of sense

to objects of thought. The latter are attained by means of the former. Let the senses be the only guide for the first workings of reason. No book but the world, no teaching but that of fact. The child who reads ceases to think, he only reads. He is acquiring words, not knowledge.... Let him know nothing because you have told him, but because he has learnt it for himself. Let him not be taught science, let him discover it. If ever you substitute authority for reason he will cease to reason, he will be a mere plaything of other people's thoughts."

Rousseau makes clear the value of exploring and making sense of natural phenomena, which he called "objects of sense" to encourage thinking and learning. These values are still present in contemporary approaches to science education.

> "Phenomena, in the contemporary science classroom, are used to ground experiences in "real-world" contexts to help students recognize the relevance of their learning."

The re-emergence of phenomena is, in part, a response to teaching approaches that have used phenomena in discrete, disconnected ways (Lee & Gaplin, 2022). Lee & Gaplin (2022) argue that science teachers have often used phenomena narrowly and often in the context of the laboratory. Quinn (2021) echoes these notions when she writes,

> "Traditional school science also introduces phenomena, through demonstrations and laboratory experiments. Usually, these are very specific and isolated events or processes, selected specifically to demonstrate the science to be learned. Too often the phenomena, and the details of them that students are expected to attend to, are neither approachable nor meaningful to students, having no apparent connection to their experience and interests. For students they represent another level of abstraction, why are we investigating this or measuring that?" (p. 848)

What, then, is a contemporary approach to phenomena? Phenomena, in the contemporary science classroom, are used to ground experiences in "real-world" contexts to help students recognize the relevance of their learning. Rather than an isolated event, phenomena can be included more systematically as a part of the science classroom (Lowell & McNeill, 2019). Two general types of phenomena are currently used in science lessons. The first is an "anchoring phenomenon" that starts the unit and is one where many scientific ideas are required to explain it (German, 2019; Penuel & Bell, 2016). The second is an "everyday phenomenon" that can be embedded into a 5E and tends to be connected to one scientific idea (Wilcox, 2022). The *Experience Science* program uses both anchoring phenomena and everyday phenomena to help students see connections between science and the real world.

Conclusion

Savvas Learning Company has integrated anchoring phenomena, everyday phenomena, and the 5E to make a powerful program called *Experience Science* This program utilizes contemporary science teaching practices to scaffold students toward achieving the performance expectations in the NGSS. Each experience is highly connected to three-dimensional learning using science and engineering practices, crosscutting concepts, and disciplinary core ideas throughout. The *Experience Science* program is built for the contemporary science classroom to help all students succeed in science.

References

Atkin, J. M., & Karplus, R. (1962). Discovery or invention?. *The Science Teacher,* 29(5), 45-51..

Brown, P. L., & Abell, S. K. (2007). Examining the learning cycle. *Science and Children, 44*(5), 58-59.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. *Colorado Springs, Co: BSCS, 5*(88-98).

Bybee, R., Taylor, J. A., Gardner, A., Van Scotter, P., Carlson Powell, J., Westbrook, A., & Landes, N. (2015). *The BSCS 5E instructional model.* Arlington, TX: NSTA press.

DeBoer, G. (2019). *A history of ideas in science education.* Teachers college press.

Dewey, J. (1938/1997). *Experience and Education.* Collier-Macmillan.

Fuller, R. G. (2003). "Don't Tell Me, I'll Find Out" Robert Karplus—A Science Education Pioneer. *Journal of Science Education and Technology, 12*(4), 359-369.

Fuller, R.G., & Hairline, B.K. (2013). Robert Karplus (1927-1990): Science Education Pioneer. In Pedersen, J., Finson, K. D., Spector, B. S., & Jablon, P. (Eds.). (2013). Going back for our future: *Carrying forward the spirit of pioneers of science education.* (pp. 178-198). IAP.

Fulmer, G. W., Tanas, J., & Weiss, K. A. (2018). The challenges of alignment for the Next Generation Science Standards. *Journal of Research in Science Teaching, 55*(7), 1076-1100.

German, S. (2019). Using the Anchoring Phenomenon Routine to introduce a science unit. *Science Scope, 42*(5), 32-35.

Rousseau, J.J. (1762/2023). *Emile, or Education.* Newcomb Livraria Press.

Kahle, J. B. (2013). Systemic reform: Research, vision, and politics. *In Handbook of research on science education* (pp. 911-941). Routledge.

Karplus, R., & Thier, H.D. (1967). A new look at elementary school science. Chicago: Rand McNally.

Kyle, W. C., Shymansky, J. A., & Alport, J. M. (1982). Alphabet soup science: A second look at the NSF-funded science curricula. *The Science Teacher, 49*(8), 49-53.

Lawson, A. E. (1988). A better way to teach biology. *The American Biology Teacher, 50*(5), 266-278.

Lawson, A.E. (2013). The Nature and Development of Scientific Reasoning: My Career in Science Education. In Pedersen, J., Finson, K. D., Spector, B. S., & Jablon, P. (Eds.). (2013). *Going back for our future: Carrying forward the spirit of pioneers of science education.* (pp. 199-216). IAP.

Lee, O., & Grapin, S. E. (2022). The role of phenomena and problems in science and STEM education: Traditional, contemporary, and future approaches. Journal of Research in Science Teaching, 1–9. https://doi.org/10.1002/tea.21776

Maier, S. J., & Marek, E. A. (2006). The learning cycle: A reintroduction. *The Physics Teacher, 44*(2), 109-113.

National Commission on Excellence in Education. (1983). *A Nation at Risk: The Imperative for Educational Reform.* Washington, D.C.: U.S. Department of Education.

National Research Council. (1996). *National science education standards.* National Academies Press.

National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. National Academies Press.

NGSS Lead States. (2013). Next generation science standards: For states, by states. The National Academies Press.

Olson, J. K. (2009). Being deliberate about concept development. *Science and Children, 46*(6), 51.

Penuel, W., and P. Bell. 2016. Qualities of a good anchor phenomenon for a coherent sequence of science lessons. STEM Teaching Tools. www. stemteachingtools.org/ assets/ landscapes/STEM-TeachingTool-28-Qualities-of-AnchorPhenomena.pdf.

Quinn, H. (2021). Commentary: The role of curriculum resources in promoting effective and equitable science learning. Journal of Science Teacher Education, 32(7), 847–851. https://doi.org/10.1080/1046560X.2021.1897293

Ravitch, D. (2016). The Death and Life of the Great American School System. (3rd Edition). Basic Books.

Rudolph, J. (2002). Scientists in the classroom: The Cold War reconstruction of American science education.

Palgrave.

Rutherford, F. J., & Ahlgren, A. (1991). *Science for all Americans.* Oxford university press.

Wilcox, J. (2022, March 31-April 2). You Started with a Phenomenon! Now What? [Presentation]. National Science Teaching Association, Houston, Texas.

Wissehr, C., Concannon, J., & Barrow, L. H. (2011). Looking back at the Sputnik era and its impact on science education. *School Science and Mathematics, 111*(7), 368-375.

Zemelman, S., Daniels, H., & Hyde, A. (2005). Best practice: Today's standards for teaching and learning in America's schools. *Education Review.*

SAVVAS
LEARNING COMPANY

Savvas.com
800-848-9500

Join the Conversation
@SavvasLearning

0624.KH.LB.Sci581R1430