A Learning Cycle for All Students

Modifying the 5E instructional model to address the needs of all learners

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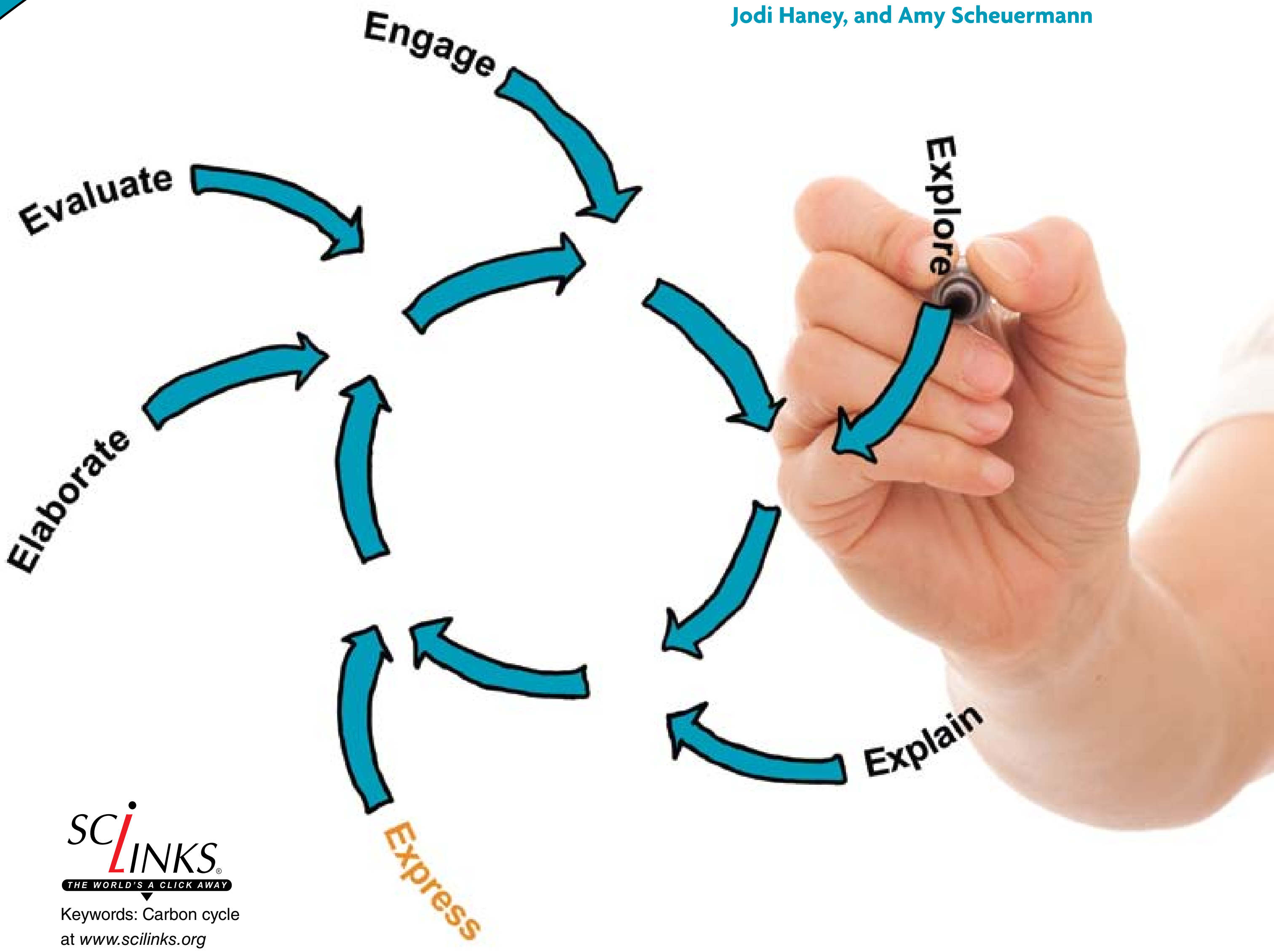

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"Science in our schools must be for all students: All students, regardless of age, sex, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science, should have the opportunity to attain high levels of scientific literacy."
—National Science Education Standards *(NRC 1996, p. 20)*

The National Science Education Standards are designed to provide a vision of scientific literacy for *all* students—regardless of age, race, ethnic background, English-language proficiency, socioeconomic status, disability, or giftedness. The Standards delineate what all students should know and be able to do by the time they graduate high school (NRC 1996). But how do we, as teachers, provide each student with the opportunity to attain scientific literacy without compromising these Standards?

One of the most powerful strategies in science instruction—which aligns with the Standards—is the use of learning cycles and instructional models. The Biological Sciences Curriculum Study (BSCS) 5E—Engage, Explore, Explain, Elaborate, and Evaluate—instructional model is perhaps the most popular and widely used in the classroom (BSCS and IBM 1989). This model has been shown to have a positive impact on science education (Bybee et al. 2006) and is constantly being refined as new research emerges to support its effectiveness.

In this article, we suggest modifying the 5E model by inserting a conscious pause in the learning cycle—what we call the *Express* phase—to assess and ensure that *all* students are progressing adequately through the early phases of the cycle.

Ultimately, this revised cycle enables all learners to meet the Standards addressed in a particular lesson by providing differentiated opportunities.

Modifying the model

One of the most widely accepted principles in science learning is the idea that students must be provided the opportunity to construct their own knowledge and understanding (Yager 2000). In this student-centered environment, the use

FIGURE 1

5E model with Express phase and modified Elaborate phase.

Adapted from Bybee et al. 2006.

Phase	Summary
Engage	The teacher accesses students' 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.
Explore	Explore experiences provide students with a common base of activities within which current concepts, 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.
Explain	The Explain phase is initiated when students have a distinctive opportunity to articulate their own understanding of the concepts encountered during the lesson cycle thus far. During this phase, the teacher helps focus students' attention on a particular aspect of their phase or exploration experiences by providing scientific explanations, introducing important vocabulary, or discussing and clarifying misconceptions. This phase provides opportunities for teachers to introduce a concept, process, or skill that capitalizes on the student explanations and experiences from the Explore or Engage parts of the lesson.
Express	The Express phase provides active formative assessment of learning that informs and guides additional differentiated instruction during the Elaborate phase.
Elaborate	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences—in a three-tiered, differentiated instruction model—students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
Evaluate	The Evaluate phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

Safety note: Indirectly vented chemicals-splash goggles are required for the activity pictured here—not safety goggles, as shown in this photo.

The tiers, explained.

- *Tier I:* Novice learning level
- *Tier II:* On-target learning level
- *Tier III:* Advanced learning level

of learning cycles in the classroom helps students construct concepts, develop reasoning patterns, (Lawson 2001) and connect their new knowledge to real-life situations (Blank 2000). The 5E instructional model is supported by current cognitive research on learning (Bransford, Brown, and Cocking 1999).

Many have modified and adjusted this model to meet the needs of teachers and students in the classroom. For example, one modification incorporates another "E"—E-search—by infusing technology in each phase (Chessin and Moore 2004). Another adds analogies to each phase to motivate students and clear up misconceptions (Orgill and Thomas 2007). And in the 7E model (Eisenkraft 2003), the Engage phase is expanded into two components—Elicit and Engage—and the Elaborate and Evaluate phases are divided into three components—Elaborate, Evaluate, and Extend. This 7E model emphasizes eliciting prior knowledge and ensures opportunities for the transfer of learning.

Our modification to the 5E model seeks to confirm that *all* students are progressing adequately through the learning cycle. Specifically, our version is based on the need to encourage evaluation throughout the entire cycle and not just during the Evaluate phase (Volkmann and Abell 2003).

This modification involves a conscious pause in the learning cycle—the Express phase—which allows the teacher to conduct active formative assessment of learning after the Explain phase (Figure 1, p. 57). The goal is to inform and guide additional differentiated instruction during the Elaborate phase. This type of assessment is different than the sometimes informal and anecdotal assessment that occurs during the Explain component.

The Express phase

We often hear teachers say the following: "I don't know why students did so poorly on the test; they participated in the exploration and seemed to enjoy themselves." To address this situation, the Express phase provides an opportunity for all students to safely express their ideas about the teaching and learning that has occurred at this point in the learning cycle. The teacher also confirms whether students are mastering the content or expected outcome.

Furthermore, this phase provides an opportunity to assess whether misconceptions identified during the Engage phase have been corrected during the Explore and Explain phases. In that regard, the Express phase allows teachers to analyze and assess their own teaching effectiveness.

Based on each student's response in this phase, the teacher can provide a three-tiered, student-specific, and differentiated Elaborate phase to meet each student's individual needs. This ensures that all learners (e.g., high achievers, average achievers, low achievers, English language learners, and special needs students) have encountered and mastered the intended lesson outcomes before the formal or final evaluation is given (Figure 1).

What it looks like

In our experience, formative assessment probes are a powerful and effective way to carry out the Express phase (Keeley 2005; Keeley, Eberle, and Farrin 2005). These probes uncover students' ideas and provide the teacher with specific feedback to inform further instruction. The probes are especially helpful because they incorporate content from the Standards and findings from student misconceptions research—they ultimately force students to confront their own thinking and misconceptions.

Answers to the assessment probes will vary according to student readiness, learning profile, and interests. The teacher then uses these responses to design three-tiered, differentiated instruction that is optimized for each student. Though these tiered activities focus on the same content and skills, they provide different challenges and levels of complexity.

Typically, the majority of students (Tier II) proceed adequately through the learning cycle and are ready for the Elaborate phase to develop deeper understanding. But perhaps a group of gifted students (Tier III) needs a more challenging Elaborate phase to keep them deeply engaged in the lesson. And perhaps students with limited English-language proficiency (Tier I) require a modified activity during this phase that accounts for their cultural background and level of language proficiency.

Depending on the results of the Express phase, students with disabilities that have Individualized Education Plans (also Tier I) may need another Explore phase with similar or adjusted activities and content, perhaps followed by another Explain phase. The goal is to differentiate instruction and address the needs of each student so that ultimately they succeed during the summative assessment (Evaluate phase).

It is important to note that tier-placing is content-specific. In other words, a student in Tier II during the photosynthesis unit might be in Tier III in the evolution unit. However, flexible grouping and cooperative teaching strategies should be used to deal with struggling students so they do not feel like "permanent members" of the Tier I group.

An example

During the *Engage* phase in a lesson on the role of the carbon cycle in photosynthesis (see "On the web"), students watch a video called *Minds of Their Own Video: Seeds to Logs* (Harvard-Smithsonian Center for Astrophysics 1995). In the first segment of this video, students are asked how they think a large piece of a log was formed, or "Where did all that 'stuff' come from?"

After watching this portion of the video, students complete a "Think-Pair-Share" activity. First, they think about the question individually for several minutes, then pair up to discuss and reconstruct their ideas, and finally, share their ideas through whole-group discussion.

During the *Explore* phase, students complete a lab exercise that involves planting, growing, and observing seeds in a closed system. They weigh the system periodically over 12 days and record observations accordingly. Students present their data and respond to the focus question: "Where did all the 'stuff' to make the new plants come from?"

During the *Explain* phase, students present their lab data and discuss their ideas regarding the focus question. The teacher then leads a discussion about the carbon cycle and the role it plays in photosynthesis.

In the *Express* phase, students are given the "Giant Sequoia Tree" assessment probe (Keeley, Eberle, and Farrin 2005). This probe is designed to assess whether students comprehend the counterintuitive concept that a gas (carbon dioxide) contributes most of the mass to the plant's structure. Students look at a picture of a giant sequoia tree and answer the question: "Where did most of the matter that makes up the wood and the leaves of this huge tree originally come from?" Students circle the best answer in a multiple-choice question and explain their thinking.

According to the authors of this assessment probe, students with novice level understanding (Tier I) may not believe that air is made up of matter or that it has mass. Tier II students may use models of atoms as they communicate their understanding of photosynthesis, though they may still have a difficult time expressing that a gas (carbon dioxide) contributes mass to the reaction. Tier III students may demonstrate an understanding that gas contributes mass, but may also reveal "intuitive" explanations that most of the mass comes from water or soil.

After students' levels of understanding are identified, they are matched to the appropriate *Elaborate* phase activity. Tier I students, and Tier II and III students if deemed appropriate by the teacher, are provided additional opportunities to explore the concept that gases have mass (e.g., dry ice teacher demonstrations), and then proceed to a computer simulation showing the flow of carbon through the environment (e.g., The Carbon Cycle Game; see "On the web").

Tier II students design and conduct an experiment to determine the role of carbon dioxide in plant photosynthesis using elodea plants and bromothymol blue indicator.

Tier III students first work alongside the Tier II students to assist in the design of the experiments; after the designs are complete, these students go off and work in small teams to develop computer animations using open-source educational software, such as Alice (see "On the web"), to illustrate the carbon cycle's role in photosynthesis.

Finally, during the *Evaluate* phase, all students are given a short multiple-choice assessment of the related concepts, written across Bloom's levels of thinking. They then receive an additional assessment probe—"Seedlings in a Jar" (Keeley 2005). During this probe, students receive a prompt (with a picture) explaining that a 12-day experiment was conducted in which five seeds were planted in a container of soil, watered, and placed in the light. The container was sealed after watering. Plants sprouted and grew as a result.

Students must determine how much the container weighs after the 12 days of growth, in comparison to how much it weighed before growth, and explain their responses. This probe can be modified to have students include concepts learned during the lesson sequence in their answer.

Conclusion

Learning cycles are research-based teaching tools that can help students explore concepts in science and assist teachers as they plan lessons intended to facilitate meaningful and deep understanding of the concepts being taught. There is a growing body of empirical evidence that the 5E instructional model positively affects mastery of subject matter, scientific reasoning, and interest and attitudes toward science (Bybee et al. 2006). However, the model should be a reference for teachers—not a rigid template.

In this article, we have added a new formative assessment phase—Express—to monitor the progress of individual students and their depths of understanding through the cycle. Here, students express their ideas and confront their thinking when answering formative assessment probes. The phase also reinforces a student-centered approach by showing students that their ideas are fully valued and used when designing instructional strategies.

More important, the results from the Express phase are used to design optimal learning opportunities for individual students based on their current understanding. This phase is different than the ongoing informal evaluation that occurs during the other phases and distinct from the summative Evaluate phase at the end of the cycle.

Specifically, the Express phase is based on student-"expressed" performance that leads into a three-tiered, student-specific, and differentiated Elaborate phase. Teachers can use the Express phase as a self-analysis of their teaching effectiveness by monitoring how students progress through the learning cycle.

A comment from one of the teachers who received professional development on this revised 5E model and had an opportunity to implement it in the classroom summarizes our initial goal: "I have completely changed my teaching strategies so that each [student] has a fair and equal opportunity to learn without being bored or not understanding."

Naturally, many teachers will need additional training to effectively and seamlessly incorporate this modified model in their classrooms—but this new phase can have a profound effect on science learning for *all*. ■

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On the web

Alice, Carnegie Mellon University: *www.alice.org*

Northwest Ohio Center for Excellence in STEM Education's 6E lesson on the carbon cycle's role in photosynthesis: *http://cosmos.bgsu.edu/resources/6E_Model.htm*

The Carbon Cycle Game: *www.windows.ucar.edu/earth/climate/carbon_cycle.html*

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There are different learning goals for students to focus on. Find out how to use the right combination to maximize your time for high-quality learning.Â There are a few different types of learning goals. Some students may benefit from a mix of educational goals, perhaps some short and some long term, or maybe one main goal for each subject area. In this article, weâ€™ll help you figure out what your students really need so you can maximize time for the quality learning that you strive to bring to your class. How to set educational goals for students. Photo credit: Gaelle Marcel. Learning, therefore, is unique to the individual learner. Students adapt their models of understanding either by reflecting on prior theories or resolving misconceptions. Students need to have a prior base of knowledge for constructivist approaches to be effective. Brunerâ€™s spiral curriculum (see below) is a great example of constructivism in action.Â Problems arise when our class has children at different stages in it, in this case, we must carefully differentiate our pedagogy to allow supportive learning for all students. 9. Kolbâ€™s Experiential Theory. Kolbâ€™s Experiential Learning Cycle. Feel free to share this infographic by clicking on it. David Kolb. The use of a learning cycle approach in the classroom differs greatly from traditional teaching methodologies. For example, learning cycles focus on constructivist principles and emphasize the explanation and investigation of phenomena, the use of evidence to back up conclusions, and experimental design.Â Although the projects differ slightly in their academic year activities, a core 2-week summer institute experience is similar for all of the teachers. The summer institute is designed to encourage teachers to explore their district-adopted inquiry-based science kits in a hands-on fashion. A scientist and science educator team facilitates each session using 5E Models as the guiding framework. Too often, we're expecting students to learn material without asking them to do much of anything with it. Why is this a problem? Where did it come from? And how can we fix it?Â Then they have some sort of worksheet where theyâ€™re basically regurgitating what was on those slides. After this cycle repeats four or five times, they have some kind of test. And thatâ€™s it. This is not good.