day and discovering the next day that the students just did not "get it"? If my teaching philosophy was based upon assumptive learning, I might assume that learning occurs because the students are listening to me, the teacher. But just because students are listening to me does not mean that they are always making sense of the words coming out of my mouth. Words are a sensory input that the learner must act upon.

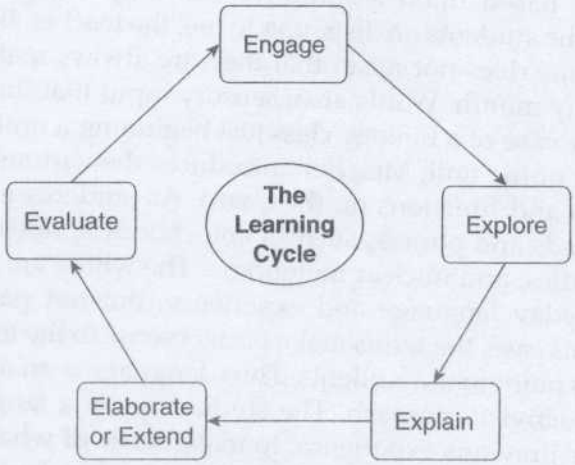
Consider the case of a biology class just beginning a unit on the parts of the cell. On the first day of the unit, Mrs. Bell introduces the various cell organelles by writing their names and functions on the board. As students are copying notes, she is spelling out words and phrases such as mitochondria, ribosome, endoplasmic reticulum, Golgi bodies, and nuclear membrane. The words are part of the sender's (the teacher's) everyday language and experience, but not part of the receivers' (the students'). In this case, the terms make perfect sense to the teacher but may not mean anything at this point to the students. Thus, language is an important aspect of learning in a constructivist approach. The student needs a language connection, based upon his or her previous experience, to make sense of what is currently being said. We can see in the organelle lesson that the teacher had the cognitive structure (schema) to make sense of these terms. In the case of students without the cognitive structure to make sense of these terms, the words enter the brain through the ear, look for connections, and, finding none, get filtered out. Students are left with puzzled looks on their faces.

THE 5E LEARNING CYCLE

There are several implications to the constructivist learning model. The 5E Learning Cycle is one of them. Like constructivism, the 5E Learning Cycle is not new. It was originally proposed for elementary school science programs in the early 1960s by J. Myron Atkin and Robert Karplus (1962) and further documented by Lawson, Abraham, and Renner (1989), Beisenherz and Dantonio (1996), Marek and Cavallo (1997), Bybee (1997), Abraham (1997), and Colburn and Clough (1997). In the last 10 years, however, it has become a popular model for high school teachers too. Many articles in *The American Biology Teacher* refer to the learning cycle approach as an effective lesson format. In addition, the Biological Sciences Curriculum Study (BSCS), a premier curriculum developer in the area of biology, uses the 5E format for its instructional model. Unlike traditional three-step lesson plans in science that begin with introducing new vocabulary, then providing a step-by-step lab to verify the information presented, and finally finishing with an end-of-chapter problem or test, the 5E Learning Cycle model (see Figure 3.1) is a constructivist teaching strategy that includes five stages consistent with cognitive theories on how learning occurs:

- Engagement
- Exploration
- Explanation
- Elaboration or Extension
- Evaluation

Figure 3.1 The Learning Cycle



During the **Engagement** stage, the teacher sets the stage for learning. This is accomplished by stating the purpose of the lesson. Often, the teacher introduces the topic of the lesson and states the expectations for learning by explaining what students should know and be able to do by the end of the lesson or unit. The Engagement phase is also a means of getting the students' attention and focus. By using attention-grabbing demonstrations and discrepant events (Liem, 1987), the teacher creates ways to "hook" students into learning. Discrepant events generate interest and curiosity that set the stage for inquiring about a particular phenomenon. Discrepant events serve to create cognitive dissonance—or, in Piaget's words, disequilibrium—because the observation of such events does not readily assimilate into the student's presently held understanding. Because the observations made from discrepant events are counterintuitive to the students' prior experience, the students quickly activate questions.

From a constructivist perspective, the Engagement phase also provides an opportunity for the teacher to activate learning, assess prior knowledge, and have students share their prior experiences about the topic. During the Engagement stage, the teacher can note possible naive conceptions or misconceptions stated by the students. These misconceptions can be addressed during and after the students have an opportunity to work through the Exploration and Explanation stages. It should be noted that it is nearly impossible for any teacher to fully ascertain all the misconceptions held by all the students. The learning cycle, specifically the Engagement stage, does, however, provide the teacher with a means of assessing students' current beliefs and understandings.

The **Exploration** stage is an excellent place to engage high school students in inquiry-based labs or teacher-initiated inquiries. During the Exploration stage, students raise questions, develop hypotheses to test, and work without direct instruction from the teacher. They go about collecting evidence and data, recording and organizing information, sharing observations, and working in cooperative groups. The Exploration stage allows students to build on a common experience as they carry out their investigations. This common experience or exploration is

essential because students will enter the classroom with different levels of experience and knowledge about the topic being studied. The Exploration stage allows all students to experience hands-on learning and helps "level the playing field" within a culturally diverse classroom. The Exploration stage also provides opportunities for students with diverse experiences to share their different understandings and broaden the perspective of the entire class.

During the teacher-directed **Explanation** stage, the teacher facilitates data- and evidence-processing techniques for the individual groups or entire class (depending on the nature of the investigation) from the information collected during the exploration. Information is discussed, and the teacher often explains the scientific concepts associated with the exploration by providing a common language for the class to use. This common (or scientific) language helps students articulate their thinking and describe their investigations and experiences in scientific terms. The teacher can continue to introduce details, vocabulary terms, and definitions to the lesson as students assimilate their understanding against the "scientific" explanation. This can be accomplished by using direct instruction/lecturing, audiovisual resources, online sources, and computer software programs. Here, the teacher uses the students' prior experiences to explain the concepts and attempts to address misconceptions uncovered during the Engagement or Exploration stages. The Explanation stage is sometimes called the "Concept Development" stage because evidence and newly developed concepts are assimilated into the cognitive structure of the student. During the Explanation stage, students may work to assimilate or accommodate new information as they make sense of their understanding, "constructing" new meaning from their experience and conceptual change.

During the **Elaboration or Extension** stage, the teacher helps reinforce the concept by extending and applying the evidence to new and real-world situations outside the classroom. This stage also facilitates the construction of valid generalizations by the students, who also may modify their presently held understandings of the phenomena being studied. During the Elaboration stage, teachers can provide follow-up, student-initiated inquiries and expand upon the teacher-initiated inquiry from the Exploration stage.

During the **Evaluation** stage, the teacher brings closure to the lesson or unit by helping students summarize the relationship between the variables studied in the lesson and posing higher-order questions that help them to make judgments, analyses, and evaluations about their work. Connections among the concepts just studied and other topics can be illustrated by using a concept map. Here, the teacher can compare the prior knowledge that was identified during the Engagement stage with the newly formed understanding gained from the lesson.

On the assessment side, the teacher will provide a means for students to assess their learning and make connections from prior understandings to new situations that encourage the application of concepts and problem-solving skills. Assessment strategies may include monitoring charts or checklists, portfolios, rubrics, and student self-evaluations. Later, in Chapter 8, we will address these assessment strategies.

The Biological Science Curriculum Study (BSCS) provides an excellent summary of the 5E Learning Cycle by indicating descriptors for the students as well as the teachers regarding consistency with the model. (See Figures 3.2 and 3.3.)

Figure 3.2 What the Student Does

Stage of the Instruction Model	*What the Student Does . . .*	
	That Is Consistent *With the 5E Model*	*That Is* Inconsistent *With the 5E Model*
Engage	Asks questions, such as: Why did this happen? What do I already know about this? Shows interest in the topic	Asks for the "right" answer Offers the "right" answer Insists on answers or explanations Seeks one solution
Explore	Thinks freely, but within the limits of the activity Tests predictions and hypotheses Forms new predictions and hypotheses Tries alternatives and discusses them with others Records observations and ideas Suspends judgment	Lets other do the thinking and exploring (passive involvement) Works quietly with little or no interaction with others (only appropriate when exploring ideas or feelings) "Plays around" indiscriminately with no goal in mind Stops with one solution
Explain	Explains possible solutions or answers to others Listens critically to others' explanations Questions one another's explanations Listens to and tries to comprehend explanations the teacher offers Refers to previous activities Uses recorded observations in explanations	Proposes explanations from "thin air" with no relationship to previous experiences Brings up irrelevant experiences and examples Accepts explanations without justification Does not attend to other plausible explanations
Elaborate	Applies new labels, definitions, explanations, and skills in new but similar situations Uses previous information to ask questions, propose solutions, make decisions, and design experiments Draws reasonable conclusions from evidence Records observations and explanations Checks for understanding among peers	"Plays around" with no goal in mind Ignores previous information or evidence Draws conclusions from "thin air" Uses only those labels that the teacher provided
Evaluate	Answers open-ended questions by using observations, evidence, and previously accepted explanations Demonstrates an understanding or knowledge of the concept or skill Evaluates his or her own progress and knowledge Asks related questions that would encourage future investigations	Draws conclusions without using evidence or previously accepted explanations Offers only yes or no answers and memorized definitions or explanations Fails to express satisfactory explanations in his or her own words Introduces new, irrelevant topics

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Figure 3.3 What the Teacher Does

Stage of the Instruction Model	*What the ~~Student~~ Teacher Does . . .*	
	That Is Consistent *With the 5E Model*	*That Is* Inconsistent *With the 5E Model*
Engage	Creates interest Generates curiosity Raises questions Elicits responses that uncover what the students know or think about the concept/topic	Explains concepts Provides definitions and answers States conclusions Provides closure Lectures
Explore	Encourages the students to work together without direct instruction from the teacher Observes and listens to the students as they interact Asks probing questions to redirect the students' investigations when necessary Provides time for students to puzzle through problems Acts as a consultant for students	Provides answers Tells or explains how to work through the problem Provides closure Tells the students that they are wrong Gives information or facts that solve the problem Leads the students step-by-step to a solution
Explain	Encourages the students to explain concepts and definitions in their own words Asks for justification (evidence) and clarification from students Formally provides definitions, explanations, and new labels Uses students' previous experiences as the basis for explaining concepts	Accepts explanations that have no justification Neglects to solicit the students' explanations Introduces unrelated concepts or skills
Elaborate	Expects the students to use formal labels, definitions, and explanations provided previously Encourages the students to apply or extend the concepts and skills in new situations Reminds the students of alternative explanations Refers the students to existing data and evidence and asks: What do you already know? Why do you think . . .? (strategies from explore apply here also).	Provides definitive answers Tells the students that they are wrong Lectures Leads students step-by-step to a solution Explains how to work through the problem
Evaluate	Observes the students as they apply new concepts and skills Assesses students' knowledge and/or skills Looks for evidence that the students have changed their thinking or behaviors Allows students to assess their own learning and group-process skills Asks open-ended questions, such as: Why do you think . . .? What evidence do you have? What do you know about x? How would you explain x?	Tests vocabulary words, terms, and isolated facts Introduces new ideas or concepts Creates ambiguity Promotes open-ended discussion unrelated to the concept or skill

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