

## A Salivating Inquiry Experience: Enzyme Catalysis via the 7E Learning Cycle

*The following is the teacher's lesson plan with teacher notes included parentheses.*

### ***Phase One: Introduction to Enzyme Catalysis via the 7E Learning Cycle***

**Engage:** What are most packing “peanuts” composed of and why?

(Allow students to answer out loud, individually, after appropriate wait time.)

(Prepare a dilute starch solution in front of the class by dissolving one or two peanuts in 1 L of distilled water.)

**Elicit:** Predict the effect of adding Lugol's iodine solution to a tube containing the starch in water. Justify your prediction. Write in complete sentences. Do this individually, then, after you have written at least three sentences, share your ideas with your neighbor and try to achieve some consensus.

(Give the students a few minutes to think, write, and discuss their ideas.)

(Elicit student responses by asking them to read *verbatim* their responses to the class. Clarify as necessary, but do not validate or criticize these ideas at this point.)

**Explore:** Direct students to add a few drops of the iodine solution to a test tube containing the starch in water. Ask students to write down as many observations as they can about the changes that take place.

(After students are finished writing, take a few minutes to summarize their observations out loud.)

Now ask the students to predict the effect of adding a few milliliters of prepared “synthetic saliva” to the tube containing the starch and iodine. Make sure to prompt them for their explanation in writing as well—this should be done in complete sentences, individually first, then shared in small groups.

At room temperature, the reaction usually takes a few minutes before a visual change can be observed. So, before asking students to share their predictions with the whole class, direct students to draw up 2 mL of the amylase solution into the graduated pipette and deliver it to the tube containing the starch and iodine, then set the tube aside.

(Elicit student responses by asking them to read *verbatim* their responses to the class. Clarify as necessary, but do not validate or criticize these ideas at this point.)

**Explain:** At this point, direct students' attention to the reaction tube and to write down as many observations as they can. Then, in pairs (or groups of up to four students), challenge them to construct a scientific explanation that accounts for their observations. If their observations conflict with their predictions, ask them to try to reconcile them.

(Elicit groups' consensus via verbal prompting, clarify ideas [including explanations] out loud, and then summarize them on the board. Ask students to analyze or criticize each idea based on their own experience and prior knowledge.)

**Evaluate (Formative):** Ask the students to write predictions or explanations for the following prompts (in complete sentences):

- What would you expect to see if more iodine solution was added to your reaction tube after the blue-black color had disappeared?
- What would happen in the test tube if additional starch solution was added to your reaction tube after the blue-black color had disappeared?
- What would have happened in your reaction tube if you had added a starch solution containing five to ten dissolved “peanuts” instead of the solution containing only one or two peanuts?

(Discuss students' ideas for a few minutes out loud before proceeding.)

Finally, provide (as needed) any direct instruction that brings closure and clarity to this phenomenon. The “big” ideas, from our perspective, are:

- Enzymes are biological catalysts whose role is to accelerate chemical reactions in living systems.
- As catalysts, enzymes are not consumed during chemical reactions and therefore, in theory, can be used indefinitely (or repeatedly).
- It is essentially impossible to predict *how fast* a catalyzed reaction will proceed without carrying it out experimentally.
- Enzymes are typically extremely substrate-specific—they will only catalyze reactions between specific reactants.
- The enzyme amylase in human saliva, catalyzes the hydrolysis of amylose (a polysaccharide that forms alpha helixes and binds triiodide ions to form a dark-blue complex) into maltose, a disaccharide that cannot bind triiodide effectively (hence the disappearance of the blue color).

### ***Phase Two: Open-Inquiry Experience (Elaborate)***

Ask the students to suggest how the hydrolysis reaction could be accelerated (how they could make the blue color disappear faster) or slowed down (how they could make the blue color persist longer). Answers will vary, but try to lead them to come up with at least three variables: temperature, pH, and substrate (or enzyme) concentration.

Now ask the students to design an experiment to answer a question about the reaction kinetics. In pairs, they will do the following:

- Define a research question
- Devise a procedure for carrying out an experiment to help answer the question posed
- Determine the data that needs to be collected
- Suggest a tentative hypothesis and their reasoning
- Carry out the procedure (with multiple trials, if possible)

- Present their findings to the class after experimentation and further reading or research on the topic (online or otherwise)

**Evaluate (Summative):** Students present their research question, procedure, results, and discussion (conclusions) to the class and open the floor for questions from the audience.

We suggest grading them in three categories:

1. Experimental method (consistency, methodology, appropriate data collected)
2. Conclusions and discussion based on their analysis and further research on the subject
3. Clarity and professionalism in their presentation and visual aids

**Extend:** Using a traditional paper and pencil test, include some items where application, synthesis, or evaluation is required to answer correctly:

1. Why are humans unable to chew up paper and digest it like a termite can?
2. Why are some people unable to digest milk products?
3. Assuming equal amounts of saliva, why would some students' reactions take longer than others?
4. What would you observe if you added the liquids in this order: (starch solution, saliva, wait 10 minutes, iodine solution)
5. What are some diseases that are caused by overactive or under active enzymes?

#### **Note from the authors:**

Lessons learned:

- Deep conceptual understanding of fundamental science ideas takes time—much more time than we often allocate to them.
- Assessing prior knowledge is essential to pinpointing and addressing misconceptions and driving conceptual change.
- (Student) exploration prior to (teacher) explanation is more effective in terms of motivation and conceptual change than the opposite approach (e.g., lecture followed by lab).
- Most students find the predict-observe-explain learning cycle to be an engaging approach to learning science.
- The more ownership and self-direction we give to the students, the more motivated the students are to perform well.
- Discerning when to answer students' questions with direct answers or another question is one of the most difficult instructional decisions to make. Trying to find their “zone of proximal development” can be difficult, since the goal is to give just enough information to push them along in their concept formation. Too little information leads to frustration, too much leads to boredom and disinterest.

Materials needed:

- starch packing peanuts
- large test tubes (3 per student)
- disposable graduated pipettes (3 per student)
- lyophilized  $\alpha$ -amylase
- Lugol's iodine solution

- buffer solutions (pH 3, 7, 8, 10, 12)
- hot plates
- stopwatches
- beakers (to hold the test tubes)
- ice