Appendix A

To exemplify the major differences between instructional strategies, the photosynthesis unit, a two-day unit, is outlined below.

Inquiry Teaching

Students begin with an exploration activity where they are given *Elodea* plants, lights, different colored filters, ice, baking soda, and heating plates and are challenged to find out what affects the rate of photosynthesis by placing *Elodea* in test tubes and measuring the change in gas levels while changing various variables. Students make alternative hypotheses and then devise ways to test them. Results are listed on the board and discussed as a class to elucidate the equation for photosynthesis.

Students then work together as groups through several historical experiments that helped in elucidating the process of photosynthesis (e.g., van Neil's experiment on sulfur-using bacteria and Engelmann's experiment on the colors of light). They are given the experimental set-up and the pertinent results. From there, they discuss with their group what conclusions should be drawn. As a class, students come up with the main components of the photosynthetic pathway.

Following these explorations, students are introduced to important terms and cellular components involved in photosynthesis via Powerpoint presentation. This concludes the first day.

The second day begins with a quick engagement activity where students plant seeds. The term introduction phase is finished, if not completed the previous day. This is followed by two application activities. The first activity is done as a group. Students answer questions about the seed they just planted. They are asked to track the metabolic activities of the growing seedling from the time that it is a seed-encased embryo to the time its cotyledon breaches the surface of the ground. Using what they have learned in the previous unit on cellular respiration, coupled with what they have learned about photosynthesis and its requirements, they should be able to answer the questions. The second activity is done individually. Students are asked to illustrate the entire process on a piece of posterboard in any fashion that makes sense to them. Students are allowed to be creative and demonstrate their knowledge in any way they see fit.

Traditional Teaching

Students begin day one with a Powerpoint lecture on photosynthesis. In this lecture, they are introduced to all the pertinent terms and cellular components involved. Important terminology is listed on the whiteboard with definitions. Students follow along with their textbooks and have little interaction with the instructor unless clarification is needed. Occasionally, the instructor will ask questions of students if it pertains to information they should have already learned in previous units.

Following the lecture, students work as groups to complete the following laboratory exercise (outlined in a laboratory manual). The laboratory exercise involves calculating the rate of photosynthesis of an *Elodea* plant using the same experimental set-up as in the inquiry condition but with no room for independent activities. The rate is calculated by observing the change in the water level due to the build-up of oxygen gas in the test tube containing *Elodea*. The calculations are laid out for students with blanks to be filled in with their observed numbers. They are directed to compare the rate of photosynthesis under white light to the rate under green light to the rate when the plant is covered in foil. Students are given an absorption spectrum graph of the different photosynthetic pigments and then asked to interpret the graph and decide if plants use green light. Terms, such as gross photosynthesis, net photosynthesis, and cellular respiration, are introduced and defined in the lab procedure. This ends the first day.

The second day begins with a pop-quiz reviewing the lecture materials from the previous day. This is followed by a Powerpoint lecture to finish what was not finished the previous day, done in the same format as before. This is followed by an additional laboratory exercise done as a group. Students are told that during the second stage of photosynthesis, plants take in carbon dioxide. They are then directed through a procedure that confirms this statement. Using phenol red solution as a pH indicator, students observe the change in pH as photosynthesis takes place. Following these exercises, students answer review questions at the end of the lab that ask directed questions about the procedures they just performed.

Appendix B

Sample unit exam questions are shown below for each instructional strategy. These questions exemplify the assessment style used by each teacher throughout the course of the semester.

Inquiry Assessment

Below is the experimental set-up as we did in class (see Figure 1) to measure the amount of calories in different foods. A test tube, containing 10 mls of water, is placed in a clamp with a thermometer in the water to measure temperature changes. Food items are burned directly beneath the test tube and the change in temperature of the water is measured.

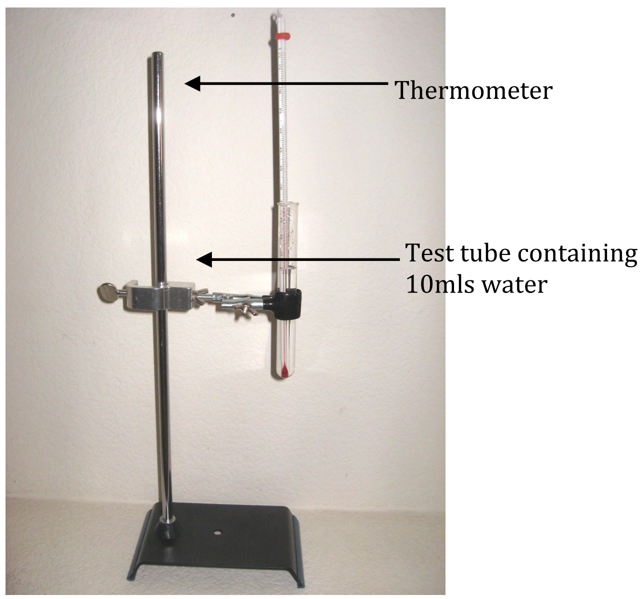


Figure 1. Food calorimetry experimental set-up

In this experiment, we are going to burn candy: Candy Corn, Jelly Bean, Caramel, and Snickers Snack Size. Table 1 shows the data we gathered.

Food Item	Change in Water Temperature (Celsius)	Change in Mass of Food	Kilocalories (C)/gram
Candy Corn	69°	1.13g	.611
Jelly Bean	17°	.42g	.405
Caramel	37°	.59g	.627

Snickers	48°	.71g	.676

Table 1. Food Calorimetry Data

1. Which food has the highest calories per gram?
   a. Candy Corn
   b. Jelly Bean
   c. Caramel
   d. Snickers
2. Why might a jelly bean have a different amount of calories per gram than Snickers?
   a. The samples were different sizes to begin with.
   b. We burned different amounts of each sample.
   c. We used different amounts of water for each sample.
   d. They contain different compositions of fats, proteins, and carbohydrates.
3. A calorie is defined as the amount of energy (in calories) required to raise 1 gram of water 1°C. If 10mls of water equals 10 grams of water, how many total calories were put off when we burned the candy corn?
   a. 6.9 calories
   b. 69 calories
   c. 690 calories
   d. 69,000 calories
4. Approximately how many dietary Calories (Kilocalories, C) do you get from a candy corn that weighs 5 grams?
   a. 5 Calories
   b. 5000 Calories
   c. 3 Calories
   d. 611 Calories
5. The nutrition label for candy corn says that a single 5 gram candy corn has 6.5 Calories. Why is our number not the same?
   a. Our candy corn probably weighed less
   b. We didn't burn the entire piece of candy corn
   c. Due to our equipment, a lot of the energy released was not measured

d. Our candy corn may have been more dense

6. Why did we have to light the food to get it started?

   a. We had to overcome the energy of activation (E_A).

   b. Since it is endergonic, we had to provide the energy for the entire reaction.

   c. We had to provide the heat to heat the water.

   d. We had to sterilize the food so there would be no contamination.

7. In our bodies, we use enzymes to facilitate our metabolic processes. What, exactly, do enzymes do (see Figure 2)?

   a. They add energy to reactions so that reactions occur that don't normally occur on their own.

   b. They lower the energy of activation allowing reactions to happen more easily.

   c. They turn endergonic reactions into exergonic reactions.

   d. They use up the end products of reactions so chemical equilibrium is never reached.

8. How do enzymes affect the ΔG (see Figure 2)?

   a. They make it *more* negative

   b. They make it *less* negative

   c. They double it

   d. They do not affect ΔG

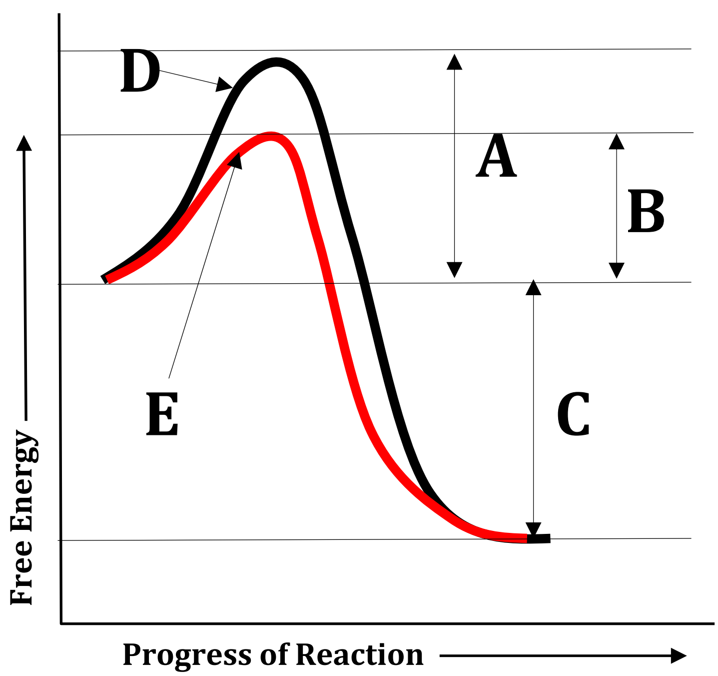


Figure 2. Energy diagram of a reaction with and without an enzyme present.

Didactic Assessment

1. Metabolism describes
    a. the cell's capacity to acquire energy.
    b. reactions that break apart nutrients to release energy.
    c. the elimination of waste products.
    d. all of the above
2. Which of the following statements is false?
    a. Once energy is used it ceases to exist.
    b. One form of energy can be converted to other forms of energy.
    c. Whenever energy conversions occur, some energy is lost.
    d. The universe has a certain amount of energy.
3. The second law of thermodynamics states that
    a. energy can be transformed into matter and, because of this, we can get something for nothing.
    b. energy can be destroyed only during nuclear reactions, such as those that occur inside the sun.
    c. if energy is gained by one region of the universe, another place in the universe also must gain energy in order to maintain the balance of nature.
    d. energy tends to become increasingly more disorganized.
4. For a chemical reaction to occur this kind of energy must be provided.
    a. combination
    b. activation
    c. thermal
    d. electrical
5. The most common form of low-quality energy released in energy conversions is
    a. metabolic.
    b. heat.
    c. entropy.
    d. exergonic emission.
6. Endergonic reactions
    a. have more energy in the reactants than in the products.
    b. have more energy in the products than in the reactants.
    c. are illustrated by the breakdown of glucose.

d. both B and C

7. $\Delta G > 0$ indicates that a reaction is

   a. spontaneous

   b. endergonic

   c. excergonic

   d. at equilibrium

8. Which of the following statements is false?

   a. Enzymes are highly specific and act on chemicals called substrates.

   b. Enzymes can become denatured when a person has a fever.

   c. Most enzymes are proteins.

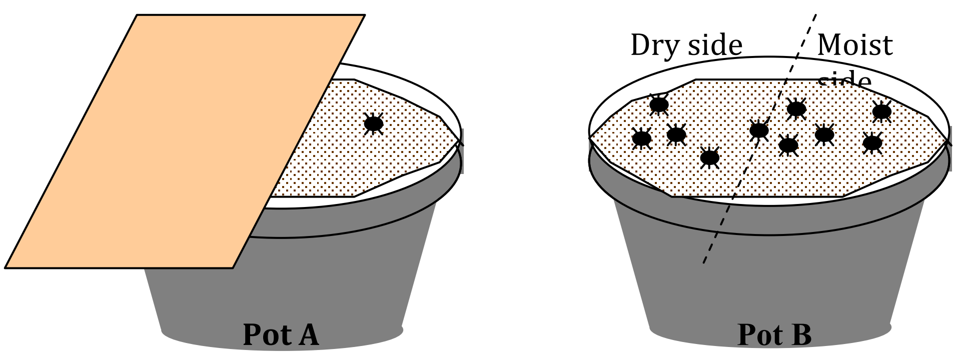
   d. Enzymes act as catalysts and speed up chemical reactions within cells.

Appendix C

Reasoning Transfer Items

Questions 1 and 2 refer to the following information:

I was observing pill bugs in my garden one day. They all seemed to be clustered underneath a flowerpot. When I lifted the flowerpot, they scattered and I noticed that the soil was very moist beneath the pot. This made me wonder if the bugs were attracted to the shade or the moisture. To test this, I obtained two pots of dirt and placed 10 pill bugs into each pot. In one of the pots, I covered half of the pot to provide shade. In the other pot, I moistened the soil just on one side, as shown below. I obtained the following results:



1. Which hypothesis is supported by the results above?
    a. Pill bugs are attracted to water but not to shade
    b. Pill bugs are attracted to shade but not to water
    c. Pill bugs are attracted to both shade and water
    d. Pill bugs have no preference for shade or water

2. If I had made the hypothesis that the pill bugs were attracted to the sunlight only, what would I predict to see in pot A above?
    a. All the bugs on the right side

b. All the bugs on the left side

c. The bugs evenly spread over the whole pot

d. All of the above would support that hypothesis

3. Sue just went to the grocery store and bought four boxes of cereal; Cheerios, Wheaties, Corn Pops, and Rice Krispies. Sometimes for breakfast Sue likes to eat just one kind of cereal, but other times she likes to eat combinations. For example, upon arriving home from the store she had a bowl of cereal in which she combined Cheerios and Wheaties. Given her four new kinds of cereal, how many combinations can she make?

   a. 4

   b. 6

   c. 10

   d. 11

   e. 15

Question 4 refers to the information below:

Salmon return to the stream where they were born to spawn. To test the hypothesis that they find their home stream using their sense of smell, a biologist captured returning East Fork and Issaquah salmon in their respective streams. He then plugged the noses of some of the fish from both streams (the experimental fish) and he left the noses of the other fish unplugged (the control fish). He then took all the fish to a release site below where the two streams joined. The fish then swam up stream and were recaptured in the East Fork or Issaquah streams. The biologist's data are shown in Tables 1 and 2. The numbers shown are actual numbers of fish used in the experiment.

Table 1. Observed Results for Control Fish with Unplugged Noses

	Recapture Site	
Capture Site	Issaquah	East Fork
Issaquah	46	0
East Fork	8	19

Table 2. Observed Results for Experimental Fish with Plugged Noses

	Recapture Site	
Capture Site	Issaquah	East Fork
Issaquah	39	12
East Fork	16	3

4. Do the results in Tables 1 and 2 provide support for the smell hypothesis?
   a. No, because some of control fish made the wrong turn and some of the experimental group fish made the correct turn.
   b. Yes, because a significantly greater percent of experimental group fish made the wrong turn than did control fish.
   c. Yes, because none of the fish with plugged noses found their home stream.
   d. No, because a significantly greater percent of experimental group fish did not make the wrong turn.
   e. Cannot tell because the sample was too small.

Questions 5 and 6 refer to the information below:

One milliliter of Bacteria X was mixed with each of the three food sources and poured into three different petri dishes. After 36 hours, the following data were obtained:

Petri Dish Number	Food Source	Number of Colonies After 36 Hours
I	Agar	0
II	Agar + glucose	200
III	Agar + glucose + hemoglobin	2500
IV	Agar + hemoglobin	0

KEY: a. hypothesis supported by results I and II

b. hypothesis supported by results I and III

c. hypothesis supported by results I and IV

d. hypothesis supported by results II and III

e. hypothesis not supported by these results

For questions 5 and 6, choose from the answer choices above:

5. Glucose is needed for growth of Bacteria X. _______
6. Hemoglobin is needed for rapid growth of Bacteria X. _______

Attitudes Post-Test Items with Scoring Categories

Indicate how well you agree with the statements below, using the following scale:

1 = I strongly agree   2 = I somewhat agree   3 = I somewhat disagree   4 = I strongly disagree

1. My group worked very well together
2. I enjoyed working with my group
3. I felt like a valuable member of my group
4. There was one (or more) person in my group that did not participate much
5. There was one (or more) person in my group that dominated most of the activities
6. I made significant contributions of knowledge and/or ideas to the group
7. My group member(s) made significant contributions of knowledge and/or ideas to the group
8. My ideas or ways of approaching topics often differed from that of my group members
9. When compromises had to be made, the group usually followed my lead
10. When compromises had to be made, my idea was usually not chosen
11. I taught one or more of my group members difficult material on several occasions
12. My group member(s) taught me difficult material on several occasions
13. I did better on an assignment/exam because of one or more of my group members

14. One or more of my group members did better on an assignment/exam because of my contribution
15. I learned how to think scientifically in this class
16. I studied with the members of my group outside of class
17. I have a better opinion of collaborative learning because of my group experience in this class
18. I would prefer working in a group over working alone in future classes
19. I feel that science is a collaborative process
20. The instructor encouraged group work
21. The assignments/activities were conducive to group work
22. Many of the activities required group work because they could NOT be completed individually
23. The instructor mostly lectured in front of the class
24. The instructor used many activities that did not require the instructor's assistance to complete
25. The instructor encouraged us to study together outside of class
26. Textbook reading helped my learning significantly
27. I am good at biology
28. I enjoy biology
29. I feel that I am able to think scientifically

Construct Assessed	**Item Numbers**
Group Function	1, 4*, 5*
Helping Behaviors	11, 12, 14
Student Confidence	9, 10*, 27
Attitude Toward Collaboration	17, 18, 19

* Indicates that the question must be reverse coded