Photosynthesis and the Source of Plant Matter

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Science Course or Class: 8th Grade science section 8-2
School Name: Saligman Middle School
Planned Teaching Dates and Times: Feb 13, 2006 10:14-10:53
Feb 15, 2006 10:15-11:43 (double period)
March 1, 2006 10:15-11:43 (double period)

1. GUIDING INFORMATION:

a. Student and Classroom Characteristics

This class consists of eighth grade science students at Saligman Middle School in Melrose Park, Pennsylvania. Saligman is a Conservative Jewish day school servicing children in grades six through eight. The class consists of twenty-one students heterogeneously grouped. They are seated at 7 lab tables throughout the room. Each table contains 3 students who work together for most lab activities. However, for this project, they will be in groups of 2 or 3 of their own choosing. Some may work alone if they so desire. Most students in this class are highly motivated and work well consistently. There are 3 or 4 students whose progress will need to be monitored more carefully to be sure they stay on track with their work.

b. Prior Knowledge

When students are asked about the source of the material needed to create a large tree from a small seedling, research shows that overwhelmingly students' answers are that the new mass comes from water and the soil (Ozay and Oztas 2003, Eisen and Stavey 1988, Wood-Robinson 1991, Project 2061). A study conducted by Eisen and Stavy (1988) asked students two questions about plant growth and nutrition. The first was "What materials does a plant absorb from its environment in order to build its body?" 73% of biology majors and 65% of non-biology majors knew that plants absorb water from their environment. 74% of biology majors listed carbon dioxide from the air as a material that is absorbed, as opposed to only 40% of non-biology majors. A full 37% of biology majors and 60% of non-biology majors listed energy as a material that is absorbed. This shows the lack of understanding students have towards the idea of energy. When a second, more specific question was posed to these same students," What is the source of the weight of a growing seedling?" both the biology majors and non-biology majors again listed water. The percentages were very similar, 53% and 52% respectively. Most surprising was the fact that the percentage of biology majors who had listed carbon dioxide as an absorbed material in response to the first question actually dropped by half from 74% to only 35%. A mere 6% of non-biology majors chose the answer of carbon dioxide. Furthermore, about 24% of biology majors and 13% of non-biology majors listed the source of the growing seedling's weight the growth itself.

A similar study by Driver et al (1984) as quoted in an article by Wood-Robinson (1991) showed that about 20% of fifteen year olds believed that a tree grew because it took in food from its environment. Fewer than 10% understood that the tree created its own tissue from other materials absorbed from its environment. In another study by Wandersee (1983) quoted in this same paper, students were given a pot with a seedling and watched the seedling grow. They were then asked to hypothesize what would have happened to the weight of the soil in the pot. Only about 25% of the students thought that the weight would have stayed the same. Between one quarter and one third of the students predicted that the weight of the soil would have dropped.

When my own students were surveyed regarding the source of new plant material, water, sun, food and the plant itself are seen as the primary source of matter for plant structures during growth, rather than air.

Water was included in 82 % of all student responses as the source of new plant material. This correlates directly with studied misconceptions of photosynthesis. A full 94.9% of my students cited water as a need for plants. The idea that water is needed by plants is fully understood. Student experiences during a drought emphasize this concept. Why water is needed is misunderstood.

The misconception that the sun or light is the source of new plant material speaks to the students' lack of understanding regarding energy. Over 92% listed sun as a need for plants to grow, but the use of this sun energy is misunderstood.

Another similarity between my classes' responses and research is shown in the 41% of students that believe the source of new mass comes from the seed or the larger plant itself.

Another 33% of my students cited soil as the source of new plant material. 64% listed soil as a need of plants. Wandersee's study reported similar misconceptions. Approximately 55% of those students hypothesized that a pot of soil would either weigh the same or less after a seedling sprouted and was allowed to grow. The similarity between those listing food as a need of plants (38.5%) and those listing it as the source of plant matter (41%) further illustrates the misconception that food from the soil is a source of plant material. Therefore the necessity of soil is understood, but the function of soil as an anchor for the plant and a source of minerals are not.

It is very interesting that only 7.7% of students chose air as the source of plant material, the correct answer. Yet 25.6% chose air as a need of plants in the second question. Based on their responses, students do not understand what this need for air is or that it is the source of plant structures.

2. PURPOSES:

a. Major Concepts

Photosynthesis is the link that makes living on this planet possible (Becker and Deamer, 1991). Photosynthesis is the mechanism by which the sun's energy is transferred into the chemical energy of covalent bonds between atoms. This chemical energy forms the basis for the food chain in every ecosystem. Photosynthesis has two parts, or components. The "photo", which is the trapping of light energy, and the "synthesis" which is the fixing, or covalently linking of carbon atoms from carbon dioxide into sugars and other molecules. The chemical equation for the process of photosynthesis is:

$$6\,CO_2 + 12\,H_20 \rightarrow C_6H_{12}O_6 + 6\,O_2 + 6\,H_20$$

This equation, taken from *The World of the Cell* (Becker and Deamer, 1991), is different from most textbook equations of photosynthesis. The appearance of water on both sides of the equation is used to represent water as both an electron donor and a product of the photosynthetic process (more on this process will be presented later). First, we must deal with the "photo" part of photosynthesis.

The cell organelle where light energy is trapped and where photosynthesis occurs is called the chloroplast. These organelles are characteristic of all autotrophic organisms, including plants. A plant chloroplast has an outer and inner membrane. A granular, fluid-like substance within is called the stroma. A network of folded membranes, primarily of flattened sacs called thylakoids, is called grana. These thylakoid membranes are the site of photosynthetic pigments, specifically chlorophyll. Chlorophyll is that all important chemical that captures the sun's energy. A photon of light energy is absorbed by chlorophyll and electrons within the chlorophyll become photoexcited. These excited electrons are unstable. They are quickly passed on to another molecule. During photosynthesis, they are passed to a molecule of NADP+, creating NADPH, an energy storing compound. However, this would leave the chlorophyll molecules with an ever decreasing number of electrons. The electron donor to replace those lost in chlorophyll is water. As water donates its electrons to chlorophyll, it is "split" into hydrogen ions and oxygen molecules. The H+ ions are, as described by MIT's biology website, "pumped across the thylakoid membranes, generating a charge separation." As the charge separation is released, energy is generated. This energy is stored in the form of ATP, another energy storing compound. The oxygen molecules are released into the atmosphere, providing the earth with its life giving atmosphere.

The two energy storing compounds created, NADPH and ATP, now are used to drive the "synthesis" part of photosynthesis. The process of synthesizing sugars is often referred to as the Calvin cycle. The steps in the Calvin cycle are called carbon fixation and take place in the stroma. Carbon dioxide molecules are absorbed and "fixed" into covalent compounds. The carbon from carbon dioxide is adjoined to a 5-carbon molecule called ribulose-5-phophate (mit.edu). The carbon dioxide molecules are joined, and then split, into two PGA molecules. ATP and NADPH are used as an energy source to drive the next two steps of the Calvin cycle. The PGA is converted into two different molecules, G-3-P and DHAP (Becker and Deamer, 1991). Two out of every twelve molecules of G-3-P made are combined to form glucose, a simple sugar. The DHAP and the other G-3-P molecules continue around the Calvin cycle. They are re-combined into ribulose-5-phosphate, the original compound used for carbon fixation at the beginning of the process during carbon dioxide absorption. Water is generated and released. The synthesized glucose molecules then become linked, forming the most important polysaccharide in plants, cellulose. Over half the carbon found in higher plants is present in cellulose (Becker and Deamer, 1991). Cellulose is what creates the structures of plants. The carbon dioxide from the air, through photosynthesis, is the source of all matter needed to change a small seedling into a huge tree.

b. Learning Goals

From Benchmarks for Science Literacy Chapter 5 section E:

- Food provides molecules that serve as fuel and building material for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food can be used immediately for fuel or materials or it may be stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms.

From National Science Education Standard C grades 6-8 and 9-12:

- For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs life science content standard
- The energy for life primarily derives from the sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon-containing (organic) molecules. These molecules can be used to assemble larger molecules with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes.

While the idea of energy storage and release at the molecular level will be left for high school, the standard of energy from the sun is addressed in this content unit, along with the assembly of larger molecules being formed into complex sugars for plant structures.
The culminating activity in this unit, of designing an experiment on a factor affecting plant growth, also addresses the following science standard from National Science Education Standard A grades 6-8:

- Design and conduct an investigation**.** Students should develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables. They should also develop the ability to clarify their ideas that are influencing and guiding the inquiry, and to understand how those ideas compare with current scientific knowledge. Students can learn to formulate questions, design investigations, execute investigations, interpret data, use evidence to generate explanations, propose alternative explanations, and critique explanations and procedures.

c. Objectives

Students will be able to:

- Design and conduct a controlled experiment about the source of plant mass increase
- Precisely weigh the amounts of water, soil and plant mass, minimizing error
- Record and analyze data
- Interpret data to show that new plant mass does NOT come from the water or soil
- Present findings in a lab report
- Determine that new plant mass comes from carbon dioxide in the air using photosynthesis

d. State Standards

N/A

3. RATIONALE:

All energy on Earth is derived from the sun. While this fact may be known by students, its implications most often are not. The sole organism that turns unusable solar energy into usable chemical energy is the plant. Through photosynthesis the plant uses the sun's energy to change the carbon dioxide in air into sugars. Some of these sugars are used to create plant matter as the plant grows from a seed into a full grown plant. Plants are then consumed by other organisms, creating the base of the energy/food web that drives Earth. As shown by the research discussed above, most students do not understand the source of new plant matter or the importance of photosynthesis. Fully understanding the chemical equation of photosynthesis necessitates having students see directly that their most common misconceptions about the source of plant matter are wrong. Therefore, this three-day activity is designed to dispel misconceptions to heighten understanding of the more abstract concept of the chemical equation of photosynthesis.

Day one will have the students reviewing their own misconceptions as to the source of new plant matter. The most common misconception is that soil and water are the source of this matter. They will design an experiment, with teacher guidance, to determine whether it is the water or the soil that is the primary source of new plant matter. Ways to measure the mass of soil and water used to grow the plants will be emphasized by the teacher. For day two, the students will present their experimental procedures to the class. This will enable them to engage in peer review, checking that their experiments are controlled. This will ensure that the two perceived factors (soil and water) are the only variables affecting the increase in plant matter. Once they see that neither one contributed to plant mass, they will be able to come to a better understanding that plant material comes from the carbon dioxide in the air. Day two will also have the students setting up their experiments. Day three comes approximately two weeks later after the plants have shown considerable growth. Plants will be weighed, final soil mass will be taken, water mass will be calculated, and students will see that the increase in new plant mass does NOT equal the masses of soil loss or water added. Students will have been introduced to the chemical equation of photosynthesis during the two weeks the plants were growing. By having the students eliminate the two most common misconceptions about the source of new plant matter, they will be better able to understand, via the chemical equation, that plant growth material comes from the air.

Students have developed experimental procedures in my classroom on prior occasions so I do not need to devote time in the lesson to teaching them how to do this.

4. CLASSROOM PREPARATION:

a. Instructional Materials

- 1 plant lighthouse per 6 growing systems
- 1 copy of Wis. Fast plant maintenance calendar per student
- Previously completed plant pre-assessment
- Photosynthesis worksheet

For each group of students:

- 1 clear plastic 20 oz cup
- 1 clear plastic 8 oz cup
- 1 water mat capillary wick
- Potting soil
- 1 dissecting needle
- 4 Wisconsin Fast Plant seeds
- 1 copper sulfate square
- Stock fertilizer solution
- Source of flame
- 1 graduated cylinder
- Access to scale

b. Management and grouping patterns

On day one, students will be reviewing their previously completed pre-assessment worksheets. They will share their ideas with their tablemates. Students will be instructed to find one or two other people who share similar ideas about where plant matter comes from that they have NOT worked with before. These groupings will remain throughout the project. Each group will construct a hypothesis and begin to formulate an experimental procedure. For day two, these same groups will finalize their procedures, get teacher approval and begin their experiments. Between day 2 and 3, one student from each group will be responsible for maintaining the experiment and collecting data. Whole class instruction on the equation for photosynthesis will also take place during this time. During day three, the student groups will collect final data. Each student will write their own lab report.

c. Safety

- Long hair must be tied back and a beaker of water nearby when students use the flame to construct their growing systems.

5. TEACHING METHOD(S), INSTRUCTIONAL PROCEDURES, AND LEARNING ACTIVITIES:

Day 1

a. Phase of Inquiry:

Launch: Students will be reviewing previously completed pre-assessment worksheets on the source of new plant material as the plant grows. This will begin (launch) the unit on photosynthesis. By creating a hypothesis on the source of new plant material, this will get students thinking about how plants grow and enable them to refine their experimental procedure.

b. Content

Day one's content objectives are for each student to specify what they think is the source of new plant matter. Each student must also begin planning their experimental procedure and refine their hypothesis.

c. Motivational opening

Each student must share their pre-assessment answers with their tablemates. They should be ready to defend their answers. Students will also find others who share their ideas about the source of plant matter. This will be the basis for forming the working groups for this activity.

d. Core Learning Activities

After groups of 2-3 students each are formed, each group will begin to develop an experimental procedure to determine the source of new plant matter as the plant grows. The teacher will circulate amongst the groups, helping them to refine their procedure. The goal is to have each student develop a plan that includes measuring the mass of soil used, the mass of water added and mass of the grown plant. The experimental procedure must be specific and repeatable. Each group must also develop a specific hypothesis as to the source of new plant matter. The procedure and hypothesis must be written on a piece of paper by each group member.

e. Critical Questions

- What are the step-by-step procedures for your experiment?
- What is your hypothesis as to the source of new plant matter as the plant grows?

f. Closure

Each group will share their hypothesis and, if time, their experimental procedure. They know that they will be setting up their experiments the next day.

Day 2

a. Phase of Inquiry
Explore: Today students will set up their experiment to determine whether water or soil is the source of new plant matter. They will be monitoring their experimental set-ups over the next 1 1/2 - 2 weeks as the plant grows.

b. Content
Day two's objective is for each group of students to properly set up their experiment in a controlled manner.

c. Motivational opening
As students enter the room, all necessary materials will be set out for them to immediately begin constructing their growing systems for their experiment.

d. Core Learning Activities
Each group of students will construct a growing system in the following manner: (This is an example procedure. Student groups will have developed similar procedures on their own the previous day).

- One member will go to the table with the lit candles. Tie back any long hair. Beakers of water will be on the table for safety. Heat the tip of the dissecting needle in the flame until it glows red hot. Poke the tip of the needle through the base of the 8 ounce cup the size of the triangle symbol imprinted on the cup. Reheat the needle as necessary to create the correct size hole. Place the dissecting needle in the beaker of water when finished.
- Meanwhile, the other member of the group should weigh an empty graduated cylinder. Record the mass of the empty cylinder. Pour 250 ml of prepared nutrient solution into the graduated cylinder. Weigh and record the mass. Calculate the mass of the nutrient solution. Pour the solution into the 20 ounce plastic cup. Place a copper sulfate square in the bottom of the cup to prevent algae growth.
- Use the cooled dissecting needle to push a capillary wick through the hole in the 8 ounce cup. Weigh and record the mass of this cup. Fill the cup about 2/3 full of potting soil. Weigh the cup again, record the mass, and calculate the weight of the potting soil.
- Moisten the soil with about 25 ml of nutrient solution. Be sure to calculate the mass of this solution as above before adding it to the soil.
- Place the 4 Wisconsin Fast Plant seeds just under the top layer of soil. Be sure they are evenly spread throughout the cup.
- Place the 8 ounce cup into the 20 ounce cup to create the growing system. Be sure the top of the capillary wick is wet to ensure that the nutrient solution travels into the 8 ounce cup. Use a pipette to squirt some of the nutrient solution onto the top of the wick if necessary.
- Label your growing system with your group member's names and place it in the plant light house.
- Monitor your plant's growth over the next 2 weeks. Add more nutrient solution as necessary, being sure to calculate and record the mass of the solution added.

e. Critical Questions

- Did you calculate and record the mass of the soil and nutrient solution used in your growing system?
- Did you monitor your plant's progress daily to see if it needed more nutrient solution?

f. Closure

Students will clean up all materials and adjust their written procedures as necessary to reflect their actual activities of the day. While the plants are growing, students will learn the chemical equation for photosynthesis and use the attached worksheet to further their understanding.

Day 3

a. Phase of Inquiry

Explore: Students will weigh the fully grown plant and compare its mass to the mass of nutrient solution added and any decrease in soil mass. They will find that the mass of the plant does not equal either one. This will lead them to the final phase of Inquiry.

Summarize: Students will compare the mass of solution added and soil lost to the total mass of the fully grown plants. They will summarize their findings and use the equation for photosynthesis to determine the true source of new plant material.

b. Content

Day 3's objectives are for each student to calculate and compare the mass of the fully grown plants to the masses of the nutrient solution added and any soil lost. They will conclude that the masses are not equal. Each student will understand, by using the photosynthesis equation, that plants create their own new mass from the carbon dioxide in the air.

c. Motivational opening

Students will enter class and immediately begin calculating the mass of their fully grown plants.

d. Core Learning Activities

Each group of students will calculate the mass of their fully grown plants in the following manner. (This is an example procedure. Students will have developed similar procedures on their own.)

- Carefully pull out all fully grown plants from the growing system. Shake off as much dirt as possible from the roots.
- Weigh and record the mass of all plants
- Weigh the 20 ounce cup with the soil inside of it
- Pour the soil out and weigh the empty cup
- Calculate the final mass of the soil
- Calculate the mass of any soil lost
- Compare the masses of nutrient solution added + any soil lost to the mass of the fully grown plants
- Clean up all materials as directed by the teacher

e. Critical Questions

- What is the mass of the fully grown plants?
- What is the mass of any soil lost?
- How do the masses of nutrient solution added + any soil lost compare to the mass of the fully grown plants?
- Where does the mass for new plant material come from, if not from the water or soil?

f. Closure

Conduct a class wide discussion about group findings. Students will create and submit a formal lab report of their findings.

6. EVALUATION STRATEGIES

Students will be assessed daily on their level of participation and cooperation within their groups. Teacher will monitor group discussions and interactions throughout the three days of activities. Each student is expected to participate in group decision making, discussions and preparation of the growing systems. Each member of the group is also expected to participate in the monitoring of plant growth between days 2 and 3. Group members are expected to support each other and help each other complete all necessary steps in all activities.

A formal, typed lab report will be submitted by each student to be graded using the attached rubric.

7. REFLECTION:

[leave blank - to be completed after instruction. This is your reflective presentation in the final week of classes]

8. ATTACHMENTS:

a. Blank sample of previously completed pre-assessment questionnaire is attached.
Photosynthesis worksheet to be completed between days 2 and 3 is attached.

b. Scoring rubric for typed lab report is attached.

c. N/A

d. Copy of teacher's guide from which this unit was modified is attached.

Resources:

AAAS Project 2061 Middle Grades Science Textbook: A Benchmarks-Based Evaluation

Becker, W and Deamer, D. (1991). The World of the Cell. Redwood City, Ca. Benjamin/Cummings Publishing

Eisen, Y. & Stavy, R. (1988) Students' Understanding of Photosynthesis. The American Biology Teacher, 50(4), 208-212.

http://web.mit.edu/esgbio/www/ps/psdir.html
posted by MIT as Biology Hypertextbook first viewed on approximately Nov. 25, 2005

Ozay, E. and Oztas, H. (2003). Secondary Students' Interpretation of Photosynthesis and Plant Nutrition. Journal of Biological Education, 37(2), 68-70.

Wood-Robinson, C. (1991). Young Peoples' Ideas About Plants. Studies in Science Education, 19, 119-135.

Organisms-From Macro to Micro. (2003). Burlington, NC. Carolina Biological Supply Publishing.

Lab Report: Photosynthesis

Student Name:

CATEGORY	4	3	2	1
Components of the report	All required elements are present and additional elements that add to the report (e.g., thoughtful comments, graphics) have been added. 5 points	All required elements are present. 4 points	One required element is missing, but additional elements that add to the report (e.g., thoughtful comments, graphics) have been added. 3 points	Several required elements are missing. 2 points
Question/Purpose	The purpose of the lab or the question to be answered during the lab is clearly identified and stated. 5 points	The purpose of the lab or the question to be answered during the lab is identified, but is stated in a somewhat unclear manner. 4 points	The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner. 3 points	The purpose of the lab or the question to be answered during the lab is erroneous or irrelevant. 2 points
Experimental Hypothesis	Hypothesis is written in a clear sentence stating which factor(s) contribute to creating new plant matter as a plant grows. 10-9 points	Hypothesis is written in a somewhat clear sentence stating which factor(s) contribute to creating new plant matter. 8-7 points	Hypothesis is written as a question or incomplete sentence stating which factor(s) contribute to new plant matter. 6-5 points	Hypothesis is unclear as to which factor(s) create new plant matter, or now hypothesis written 4-0 points
Materials	All materials and setup used in the experiment are clearly and accurately described. 5 points	Almost all materials and the setup used in the experiment are clearly and accurately described. 4 points	Most of the materials and the setup used in the experiment are accurately described. 3 points	Many materials are described inaccurately OR are not described at all. 2-0 points
Procedures	Procedures are listed in clear steps. Every procedure used is listed. Correct format is used. 10-9 points	Procedures are listed in a logical order, but are difficult to follow. 8-7 points	Procedures are listed but are not in a logical order or are difficult to follow. Correct format is not used. 6-5 points	Procedures do not accurately list the steps of the experiment. 4-0 points
Data	Professional looking and accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled. all data is included. 15-10 points	Accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled. All data is included. 9-7 points	Accurate representation of the data in written form, but no graphs or tables are presented. Not all data is included. 6-4 points	Data are not shown OR are inaccurate. 3-0 points

Conclusion	Conclusion includes whether the findings supported the hypothesis. Source of new plant matter clearly stated with supporting evidence. 25-22 points	Conclusion includes whether the findings supported the hypothesis. Source of new plant matter clearly stated with some supporting evidence. 21-18 points	Conclusion includes whether the findings supported the hypothesis. Source of new plant matter stated with no supporting evidence. 17-12 points	No conclusion was included in the report OR shows little effort and reflection. 11-0 points
Sources of error	Experimental errors, their possible effects, and ways to reduce errors are discussed. 15-12 points	Experimental errors and their possible effects are discussed. 11-8 points	Experimental errors are mentioned. 7-4 points	There is no discussion of errors.or possible errors are unrealistic. 3-0 points
Spelling, Punctuation and Grammar	One or fewer errors in spelling, punctuation and grammar in the report. Neatly typed.5 points	Two or three errors in spelling, punctuation and grammar in the report. Neatly typed 4 points	Four errors in spelling, punctuation and grammar in the report. Neatly hand written3 points	More than 4 errors in spelling, punctuation and grammar in the report. Sloppy handwriting. 2-0 points