# Photosynthesis: What Have you Done for me Lately?

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## Overview

Plants make their own food through the process of photosynthesis: plants obtain light energy from the sun; carbon dioxide and water from their surrounding environment; and, convert these three components to chemical energy and carbohydrates. Herbivores eat plants to obtain energy. Humans are omnivores and eat both plants and animals for energy. Equally important, the oxygen we need to breath is provided mainly by plants as one of the by-products of photosynthesis. Humans depend on plants as a food source, a source of oxygen, a source of fiber, and of fuel on which civilization depend.

The purpose of the unit is to use performance-based learning and assessment (PBLA) as a learning strategy for the acquisition of the process of photosynthesis through the performance of tasks that engage students to think critically and make logical inferences from information presented in documents.

## Rationale

Photosynthesis is one of the most important concepts in the biology curriculum. Photosynthesis is the key biochemical process that provides energy for almost all life on Earth. However, this process of combining six carbon dioxide, six water molecules, and light to form six-carbon organic compound and six molecules of oxygen is very difficult for most high school students to understand (Özay and Öztaş 2003). The three stages of photosynthesis: first stage, the absorption of mostly blue and red wavelengths by chlorophylls in plants; second stage, light energy is converted to chemical energy, which is temporary stored in ATP and the energy carrier molecule NADPH; and third stage, the chemical energy stored in ATP and NADPH powers the formation of organic compounds, using carbon dioxide, $CO_2$ are abstract stages that most high school students have hard time putting into context and imagining taking place inside a plant (Johnson and Raven 2004, p. 97; Özay and Öztaş 2003). Also, the process of photosynthesis lends itself to mostly lecturing to students (Weinburgh 2004). Lastly, Weinburgh (2004) demonstrated that photosynthesis do not lend itself to true laboratory investigations due to the fact that most students do not make the connection between leaves having starch and the production of

glucose as product of photosynthesis after they have performed multiple inquiry-based laboratories (pp. 15-16). However, there are some ways in which students are engaged in learning a topic like photosynthesis without lecturing and doing laboratory activity. The following paragraph describes performance-based learning and assessment as a way of removing both barriers—lecturing and laboratory activity—to teach photosynthesis successfully in a high school classroom.

Several core beliefs are behind performance-based learning and assessment. Frist, that knowledge is socially and individually constructed: "People obtain content knowledge, acquired skills, and develop work habits—and practice the application of all three to 'real world' situations" (Hibbard 1996, p. 10). Second, for the acquisition and application of knowledge, skills, and work habits the performance tasks must be meaningful and engaging to students (ibid). And third, the content must be taught critically to students (ibid). The next paragraph explains how I incorporate these three beliefs to construct my unit on photosynthesis.

I begin writing the unit on photosynthesis by creating an essential question that can't be easily answer and seems engaging to the students: photosynthesis, what have you done for me lately? Next, I create an authentic real-world situation and a role that most of my students see themselves getting into: a college students taking his/her first test. I also ask my students to produce an authentic product: a written response to their professor explaining the process of photosynthesis. Next, I construct goals that I hope my students can achieve from learning about photosynthesis. These are both present and future goals. My present goal is that I want them to learn about photosynthesis. However, I would like my students to be able to analyze data from graphs, charts, and table and make logical conclusion about something from information presented in newspapers, books, and television by high school. I want my students to become critical thinkers and well-rounded citizens. To achieve these goal, I create tasks that allow my students to process and demonstrate those skills (See Document A, B, and C). Next, I research frequent misconceptions and prior knowledge of my students in terms of photosynthesis. In general, struggling students know that food is related to health and growth; however, they have the misconception that food is converted directly to health and goodness (AAAS 1989). On the other hand, typical students know that plants need water, minerals, $C0_2$ and sunlight; however, they have the misconception that plants get food from soil and don't make their own food (ibid). Last, high achieving students know what photosynthesis is, but can't explain it; however, they believe plant mass comes from water. Based on students' prior knowledge and misconceptions, I create two documents (B and C) in which students learn by performing tasks that the mass of a plant does not come from water or soil, rather $CO_2$.

After completing the photosynthesis unit, students will have a better understanding of the stages of photosynthesis. Students will be better prepared to apply their knowledge and skills learned during their performance-based learning and assessment and apply these to different disciplinary core ideas.

## Objectives

The unit is intended for high school students, grades 9-12. In general, in the School District of Philadelphia (SDP), students are required to take a minimum of three years of science to fulfill the graduation requirements. Freshmen are taught Physical Science; sophomores are taught Biology; and, juniors are taught Chemistry. The unit photosynthesis is taught in Biology during the 2nd marking period. My aim is to teach this unit to 10th graders in a standard classroom.

The objectives of the unit are aligned with the Pennsylvania standards (See Appendix)

The objectives of the unit will be:

- Students will be able to analyze the flow of energy through living systems
- Students will be able to construct an explanation on how photosynthesis transforms light energy into stored chemical energy
- Students will be able to describe the process of photosynthesis and how it is important to living things.
- Students will be able to make inferences about photosynthesis from information presented
- Students will be to analyze data from graphs, charts, and tables
- Students will be able to determine the credibility and limitations of a graph, chart and table
- Students will be able to determine reliability, credibility and limitations of a document
- Students will be able to ask questions as a result of having limited information

## Strategies

The strategies that I hope to incorporate in my unit are as follows:

- Scaffolding—design questions to assist learners in achieving learning goals.
- Cooperative learning—having students work together in small groups for the achievement of learning goals.
- Active learning—instructional strategies that allow students to move around the classroom, stimulate critical thinking and greater awareness of content and learning.
- Inquiry-based learning—instructional strategies that allow students to think methodologically and investigate strategies that help students yield the desired learning outcomes.
- Hands-on activities—instructional strategies Laboratory learning—Hands-on activities that allow students create to create a physical object.

## Classroom Activities

Lesson 1: Introduction to Performance-Based Learning and Assessment
Lesson 2: Historical Perspective of Photosynthesis

Lesson 3: Where Does the Mass in Plants Come from?
Lesson 4: Misleading Information
Lesson 5: Students Written Response on the Process of Photosynthesis

Lesson 1: Intro to Performance-Based Learning and Assessment

Objectives

- Students will be able to construct an explanation on how photosynthesis transforms light energy into stored chemical energy
- Students will be able to describe the process of photosynthesis and how it is important to living things.
- Students will be able to make inferences about photosynthesis from information presented

Students will be introduced to the performance-based learning and assessment by explaining to them what is PBLA and how the different performance tasks will be used to learn about photosynthesis. They should be told that this activity will test their knowledge of photosynthesis based on several important documents of information. On the day of the PBLA is started students should be divided into small groups. They should be given the task and allowed to read the scenario and the question. They should not be allowed to read any documents. At this point, students should be asked if they have any questions and they understand fully, what is expected of them to turn in for an acceptable response. Students should not be allowed to use any notes or other documents except for those provided. Student's thoughts should be organized on their PBLA Analysis Tool. At the end of each lesson, there should be a debrief of the document and formative assessment (4x6 index card) of student's learning about the document. Teacher should provide feedback after reading student's index cards. Teacher should instruct students to use their index cards and PBLA Analysis as a pre-writing organizer for their response to Professor Calvin.

The final product is a written document that explains the process of photosynthesis. All reasoning must be supported by specific information from the documents provided. Students should make logical inferences and give detail for any thoughts that they include in their response. I predict that in a typical 50-minute class period, it will take students at least 6 periods to get through the PBLA.

Instructions
You are about to work on an activity that is designed to assess your skills of critical thinking, reasoning, problem solving and written communication. In addition to these important "scientific" skills, your knowledge about the process of photosynthesis will be evaluated. You will prepare a written response to a realistic situation. In this activity you will find a series of documents that include a wide range of information sources. You should base your written response on the evidence in these documents and your knowledge of the process of photosynthesis.

The Scenario

Congratulations, it has finally happened. You have graduated from high school and are starting your first year as a biology major at Temple University. The first day of class you have an 8:00 AM Biology lecture with Professor Calvin. All has started out fine, you made it to breakfast and then to the lecture hall on time. When Professor Calvin comes into the hall he introduces himself to the group and proceeds to give you your first test! How could this be? The first day and you have to take a test? He hasn't taught you a single thing! You feel doomed to flunk out before you finish your first year. What will your parents say?

As fate would have it, you are prepared for what Professor Calvin has asked of the class. You are to determine how plants get energy and food. This is great as you were an exemplary student in high school biology and you were taught in great depth the process by which plants get energy and food. In his explanation of the test, Professor Calvin shows an image of the energy cycle (see Figure 1). Apparently, Professor Calvin wants to know what plants have done for organisms to survive on Earth.

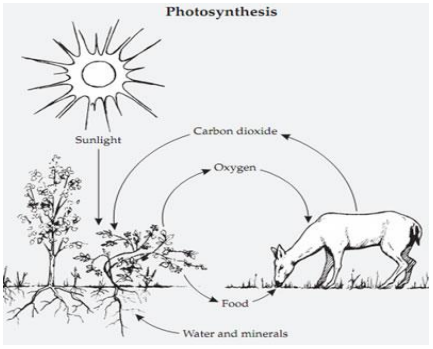



Figure 1. Image provided by Professor Calvin showing the flow of energy on Earth.

Figure from http://lifeofplant.blogspot.com/2011/03/photosynthesis.html

The Question

Professor Calvin has asked all of his first year students to explain how plants help maintain life on Earth. Based on the documents he has provided you and the process of photosynthesis that you have learned in your high school biology class, please provide him a written response explaining how plants help maintain life on Earth. In order for you to get an acceptable grade on your first college biology test, the answer to the question should include appropriate and relevant evidence necessary to support your claim. In your written response please support the reasons for your claim by specifically referencing documents, data and statements in the packet of information.

Lesson 2: Historical Perspective of Photosynthesis

Objectives:

- Students will be able to analyze the flow of energy through living systems.
- Students will be able to construct an explanation on how photosynthesis transforms light energy into stored chemical energy.
- Students will be able to make inferences about photosynthesis from information presented

The purpose of document A is to introduce students to photosynthesis. Documents A contains facts about the process of photosynthesis and experiments from scientists that led to our understanding of photosynthesis. The first activity of the PBLA starts by asking students how a detective solves a mystery or a case. Students will quickly point out that a detective solves a mystery by looking for clues. Next, students are asked how we might solve a scientific mystery. Eventually, students will quickly suggest by using clues. At this point, I introduce them to document A and explain to them that they are detectives charged with solving the mystery of how a plant gets energy. They are to work in small groups to piece together their own understanding of how a plant gets energy. Students work in small groups perform an analysis of Document A as follows:

1. Description of Document:

    - When was the document written or what dates and times are addressed in the document?

    - Why was the document written?

    - Who wrote the document?

    - Who was the document addressed to?

2. Performance Task for Document A:

    - Your task is to use the information that scientists have gathered over several hundred years to determine how a plant gets energy.

    - Use the clues provided by other scientists to help you solve the mystery. Cut out the clues below and arrange them into categories that help you develop your answer.

    - Present how your group solved how photosynthesis works in plants by providing evidence from the clues.

Document A

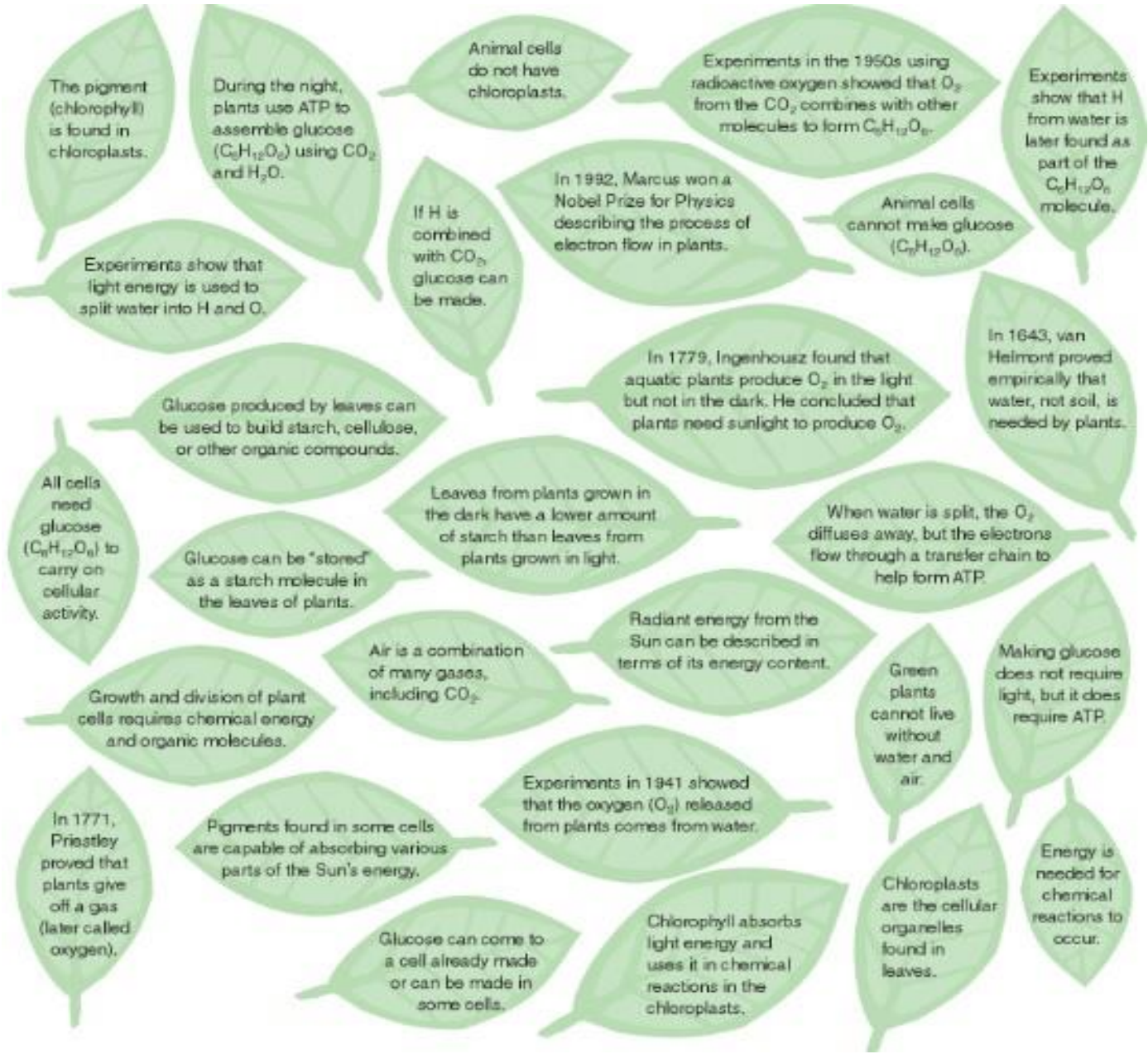



Figure from: http://www.nsta.org/publications/news/story.aspx?id=49453

Lesson 3: Where Does the Mass in Plants Come from?

Objectives:

- Students will be to analyze data from graphs, charts, and tables
- Students will be able to determine the credibility and limitations of a graph, chart and table.
- Students will be able to make inferences about photosynthesis from information presented.
- Students will be able to describe the process of photosynthesis and how it is important to living things.

The purposes of document B and C are for students to understand that the mass of plants actually comes from the air in the form of carbon dioxide, not water or soils. Second, they are to learn that the two major components of photosynthesis are water and carbon dioxide. The lesson begins by explaining to students that their second activity for the PBLA is to analyze two documents to make inferences about the process of photosynthesis. That is, where does the mass in plants come from? They are to use both documents to piece together their own understanding of how a plant grows and gets energy.

1. Description of Document B

    - When was the document written or what dates and times are addressed in the document?

    - Why was the document written?

    - Who wrote the document?

    - Who was the document addressed to?

2. Description of Document C

    - When was the document written or what dates and times are addressed in the document?

    - Why was the document written?

    - Who wrote the document?

    - Who was the document addressed to?

3. Performance Task for Document B

    - Your task is to answer the following questions to help you create your response:
        1. What does the data indicate?

        2. What was not being controlled?

        3. What can you conclude from your data about the mass of plants? Why?

        4. Where did the increase in plant mass come from?

4. Performance Task for Document C

    - Your task is to answer the following questions to help you create your response:
        5. What does the data indicate?

        6. What was not being controlled?

        7. What can you conclude from your data about the mass of plants? Why?

        8. Where did the increase in plant mass come from?

Document B

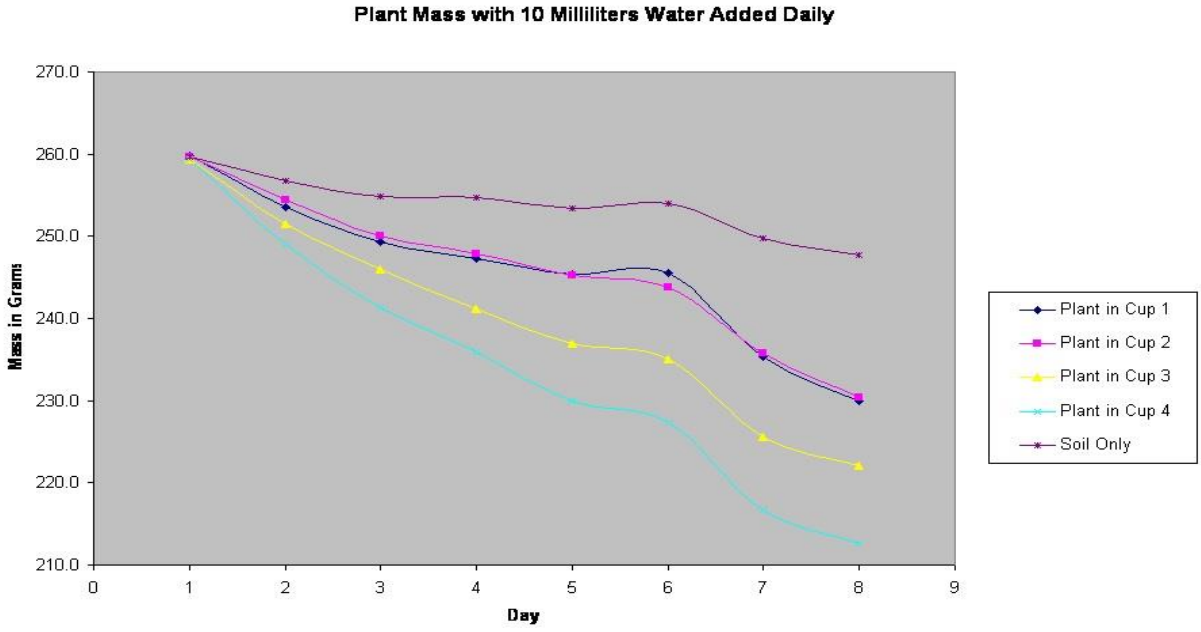
*New Phytologist*
*Volume 178, Issue 4, pages 719–739, June 2008*

**Where Does the Mass in Plants Come From?**

Jackie Campbell[1] (Iowa State University)

**DATA COLLECTION**

| Cup Number | Day | Mass in Grams | Cup Number | Day | Mass in Grams | Cup Number | Day | Mass in Grams |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 259.8 | 2 | 1 | 259.7 | 3 | 1 | 259.4 |
| Plant | 2 | 253.6 | Plant | 2 | 254.4 | Plant | 2 | 251.5 |
| | 3 | 249.3 | | 3 | 250.0 | | 3 | 245.9 |
| | 4 | 247.3 | | 4 | 247.9 | | 4 | 241.2 |
| | 5 | 245.4 | | 5 | 245.2 | | 5 | 237.0 |
| | 6 | 245.5 | | 6 | 243.8 | | 6 | 235.0 |
| | 7 | 235.3 | | 7 | 235.8 | | 7 | 225.6 |
| | 8 | 230.0 | | 8 | 230.4 | | 8 | 222.1 |
| 4 | 1 | 259.3 | 5 | 1 | 259.6 | | | |
| Plant | 2 | 249.1 | Soil | 2 | 256.7 | | | |
| | 3 | 241.3 | Only | 3 | 254.9 | | | |
| | 4 | 235.9 | | 4 | 254.7 | | | |
| | 5 | 230.0 | | 5 | 253.4 | | | |
| | 6 | 227.3 | | 6 | 254.0 | | | |
| | 7 | 216.7 | | 7 | 249.8 | | | |
| | 8 | 212.6 | | 8 | 247.7 | | | |




Figures from http://www.csun.edu/scied/2-longitudinal/plant_mass/

Document C

Plant Physiology,

Volume 98, Issue 3, pages 211–225, March 2012

**Does Plant Mass Come from the Soil?**

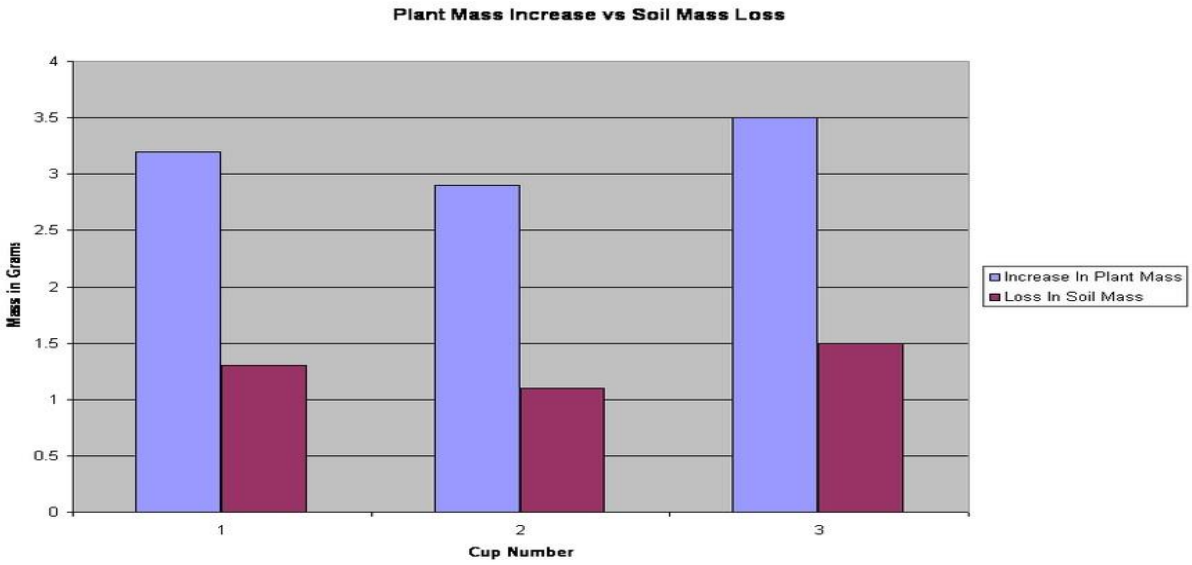
Sergio Alvez[1] and Brent Johnson[2] ([1]University of New Mexico & [2]Duke University)

**DATA COLLECTION DAY 1**

| | | | |
|---|---|---|---|
| Cup 1 = 9.2 g | Cup 2 = 8.4 g | Cup 3 = 8.8 g | Cup 4 = 8.4 g |
| Plant 1 = 23.7 g | Plant 2 = 26.8 g | Plant 3 = 24.6 g | |
| Soil 1 = 84.9 g | Soil 2 = 76.5 g | Soil 3 = 77.8 g | Soil 4 = 80.6 g |

**DATA COLLECTION DAY 14**

| | | | |
|---|---|---|---|
| Cup 1 = 9.2 g | Cup 2 = 8.4 g | Cup 3 = 8.8 g | Cup 4 = 8.4 g |
| Plant 1 = 26.9 g | Plant 2 = 29.7 g | Plant 3 = 28.1 g | |
| Soil 1 = 83.6 g | Soil 2 = 75.4 g | Soil 3 = 76.3 g | Soil 4 = 80.6 g |
| Change in Plant Mass = 3.2 g | Change in Plant Mass = 2.9 g | Change in Plant Mass = 3.5 g | |
| Change in Soil Mass = 1.3g | Change in Soil Mass = 1.1g | Change in Soil Mass = 1.5g | No Change |




Figures from http://www.csun.edu/scied/2-longitudinal/plant_mass/

Lesson 4:  Misleading Information

Objectives:

- Students will be able to determine the credibility and limitations of a given document
- Students will be able to ask questions as a result of having limited information

The purposes of document D is for students to ask questions as a result of having limited information. Students should be able to make logical inferences from information presented in the article. The lesson begins by explaining to students that their third activity for the PBLA is to analyze a document. Students in small groups are to read and complete the analysis of Document D for today's lesson.

1. Description of Document D

    - When was the document written or what dates and times are addressed in the document?

    - Why was the document written?

    - Who wrote the document?

    - Who was the document addressed to?

2. Performance Task for Document D

    - Provide evidences from the article that the process of photosynthesis is taking place in plants.

    - Provide evidences that this article is a reliable source to learn about photosynthesis.

Document D

# Blog

## Scientists respond to “misleading” Times article about climate change’s impact on crop yields

- 21 Mar 2014, 12:35
- Roz Pidcock

The authors of a new paper on how climate change could affect crop yields in the future have reacted to an article in the Times yesterday, calling the headline "very misleading".

The Times piece suggested the new research shows climate change will boost crop yields, a conclusion the newspaper said is "at odds" with the mainstream scientific view. But this interpretation is "fabricating controversy where none actually exists", the authors tell us.

**Extreme heat**

The new study is the first to quantify the effect of future heatwaves on food production. The latest report from the Intergovernmental Panel on Climate Change (IPCC) concluded it is very likely heatwaves will get longer and more frequent this century.

Until now, studies have only looked at what effect the rise in the global average temperature might have on crops.

Writing in the journal Environmental Research Letters, the authors looked at how the extra impact of heat waves will affect yields of three major crops - maize, spring wheat and soybean.

**Crops and carbon dioxide fertilization**

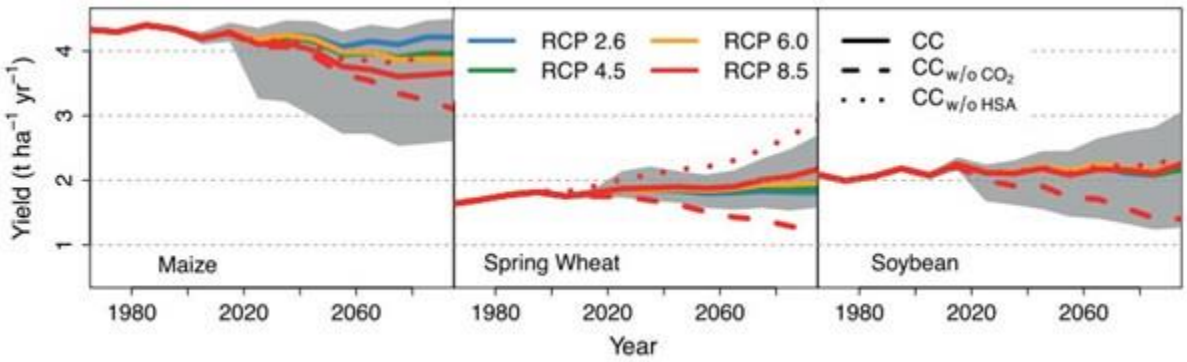
Heat waves have a negative impact on all three crops, with maize suffering the biggest losses, the researchers found. Their findings show heatwaves could double maize losses by the 2080s, compared to the 1980s.

As well as temperature, the researchers took into account how rising carbon dioxide in the atmosphere could influence crop growth. Experiments have shown that raising carbon dioxide levels could make plants more efficient at using water, boosting growth.

The new paper's calculations included the possibility that this 'carbon dioxide fertilisation' effect could counteract some of the losses that come from higher temperatures and heatwaves.

But while the carbon dioxide fertilisation effect works for some plants, not all respond in the same way. Maize doesn't see much of a benefit, which is why the new research shows yields decreasing under climate change.

On the other hand, spring wheat and soybeans are in the group of plants expected to see better yields with raised carbon dioxide. According to the paper's calculations, the benefits could be such that they outweigh the losses, meaning yields increase up to the 2080s.




*Expected yields of maize, spring wheat and soybean. Coloured lines are different climate change scenarios. Dashed red line is expected yield with no carbon dioxide fertilisation. Dotted red line is yield without accounting for heatwaves.* Source: Deryng et al., (2014)

Article form http://www.carbonbrief.org/blog/2014/03/scientists-respond-to-%E2%80%9Cmisleading%E2%80%9D-times-article-about-climate-change%E2%80%99s-impact-on-crop-yields/

Lesson 5: Students Written Response on the Process of Photosynthesis
Objectives:

- Students will be able to construct an explanation on how photosynthesis transforms light energy into stored chemical energy
- Students will be able to describe the process of photosynthesis and how it is important to living things.
- Students will be able to make inferences about photosynthesis from information presented

The fourth lesson of the performance task will be an accumulation on what the students have learned and completed during the first three activities of the DBCS. Students working in small group use their completed performance task documents to write their response to Professor Calvin.

STUDENT RESPONSE SCORING RUBRIC

| | | EMERGING<br>0-2 | DEVELOPING<br>3-4 | MASTERY<br>5-6 |
|---|---|---|---|---|
| **ANALYTIC REASONING AND EVALUAITON** | Interpreting, analyzing identifying information that is relevant to a problem, emphasizing connected and conflicting information, detecting flaws in logic and questionable , and evaluating the quality of information. This requires assumptions, and explaining why information is credible, unreliable, or limited | • Identifies very few facts or ideas that support or refute arguments presented in the Document Library.<br>• Disregards or misinterprets much of the Document Library.<br>• Does not make claims about the quality of information and present some unreliable information as credible. | • Identifies several facts or ideas that support or refute all major arguments presented in the Document Library.<br>• Demonstrates accurate understanding of much of the Document Library content, but disregards some information.<br>• Makes a few accurate claims about the quality of information. | • Identifies most facts or ideas that support or refute all major arguments presented in the Document Library.<br>• Provides analysis that goes beyond the obvious.<br>• Demonstrates accurate understanding of a large body of information from the Document Library.<br>• Makes several accurate claims about the quality of information. |
| **PROBLEM SOLVING** | Considering and weighing information from separate sources to make decisions (draw conclusions) that logically follow from valid arguments, evidence, and examples. | • Provides or implies a decision but little rationale is provided or it is based on unreliable evidence. | • Provides a decision with credible evidence to back it up. Possibly does not account for credible, contradictory evidence. | • Provides a decision and a solid rationale based on credible evidence from a variety of sources. Weighs other options, but presents the decision as best given the available evidence. |
| **EVIDENCE AND EXPALANTION** | Constructing organized and logically cohesive arguments. Strengthening the writer's position by providing elaboration on facts or ideas (e.g. explaining how evidence bears on the problem, providing examples, and emphasizing especially convincing evidence). | • Provides limited, invalid, overstated, or very unclear arguments.<br>• May present information in a disorganized fashion or undermine own points.<br>• Any elaboration on facts or ideas tends to be vague, irrelevant, inaccurate, or unreliable (e.g. based entirely on writer's opinion). Sources information are often unclear. | • Organizes response in a way that makes the writer's arguments and logic of those arguments apparent but not obvious.<br>• Provides valid elaboration on facts or ideas related to each argument and cites sources of information. | • Organizes responses in a logically cohesive way that makes it very easy to follow the writer's arguments.<br>• Provides a valid and comprehensive elaboration of facts and ideas related to each argument and clearly cites sources of information. |

| | | | | |
|---|---|---|---|---|
| **AUTHENTIC TASK** | | • The written argument is brief and may contain numerous grammatical errors.<br>• The writing is difficult to understand<br>• Ideas do not connect or show logical progression supporting a particular claim. | • Writing may have a few grammatical errors<br>• The claim and supporting evidence needs some improvement for the reader to understand the writer's point<br>• In general the writing indicates some understanding and ability to support a claim. | • Excellent grammar.<br>• The claim and supporting evidence are easily understandable by the reader.<br>• The writing follows a logical progression in support of the claim. |

# PERFORMANCE TASK SCORING GUIDELINES

| | EMERGING<br>0-2 | DEVELOPING<br>3-4 | MASTERY<br>5-6 |
|---|---|---|---|
| SCORING GUIDELINES | ○ Focuses on Document a to the exclusion of other pertinent information<br>○ Accepts all documents without argument<br>○ Is unable to refer to specific facts to back up an argument<br>○ Makes incoherent arguments | ○ Cites 2 of 4 documents provided in the task and attempts to identify the credibility of the document or individual mentioned in the document.<br>○ Student shows some understanding and cites some documents but tends to over-generalize without robust support for their claim.<br>○ Student glosses over basic the process of photosynthesis or makes some assumptions that are not supportable | ○ Cites most or all documents provided in the task and addresses the credibility of the document or individual mentioned in the document.<br>○ The student will point out several specific ideas to support their claim (living or not-living) .Student will support their argument by writing specific process that occurs during photosynthesis.<br>○ An exemplary answer will at least mention 7 of 8 criteria. |

**Annotated Bibliography/Resources**

Activity Resources

http://www.nsta.org/publications/news/story.aspx?id=49453

This is a link to Document A in the PBLA.

http://www.csun.edu/scied/2-longitudinal/plant_mass/

This is a link to Document B and C in the PBLA.

http://www.carbonbrief.org/blog/2014/03/scientists-respond-to-%E2%80%9Cmisleading%E2%80%9D-times-article-about-climate-change%E2%80%99s-impact-on-crop-yields/

This is a link to Document D in the PBLA.

Hibbard, K. M. (1996). *Performance-Based Learning and Assessment. A Teacher's Guide*. Association for Supervision and Curriculum Development, 1250 N. Pitt Street, Alexandria, VA 22314.

This book describes a Connecticut school district's approach to teaching and learning that balances basic instruction with performance-based learning and assessment, using tools such as performance tasks, benchmarks, assessment lists, rubrics, and portfolios.

Johnson, G. B., & Raven, P. H. (2004). *Biology*. Orlando, Fl: Holt Rinehart and Winston.

This a high school biology textbook

Özay, E., & Öztaş, H. (2003). Secondary students' interpretations of photosynthesis and plant nutrition. *Journal of Biological Education*, 37(2), 68-70.

This article studies the misconceptions held by Grade 9 students (14 – 15 years old) in Turkey about photosynthesis and plant nutrition.

Project 2061 (American Association for the Advancement of Science). (1989). *Science for all Americans: A Project 2061 report on literacy goals in science, mathematics, and technology* (Vol. 1). Amer Assn for the Advancement of.

Project 2061 is a report on literacy goals in science, mathematics, and technology that was released in 1989 by American Association for the Advancement of Science (AAAS) on

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

The National Research Council (NRC) recommendations on key science ideas and practices that all students should learn in primary and secondary school.

Weinburgh, M. (2004). Teaching photosynthesis: More than a lecture but less than a Lab. *Science Scope*, 27(9), 15-17.

This article advices us that photosynthesis is a very abstract topic and does not allow true project-based investigations by students at the middle school level. The article describes how the author uses clues and cases to help students learn about the processes of photosynthesis.

**Appendix/Content Standards**

Taken from Pennsylvania Department of Education Standards Aligned System

Biology

**BIO.A.3.2**: Identify and describe how energy is captured and transformed in organisms to drive their life processes.

**3.1.10.A2**: Explain cell processes in terms of chemical reactions and energy changes.

**3.1.10.A7**: Describe the relationship between the structure of organic molecules and the function they serve in living organisms.