

CORRECTED

Supplemental Material

CBE—Life Sciences Education

Weston et al.

Supplemental Material

Table S1

Demographics for responder group and interview group

| | Homework Responders | | Non-responders ^c |
|------------------------------|------------------------------|--------------------------|-----------------------------|
| | Not Interviewed ^a | Interviewed ^b | |
| Ethnicity | | | |
| American Indian | 2 | 0 | 0 |
| Asian | 16 | 2 | 2 |
| Black | 12 | 0 | 13 |
| Hawaiian/Pacific Islander | 1 | 0 | 0 |
| Hispanic | 12 | 0 | 7 |
| Multiple | 9 | 1 | 3 |
| White | 242 | 17 | 105 |
| Blank | 3 | 0 | 0 |
| Not Requested | 5 | 0 | 9 |
| Gender | | | |
| Male | 113 | 5 | 74 |
| Female | 189 | 15 | 65 |
| Course Grade | 2.4 | *3.03 | †1.87 |
| Cumulative GPA Start of Term | 2.76 | 2.65 | †2.50 |

^aThis group includes students who responded to the homework question and for whom we have complete demographic information. It does not include those students that were interviewed. ^an=302. ^bThis group includes students that responded to the homework and were interviewed. ^bn=20. ^cThis group includes students who did not respond to the homework question and for whom we have complete demographic information (three non-responders had incomplete demographic information and were removed). ^cn=139. *p<.05; comparison between not-interviewed and interviewed responders. †p<.05; comparison between homework responders and non-responders.

Table S2
Photosynthesis Rubric

| Scientific or Alternative Concept | Description | Positive Example | Number of Responses (n=322) |
|------------------------------------|---|--|-----------------------------|
| <u>Correct Process</u> | Response mentions photosynthesis or the Calvin Cycle. | <i>Photosynthesis adds biomass by converting carbon dioxide into sugar that the plants can use for fuel and growth.</i> | 181 |
| <u>Incorrect Process</u> | Response mentions respiration, the light reactions only, cell division or replication, DNA replication, or an agricultural process such as selective breeding. | <i>The process that is responsible for this increase is cell reproduction by cell division. Cells replicate their DNA and split into daughter cells. As more cells are produced the biomass grows.</i> | 119 |
| <u>Correct Source of Biomass</u> | Response mentions carbon dioxide or carbon from the atmosphere. | <i>It comes from the incorporation of CO₂ from the atmosphere into the molecules in the green leaves.</i> | 94 |
| <u>Incorrect Source of Biomass</u> | Response mentions oxygen alone, sunlight as mass or sunlight alone, or ATP that is not specified as being used for the Calvin cycle. | <i>The huge increase in biomass comes from energy from light that is changed into carbon and other molecules that build cells in the corn. This is done by photosynthesis.</i> | 21 |
| <u>Water as Source</u> | Response mentions water, but does not indicate that something else is the main contributor of biomass or that the water is used for energy. | <i>The huge increase in biomass comes from the enormous amount of weight that water is responsible for in biomass.</i> | 86 |
| <u>Nutrients from the Soil</u> | Response mentions nutrients, minerals, organic compounds, soil, or fertilizer and does not indicate that something else is the main contributor of biomass or that the nutrients are used for energy. | <i>The biomass comes from the sun's energy and the nutrients in the soil. The process is photosynthesis and mitosis.</i> | 68 |
| <u>Correct Product</u> | Response mentions glucose, sugar, carbohydrates, or starch as a product or end result of photosynthesis. | <i>The biomass in the corn comes from the uptake of carbon dioxide and water in the process of photosynthesis. As each seed uses this process to grow over time the forming of carbohydrates causes the plants to increase in weight and size.</i> | 69 |
| <u>Incorrect Product</u> | Response mentions carbon dioxide, ATP, or energy as a product or end result of photosynthesis. | <i>Photosynthesis and Cellular Respiration occur which causes the biomass of the peanuts to increase. The intake of CO₂ H₂O and light is converted into ATP and heat. The peanuts feed on the energy being produced.</i> | 16 |

Interview Protocol

Note. The portions of the interview protocol in italics were intended to be read out loud to the student.

Thank the student for participating.

Introduce yourself as a student working with a research team interested in developing and improving biology assessments.

Briefly review consent form and ask again for permission to record.

Have participant sign a copy of the consent form which you will keep. Give participant a copy for his or her records.

Part 1: Answering the photosynthesis question

Each student will be asked to answer the same version of the stem that he or she answered on the homework.

Give student a copy of question. Make a note of the question version.

Script: "You may be familiar with this question from last semester's introductory biology course. Please read the question and answer it to the best of your ability. Feel free to use the pencil/pen and paper provided as you work through the question. As you formulate your answer, talk me through how you answered this question."

Version 1: corn PB

Each Spring, farmers plant about 5-10 kg of dry seed corn per acre for commercial corn production. By the Fall, this same acre of corn will yield approximately 4-5 metric tons of dry harvested corn. Explain what process adds this huge increase in biomass and where the biomass comes from.

Version 2: corn BP

Each Spring, farmers plant about 5-10 kg of dry seed corn per acre for commercial corn production. By the Fall, this same acre of corn will yield approximately 4-5 metric tons of dry harvested corn. Explain where this huge increase in biomass comes from and by what process?

Version 3: peanut BP

Each Spring, farmers plant about 5-10 kg of peanut seeds per acre for commercial peanut production. By the Fall, this same acre of peanuts will yield approximately 4-5 metric tons of dry harvested peanuts. Explain where this huge increase in biomass comes from and by what process?

Version 4: peanut PB

Each Spring, farmers plant about 5-10 kg of peanut seeds per acre for commercial peanut production. By the Fall, this same acre of peanuts will yield approximately 4-5 metric tons of dry harvested peanuts. Explain what process adds this huge increase in biomass and where the biomass comes from.

Part 2: Content Probes

Script: "Thanks! I also have a copy of your answer from last semester's homework assignment. Let's take a look at the similarities and differences between the two. What changes, if any, do you notice in your written and verbal answers?"

Script: "Please describe why your explanations differed? "

- We are interested in changes in:

- the presence and absence of the process and/or source
- the content related to the process and the source

Based on keywords/phrases in response, probe for further explanation

Organism-specific:

-Agricultural plant (What is different about agricultural plants/how would your answer be different if the plant was not agricultural?)

-GMO, fertilizers--may increase mass rapidly (might mention this instead of photosynthesis)

-Photosynthesizing vs. non-photosynthesizing plants

-peanuts underground--students might not make the connection that there is also above ground structure to photosynthesize

-corn is yellow--some may say this means plant isn't photosynthesizing

-Asexual reproduction (this is sometimes linked to mitosis and replication)

-cell division=more mass (esp. might come up with peanuts)

General probes for clarity in writing:

-References to cellular respiration for energy and growth (How is it coupled to photosynthesis?)

-may talk about respiration for energy but not mention photosynthesis

- mentions of respiration leading to growth

-Sunlight (What do students mean?)

-may include with CO₂, water--what role do they see sunlight playing?

Part 3: Stem Probes

Script: "We will return to your response shortly.

*Let's talk a bit about the question itself. Are you having any **problems** with any parts of the question? Are there any parts that are **confusing**?"*

- Ask participants to highlight them in yellow or orange

*Script: "What are the parts of the question that you felt are **most relevant** to your attempts to answer it?"*

- Ask participants to circle them

*Script: "Are there any parts that you feel are unnecessary, that is, parts that you consider **irrelevant** to the question that you can simply ignore?"*

- Ask participants to Strikethrough these items.

Script: "Are "process" and "where" asking for different things or are they redundant/vague language in the questions?"

If student responds "redundant/vague" - then "What do you think they are asking?"

If student responds "different" - then "how are they different? What is "process" asking for? What is "where" asking for?"

Script: "How would you reword this question to be most clear?"

4. Additional content probes

Ask students to talk more about:

Photosynthesis

Biomass

Water

Soil

Carbon dioxide

Begin with word mentioned in the student's response, then ask students to explain further.

Try not to mention photosynthesis or carbon dioxide until the students have brought them up.

Script: "Thank you for taking the time to participate in this interview. Your responses will help us improve biology assessments for future classes."

Pay the student for his/her time.

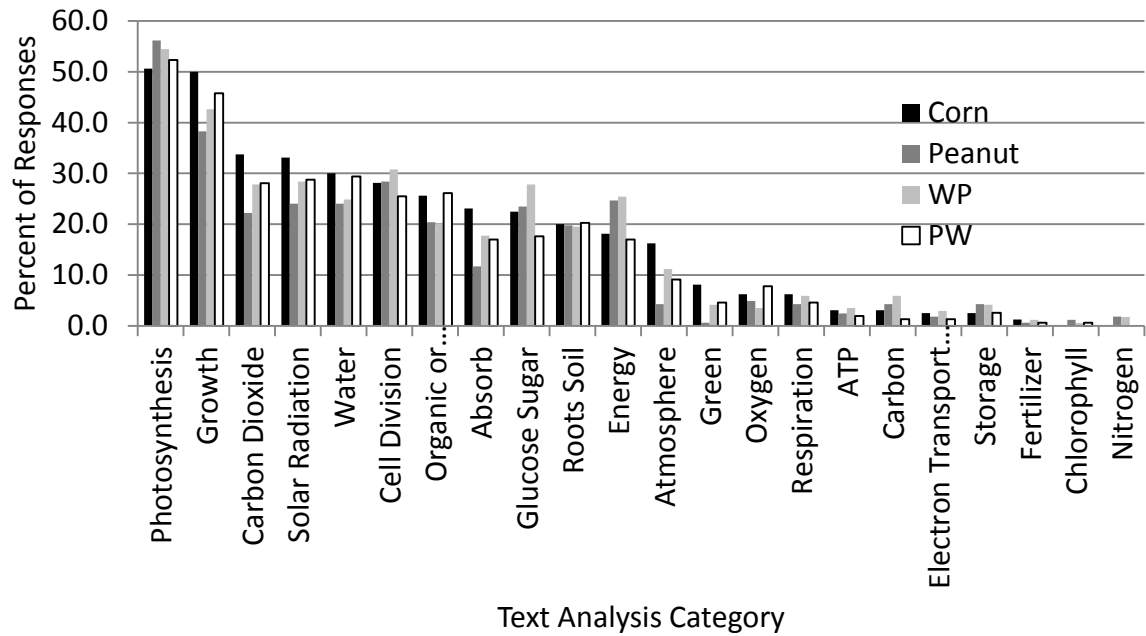


Figure S1. Distribution of responses in text analysis categories by question stem surface features. The categories *don't know*, *seed dispersal*, and *self-pollination* had fewer than 1% of the responses and were removed from the graph. n=322.

Table S3

Distribution of responses from interviewed students across TA categories on the homework and interview^a

| Category | Agreement | | Disagreement | | Percent Agreement |
|---------------------------------|---------------------------------|--------------------------------|--------------------------|---------------------------|-------------------|
| | Present in Homework & interview | Absent in Homework & Interview | Present in Homework Only | Present in Interview Only | |
| <i>ATP</i> | 0 | 19 | 1 | 0 | 95 |
| <i>Absorb</i> | 2 | 14 | 0 | 4 | 80 |
| <i>Atmosphere</i> | 0 | 17 | 1 | 2 | 85 |
| <i>Carbon</i> | 0 | 18 | 0 | 2 | 90 |
| <i>Carbon Dioxide</i> | 4 | 13 | 0 | 3 | 85 |
| <i>Cell Division</i> | 1 | 17 | 2 | 0 | 90 |
| <i>Electron Transport Chain</i> | 0 | 17 | 2 | 1 | 85 |
| <i>*Energy</i> | 0 | 14 | 3 | 2 | 70 |
| <i>*Sugars</i> | 2 | 12 | 5 | 1 | 70 |
| <i>*Growth</i> | 5 | 6 | 6 | 3 | 55 |
| <i>*In/organic</i> | 4 | 10 | 3 | 3 | 70 |
| <i>Oxygen</i> | 1 | 17 | 0 | 2 | 90 |
| <i>Photosynthesis</i> | 10 | 7 | 2 | 1 | 85 |
| <i>Respiration</i> | 1 | 16 | 1 | 2 | 85 |
| <i>Roots Soil</i> | 2 | 13 | 2 | 3 | 75 |
| <i>Seed Dispersal</i> | 0 | 19 | 1 | 0 | 95 |
| <i>Solar Radiation</i> | 2 | 14 | 4 | 0 | 80 |
| <i>Storage</i> | 0 | 19 | 0 | 1 | 95 |
| <i>*Water</i> | 4 | 10 | 4 | 2 | 70 |

^aThe following categories did not have any responses and were removed from the table: *chlorophyll, fertilizer, green, "I Don't Know", Nitrogen, and self-pollination*. n=20. *These TA categories did not have agreement between the homework and interview for at least 15 of the 20 students.