Studying How Students Connect Macro-Scale Explanations of Photosynthesis With Global Processes

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Introduction

- *Carbon TIME (Carbon: Transformations in Matter and Energy)* is a curriculum development project designed to teach carbon-transforming processes to middle and high school students.
- Each unit of this program has identical pretest and posttest that are used to evaluate each student's learning gains after experiencing the unit. Each student is assigned a level based on their response to the questions.
- In this study, we evaluated two questions from the unit posttests to see how well students transferred knowledge from macroscopic-scale questions to global-scale questions about plant growth.

Question:

How successfully do students reason about plant growth processes (photosynthesis) and how well do they transfer this knowledge to global-scale context (explaining seasonal variation in CO_2 concentrations)?

Methods

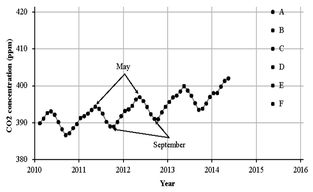
- We analyzed a sample of 235 students pretest and posttest responses based on the questions KLGONECAUSE and OAKTREEPARTS.
- Students need to notice that CO_2 levels decrease in the summer and must recognize that only plant growth can explain this.
  - Level 3 and 4 answers to OAKTREE recognize that plants absorb CO_2
  - Level 3 and 4 answers to KLG use this knowledge to explain the graph

Results

KLGONECAUSE: Every year the CO2 concentration reaches a peak in May, then goes down until September. What causes this variation? Please rate the likelihood that the following activities cause the variation in CO2 concentration over one year:

Measurement error (poor equipment or mistakes that the observers made)
Variation in people's use of fossil fuels (e.g., driving cars, heating homes)
Variation in plant growth
Variation in volcanic activity
Variation in nuclear power plant use
Global climate change MAJOR CAUSE/MINOR CAUSE/NOT A CAUSE

Explain your reasoning. Why is the main cause you chose for the yearly variation more important than the others?



	Student Responses
Level 4: Students recognize the periodicity of the figure and identify plant processes as the primary cause.	*//A minor cause/ A minor cause/ The main cause/ A minor cause/ A minor cause/ A minor cause// Plants growing take in CO2 through photosynthesis, so plant growth during the summer (May-September) makes sense in respect to lower concentrations of CO2.*
Level 3: Students recognize the periodicity of the figure but make mistakes explaining the mechansism for its cause. Or they recognize plant processes as the primary cause, but don't explicitly relate those processes to the seasonal pattern.	*//Not a cause/The main cause/The main cause/Not a cause/Not a cause/A minor cause// Yearly variation is a main thing for CO2 because different years may bring different things. In May there are more people doing activities and planting and etc, while in September, people are using their vehicles more, heating their houses...*
Level 2: Students identify fossil fuels as a carbon source.	*//Not a cause/The main cause/The main cause/A minor cause/A minor cause/A minor cause// The main sources of Carbon Dioxide is fossil fuels and plant respiration, the major parts of the Carbon Cycle. Changes/variations in these is the main cause of Carbon Dioxide variation in the atmosphere.*
Level 1: Students identify certain processes as "harmful" without a mechanisitic understanding of why, or they provide marginally relevant information.	*//Not a cause/A minor cause/A minor cause/The main cause/Not a cause/A minor cause//The main cause is volcanic activity because the data was taken on an island in Hawaii with volcanic activity. Minor causes are Variation in peoples fossil fuels and plant growth because they dont cause as much of a change as the volcanic activity does.*

OAKTREEPARTS: Like all materials, the wood of a large oak tree is made of atoms. There were some atoms in the original acorn that the oak tree grew from. Where do you think the additional atoms came from?
- ALL of the additional atoms were originally outside the tree
- SOME of the additional atoms were made by the tree as it grew.

How much of the dry mass comes from the air? ALL OR MOST/SOME/NONE
How much of the dry mass comes from sunlight?
How much of the dry mass comes from water?
How much of the dry mass comes from soil nutrients?

How do you think the different parts of a tree help the oak tree gain mass as it grows? How do the leaves help the oak tree gain mass as it grows?

	Student Responses
How do the roots help the oak tree gain mass as it grows? Level 4: Directly link C from the air to biomass in the tree; explain that roots take up water/nutrients used in photosynthesis, or recognize the water doesn't account for much mass	*//All or most/Some/Some/None//The leaves bring in CO2 and H2O from the air and then the tree adds O2 to the mix and the it creates a new molecule, glucose (C6H12OH). The roots bring in water which helps the process of photsynthisis and also brings in certain nutrients from the earth that the tree cant get from the air such as nitrogen or sulfer.// They bring in water which is most of the tress wet mass.*
Level 3: Link air/CO2 with growth, but either stop at the creation of glucose or have vague/incorrect ideas about the process. Roots serve to bring water and nutrients to tree.	*//All/All or most/None/All or most/Some// The leaves collect the carbon dioxide from the air, and uses water and sunlight to create glucose (photosynthesis). With that glucose, the plant can make other types biomass. /The roots are where the water is collected for photosynthesis.*
Level 2: Recognize that leaves are involved in providing mass to the tree but are general in their explanations or they don't distinguish among matter sources.	*//All/All or most/None/Some/Some/The leaves help the oak tree gain mass because it pulls in carbon dioxide. (co2)/ The roots help the oak tree gain mass because its pulling up water from the ground.*

KLGvsOAKTREE	KLGONE CAUSE				
OAKTREEPARTS	1	2	3	4	Grand Total
2	35	4	13	7	59
3	41	7	22	20	90
4	22	5	26	33	86
Grand Total	**98**	**16**	**61**	**60**	**235**

No good explanation
Good explanation of one but not the other
Good explanation of both

17% of students were unable to produce a good explanation for both questions.

9% of students could explain KLGONECAUSE well, but not OAKTREEPARTS.
32% of students could give a good explanation for OAKTREEPARTS but not KLGONECAUSE.

43% of students could effectively explain both questions.

Discussion

- More students had level 4 responses in the macro-scale than global-scale question
- Most responses for the global-scale question were level 1
- Most responses for the macro-scale question were level 3
- This information suggests that students understand macro-scale questions better than global-scale.
- Connecting global- and macro-scale processes is difficult. Just because a student understands trees as an organism, does not mean they will see its role in global carbon cycling.
- We can use this information to further develop the curriculum and we can assume that students need additional materials to bridge the gap between small and large scale questions.

Acknowledgements

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