

Connections between students' explanations and interpretations of arguments from evidence

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Introduction

- *Next Generation Science Standards:*
 - Constructing explanations
 - Engaging in argument from evidence during experimentation
- Students struggle to explain plant growth
 - Prior knowledge may not be scientific, but is important
- Students may misinterpret the purpose of the classroom investigations
 - to explore, to make something happen by manipulating variables, or to solicit attention
- Students' stories and interpretations are reflected in:
 - Explanations of the process of plants growing,
 - Reasoning about investigations of plant growth.

Overview of Study

- **Tasks:**
 - How plants grow and gain mass
 - Analyze and critique arguments from evidence about the source of matter for plant growth.
- **Our focus:**
 - Consistency between students' explanations and their interpretations of arguments from evidence.
- **Hypothesis:**
 - Students' sense-making strategies and understanding of chemical change lead them to interpret—or misinterpret—purposes investigations and arguments from evidence.



Data Collection

- 22 student post interviews after Carbon TIME instruction
 - 4 middle school
 - 18 high school
- Biology teachers conducted semi-structured, face-to-face interviews during the 2012-2013 school year.
 - **Explanation 1: Oak Tree growth (focus)**
 - **Inquiry: Karen and Mike investigations (focus)**
 - **Explanation 2: Pound of Wood**

Tree Growth Question

Oak Tree Questions

- *What does a tree need to grow*
- *Does the tree do anything with the air that surrounds it?*
- *Is there a connection between exchanging gases and growing for the tree?*





Data Analysis: Learning Progression

Components	Level 4	Level 3	Level 2
Changes in Materials	Describes transformation of matter at the atomic-molecular level specifically describing the breaking and rearrangement of molecules		
Movement of Matter	Traces atoms and molecules even when prompted at the macroscopic level		



Data Analysis: Learning Progression

	Level 4	Level 3	Level 2
Changes in Materials	Describes transformation of matter at the atomic-molecular level specifically describing the breaking and rearrangement of molecules	Describes transformation of matter but with inconsistencies including matter-energy conflation or breaking law of conservation of matter.	
Movement of Matter	Traces atoms and molecules even when prompted at the macroscopic level	Traces using atoms and molecule language, but with mistakes or inconsistency at the atomic-molecular level	



Data Analysis: Learning Progression

	Level 4	Level 3	Level 2
Changes in Materials	Describes transformation of matter at the atomic-molecular level specifically describing the breaking and rearrangement of molecules	Describes transformation of matter but with inconsistencies including matter-energy conflation or breaking law of conservation of matter.	No description of chemical change
Movement of Matter	Traces atoms and molecules even when prompted at the macroscopic level	Traces using atoms and molecule language, but with mistakes or inconsistency at the atomic-molecular level	Tracing cause and effect

Inquiry Question

Plants gain most of their weight from materials that came from the **air**.

Karen



Plants gain most of their weight from materials that came from nutrients in the **soil**.

Mike



Interview Prompt: Who do you think is right?

Inquiry Question

You can grow a big plant in a little pot without a lot of soil.

Karen



Seed
1 g

Soil
80 g

Seed Planting



Plant
50 g

Soil
78 g

1 year later

Plants have roots to take up nutrients from the soil to grow.

Mike



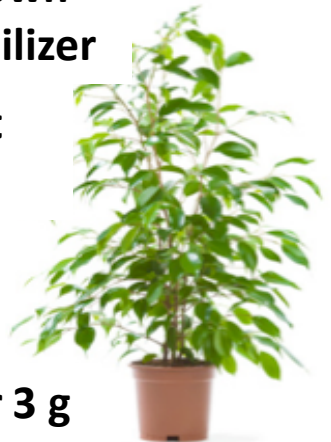
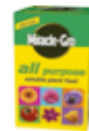
Plant grown without fertilizer

Plant
50 g



Plant grown with fertilizer

Plant
65 g



Fertilizer 3 g



Inquiry Questions

Based on who they chose...

- *How does her/his argument support her/his idea that the plant gains weight from materials that came from the air/soil?*

- *Are there some weaknesses in her/his argument? Explain what they are. What evidence would strengthen her/his argument?*

Then students are asked about the other person's argument.

Question	Level
Oak Tree: Is there a connection between exchanging gases and growing?	
Choice: Karen or Mike	
Karen: How does Karen's argument support her idea that the plant gains weight from materials that came from the air?	
Mike: Are there some weaknesses in Mike's argument? Explain what they are.	

Oak Tree: Is there a connection between exchanging gases and growing?

That's how all the carbon dioxide gets into the tree to build the glucose and then also how the oxygen gets in to perform cellular respiration in order to, like, give the tree energy...then since oxygen is a byproduct of photosynthesis too it releases both oxygen and CO₂.

Choice: Karen or Mike

Karen: How does Karen's argument support her idea that the plant gains weight from materials that came from the air?

Mike: Are there some weaknesses in Mike's argument? Explain what they are.



Oak Tree: Is there a connection between exchanging gases and growing?

That's how all the carbon dioxide gets into the tree to build the glucose and then also how the oxygen gets in to perform cellular respiration in order to, like, give the tree energy...then since oxygen is a byproduct of photosynthesis too it releases both oxygen and CO₂.

Choice: Karen or Mike

Karen

Karen: How does Karen's argument support her idea that the plant gains weight from materials that came from the air?

...because the soil only, like its mass only decreased by two grams while the plant's mass increased by forty-nine grams so forty-seven of those grams had to come from some place. Forty seven of the grams that the plant's mass increased had to come somewhere else besides the soil.

Mike: Are there some weaknesses in Mike's argument? Explain what

Oak Tree: Is there a connection between exchanging gases and growing?

That's how all the carbon dioxide gets into the tree to build the glucose and then also how the oxygen gets in to perform cellular respiration in order to, like, give the tree energy...then since oxygen is a byproduct of photosynthesis too it releases both oxygen and CO₂.

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...because the soil only, like its mass only decreased by two grams while the plant's mass increased by forty-nine grams so forty-seven of those grams had to come from some place. Forty seven of the grams that the plant's mass increased had to come somewhere else besides the soil.

Mike: Are there some weaknesses in Mike's argument? Explain what they are.

Yeah, well the plant only gained three more grams...the plant gained fifteen more grams when only three grams were added from the soil so that means not all of its mass came from the soil it just helped it grow more.

Question

Level 3

Oak Tree :How does a tree use air to grow?

Is there a connection between exchanging gases and growing?

Yeah, it needs oxygen to create photosynthesis I think. You have to have sunlight and water and oxygen to make that... Oh no— carbon dioxide, sorry.

Yeah, because parts of the carbon dioxide, like once it's broken down, it's used with the hydrogen to make glucose, which helps it grow.

Choice: Karen or Mike

Karen: How does Karen's argument support her idea that the plant gains weight from materials that came from the air?

Question

Level 3

Oak Tree: Is there a connection between exchanging gases and growing?

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Choice: Karen or Mike

Karen: How does Karen's argument support her idea that the plant gains weight from materials that came from the air?

Karen

...there's only a little bit of soil and her plant still gained a lot of mass, the soil isn't what gives it most of its mass it's the air.

Question	Level 3
Oak Tree: Is there a connection between exchanging gases and growing?	Yeah, because parts of the carbon dioxide, like once it's broken down, it's used with the hydrogen to make glucose, which helps it grow.
Choice: Karen or Mike	Karen
Karen: How does Karen's argument support her idea that the plant gains weight from materials that came from the air?	...there's only a little bit of soil and her plant still gained a lot of mass, the soil isn't what gives it most of its mass it's the air.
Mike: Are there some weaknesses in Mike's argument? Explain what they are.	I guess the same as with Karen's he didn't test any other factors other than just with and without fertilizer.

Question	Level 2
<p>Oak Tree: Is there a connection between exchanging gases and growing?</p>	<p>The more oxygen it breathes out, I mean the more carbon...tree takes in carbon and makes more oxygen.</p>
<p>Choice: Karen or Mike</p>	
<p>Karen: How does Karen's argument support her idea that the plant gains weight from materials that came from the air?</p>	
<p>Mike: Are there some weaknesses in Mike's argument? Explain what they are.</p>	

Question	Level 2
<p>Oak Tree: Is there a connection between exchanging gases and growing?</p>	<p>The more oxygen it breathes out, I mean the more carbon...tree takes in carbon and makes more oxygen.</p>
<p>Choice: Karen or Mike</p>	<p>Karen...Mike is kind of right too</p>
<p>Karen: How does Karen's argument support her idea that the plant gains weight from materials that came from the air?</p>	<p>...and the soil amount got smaller. If there wasn't any air that the plant wouldn't have gotten as big as it did</p>
<p>Mike: Are there some weaknesses in Mike's argument? Explain what they are.</p>	

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Karen: How does Karen's argument support her idea that the plant gains weight from materials that came from the air?	...and the soil amount got smaller. If there wasn't any air that the plant wouldn't have gotten as big as it did
Mike: Are there some weaknesses in Mike's argument? Explain what they are.	That the plant can't just grow with fertilizer it needs other things too.

Purposes of the Experiments

			Karen Question			Mike Question		
Types of Explanations	Choice	Uncodeables	Tracing Matter	Strategies for plant growth	Identifying Needs and Enablers	Tracing Matter	Strategies for plant growth	Identifying Needs and Enablers
Level 4	6-K 1-M		7	0	0	5	2	0
Level 3	14-K 3-M		10	4	3	7	8	2
Level 2	3-K 2-M	1	0	1	3	0	2	3
Total		1	17	5	6	12	12	5

Patterns

- **Level 4 Students:**
 - Trace matter in explanations
 - Trace matter in Karen and Mike questions
- **Level 3 Students:**
 - In Zone of Proximal Development (Vygotsky, 1978)
 - Scaffolding helped
 - Interpreted Karen and Mike investigations differently
- **Level 2 Students:**
 - Explanations focused on what plants need to grow
 - Interpretations of Karen and Mike were “What do plants need to grow?”

Level 2 and 3 Students: Reinterpreted the nature of Karen and Mike’s claims and the purposes of their investigations, focusing on strategies for growing plants or identifying enablers that help plants to grow rather than tracing matter.



Conclusion

- Many students re-interpret the hypotheses and results of standard investigations of plant growth to match their own understandings.
- Students may benefit from instructional strategies that scaffold their explanations and inquiry about how plants grow.



Teaching Implications

- The role of scaffolding.
- Understanding the nature of scientific explanations.
- Using conservation laws and atomic-molecular theory as rules.
- Understanding purposes of investigations.



Next Steps

- How does instruction using the *Carbon TIME* units affect student reasoning?
 - Compare pre to post data

Thank you!

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Three Questions Poster

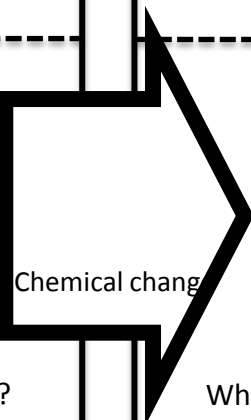
Question	Rules to Follow	Connecting Atoms to Evidence
<p>The Location/Movement Question: Where are atoms moving? Where are atoms moving from? Where are atoms going to?</p>	<p>Atoms last forever in combustion and living systems All materials (solids, liquids, and gases) are made of atoms</p>	<p>When materials change mass, atoms are moving When materials move, atoms are moving</p>
<p>The Carbon Question: What is happening to carbon atoms? What molecules are carbon atoms in before the process? How are the atoms rearranged into new molecules?</p>	<p>Carbon atoms are bound to other atoms in molecules Atoms can be rearranged to make new molecules</p>	<p>The air has carbon atoms in CO₂ Organic materials are made of molecules with carbon atoms</p> <ul style="list-style-type: none"> • Foods • Fuels • Living and dead plants and animals
<p>The Energy Question: What is happening to chemical energy? What forms of energy are involved? How is energy changing from one form to another?</p>	<p>Energy lasts forever in combustion and living systems C-C and C-H bonds have more stored chemical energy than C-O and H-O bonds</p>	<p>We can observe indicators of different forms of energy</p> <ul style="list-style-type: none"> • Organic materials with chemical energy • Light • Heat energy • Motion



What happens when ethanol burns?

Where are atoms moving from?

Where are atoms moving to?



Chemical change

What molecules are carbon atoms in before the change?
What other molecules are involved?

What molecules are carbon atoms in after the change?
What other molecules are produced?

What forms of energy are in the reactants?

What forms of energy are in the products?

Remember: **Atoms last forever** (so you can rearrange atoms into new molecules, but can't add or subtract atoms)
Energy lasts forever (so you can change forms of energy, but energy units can't appear or go away)



Comparing pre to post interviews:

Pre interview (level 2)

- Chooses Mike (fertilizer = “plant steroids”)
- Where does the pound of wood come from?
“The tree itself. It makes more cells. “
- Does something in the tree’s environment have to lose weight in order for the tree to gain weight?
“Yes, but I don’t know what.”



Post interview (level 3)

- Chooses Karen (soil didn't lose enough to account for mass gain)
- where does the pound of wood come from?

“It comes from the glucose made during photosynthesis and the tree uses that to grow.”
- Does something in the tree's environment have to lose weight in order for the tree to gain weight?

“No.”
- When you gain weight you use the food you eat so it loses weight. Is there anything like that for the tree? The tree uses it so that it loses weight when the tree grows.

“The ... I mean I guess the air might lose mass because it's taking in matter from the air so actually yes the air loses mass.”

Preliminary Results-Pre Interviews

		Karen Question			Mike Question		
Types of Explanations	Choice	Tracing Matter	Strategies for plant growth	Identifying Needs and Enablers	Tracing Matter	Strategies for plant growth	Identifying Needs and Enablers
Level 4	0	0	0	0	0	0	0
Level 3	10-K 3-M 1-Both	7	3	4			
Level 2	6-K 4-M	0	2	8			
Total		7	5	12			

Emerging patterns

- Level 3 students very sensitive to scaffolding
- Recognizing that air has mass a key factor in interpreting the claims in the investigation