How to Support Biology Students in Constructing Explanations about Carbon-Transforming Processes

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Goals of the Session

- Share insights from an experienced high school biology teacher about how to support students in **constructing explanations** about phenomena using the crosscutting concepts of energy and matter conservation.

- Share how the *Carbon TIME* curriculum supports students in being more metacognitive, or aware of their own thinking.
  - Using Process Tools to scaffold particular types of discourse
  - Using Process Tools to see how much learning or growth has occurred by the end of a unit

- Q & A at the end of the session
Context of the Collaboration

+ large-scale curriculum implementation project
+ carbon-transforming processes in socio-ecological systems
+ teachers participate for 2 years
+ F2F and online PD support
+ case study classrooms for more in-depth investigation

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Phenomena in *Carbon TIME*

<table>
<thead>
<tr>
<th><em>Carbon TIME Units</em></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Introductory</strong></td>
<td>Systems and Scale</td>
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<tr>
<td></td>
<td>Plants</td>
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<tr>
<td></td>
<td>Animals</td>
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<td></td>
<td>Decomposers</td>
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<tr>
<td><strong>Organismal</strong></td>
<td>Ecosystems</td>
</tr>
<tr>
<td></td>
<td>Human Energy Systems</td>
</tr>
</tbody>
</table>

- Animals moving and growing
- Plants growing
- Ethanol burning
Scientific Practice: Constructing Explanations

supporting students’ engagement in 3-dimensional learning

construct explanations about plants growing using conservation of matter and energy

scientific practice
crosscutting concept
disciplinary core idea

+ evidence from investigations
Demonstration

Expressing Ideas about Plants Growing

1. Share what you wrote with your shoulder partner.
2. Strategies for getting students to express their ideas and share with a partner.
3. Strategies for sharing as a whole-class.
1.2 Expressing Ideas Tool: How do you think a plant grows, moves, and functions?

**Draw** labeled arrows to show your ideas about what might be moving into, out of, or through the radish plant. Think about what materials are moving and how they might be moving.

**What goes in:** List all the things you can think of that go into the plant.

**What comes out:** List all the things you can think of that come out of the plant.

**Your Explanation:** Write your explanation for how a plant grows, moves, and functions. Think about what materials and processes you listed in your drawing above.

Preparation of students to think about movement of matter

Science Practice of Constructing Explanations
Core Student Practices in Each *Carbon* TIME Unit

- **Predicting** Observations during Investigation
- **Expressing Ideas** about observable phenomena (growth, movement)
- **Evidence-Based Arguments** based on observations
- **Explanations** of phenomena using atomic-molecular models

**Observations**
- **Patterns**
- **Models**

**Inquiry (up the triangle)**
- **Observe**
- **Predict & Express Ideas**
- **Evidence-Based Arguments**

**Application (down the triangle)**
- **Coach**
- **Model**
- **Fade**

**Pretest**
- **Establish the Problem**
- **Foundational Knowledge and Practice**

**Start**
- **Post Test**
- **Maintain**
- **Next Unit**
**3.1GL Predictions Tool: What do you predict you will observe in your plant investigations?**

<table>
<thead>
<tr>
<th>The Matter Movement Question</th>
<th>The Atomic-Molecular Scale: Explain your predictions using the Three Questions.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictions about mass</td>
<td>Where will the matter in the gel and air move to after one day? Draw labeled arrows to show how molecules with carbon atoms might be moving into and out of the radish plant as it grows.</td>
</tr>
<tr>
<td>How will the movement of matter change the mass of:</td>
<td></td>
</tr>
<tr>
<td>the plant?</td>
<td></td>
</tr>
<tr>
<td>the gel?</td>
<td></td>
</tr>
<tr>
<td>everything in the test tube?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The Matter Movement Question</th>
<th>Predictions about changes in BTB</th>
</tr>
</thead>
<tbody>
<tr>
<td>How will matter changes in this system affect CO₂ in the air and the color of the BTB with plants in the light?</td>
<td>What molecules do you think carbon atoms are in the plant before it grows?</td>
</tr>
<tr>
<td>How will matter changes in this system affect CO₂ in the air and the color of the BTB with plants in the dark?</td>
<td>What molecules do you think carbon atoms are in while the plant lives and grows?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The Energy Change Question</th>
<th>Predictions about energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>What evidence of energy change will you be able to observe?</td>
<td>What forms of energy do you think are coming into the plant?</td>
</tr>
</tbody>
</table>

**Chemical Change**

**Energy Transformation**

| What other molecules will be involved? | How does that energy change as the plant lives and grows? |
Core Student Practices in Each Carbon TIME Unit

Predicting Observations during Investigation

Expressing Ideas about observable phenomena (growth, movement)

Evidence-Based Arguments based on observations

Explanations of phenomena using atomic-molecular models

Observations

Patterns

Models

Inquiry (up the triangle)

Application (down the triangle)

Start

Pretest

Establish the Problem

Foundational Knowledge and Practice

Predict & Express Ideas

Model

Coach

Fade

Post Test

Maintain

Next Unit
Moment of Reflection

What are some takeaways about the challenges of 3D science teaching, and how do we support students in engaging in 3D science learning?

What unanswered questions do you still have?
### Plants in Light and Dark Class Results Poster

<table>
<thead>
<tr>
<th>Group</th>
<th>Plants in the Light</th>
<th>Plants in the Dark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Start BTB Color</td>
<td>End BTB Color</td>
</tr>
<tr>
<td>1</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>Blue</td>
</tr>
<tr>
<td>2</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>Blue</td>
</tr>
<tr>
<td>3</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>Blue</td>
</tr>
<tr>
<td>4</td>
<td>Yellow</td>
<td>Yellow</td>
</tr>
<tr>
<td></td>
<td>Blue</td>
<td>Blue</td>
</tr>
</tbody>
</table>
3.5 Evidence-Based Arguments Tool:
What Happens When Plants are in Light & Dark? & What Happens When Plants Grow?

Think about your plant investigations. Complete this tool with patterns from class evidence, conclusions, and unanswered questions.

<table>
<thead>
<tr>
<th>Class Evidence</th>
<th>Conclusions</th>
<th>Unanswered Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>What patterns did we find in our class evidence about each of the Three Questions?</td>
<td>What can we conclude about each of the Three Questions using this evidence?</td>
<td>What do we still need to know in order to answer each of the Three Questions?</td>
</tr>
<tr>
<td>Class Evidence</td>
<td>Conclusions</td>
<td>Unanswered Questions</td>
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<td>----------------</td>
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</table>
Students working with molecular model kits to make connections between observations of macroscopic phenomena and atomic-molecular scales.
C. Atoms last forever! Energy lasts forever!
Review the table below to account for all the atoms and types of energy in your models. Then answer the “Check Yourself” questions below the table.

<table>
<thead>
<tr>
<th></th>
<th><strong>MATTER</strong></th>
<th><strong>ENERGY</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reactants</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>REACTANTS TOTALS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Products</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PRODUCTS TOTALS</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.4 Explanations Tool: How does a potato plant make the food it needs to grow and function?

**The Matter Movement Question**
- Draw and label arrows that show molecules moving into, through and out of a cell in a potato plant
  - Show molecules with carbon atoms moving into and out of the cell in the plant’s leaf that makes the food
  - Show other relevant molecules

**The Matter Change Question**
- Name the chemical change that allows cells to make food:
- Write the chemical equation for this change:

**The Energy Change Question**
- What forms of energy go into this chemical change?
- What forms of energy come out of this chemical change?

**Explain in words:** How does a potato plant make the food it needs to grow and function? (Answer on back).

*Use this Explanation Tool to help guide your written explanation, be sure to answer the Three Questions.*

Remember: **Atoms last forever** (so you can arrange 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).
Quotes from Students

“I think it takes more like, thought to answer those kinds of questions, like A, B, C, or D. Like it’s, it kind of gets you more engaged in the test, what you’re taking. It’s more thinking. Which can be good because then it means that you actually, you really know your information, you know how to piece everything together.”

“I just kind of like it [the Explanations Tool] because it’s sort of like a sheet where you can get all of your ideas and all of your knowledge on a topic, all onto one page. So it’s not just like scattered everywhere like in a bundle. You can look at this and be like, this is how that works, and this is how that works, and how it all kind of works together.”

“Animals and plants…they have mitochondria, too… it just works together so well, and then like, you start to question the bigger questions, like the bigger things, like, who set this system up this way? And why do things work this way? And then why do things exist at all, and you know?

“I was just kind of wondering how, like the seed gets the energy to to like, grow, in like… plant, because I think we talked about it for like a bit. Like, originally the radish plant kind of like, put in like a lot of chemical energy into the seed, and that’s why it was able to grow, but I don’t know. It’s, like how there’s energy stored in the seed.”
Q & A

For more information about Carbon TIME:
envlit@msu.edu

Website with free curriculum:
http://carbontime.bscs.org/

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