# Does Principle-oriented Instruction Improve Student Performance in Novel Contexts?

BIOLOGY EDUCATION RESEARCH GROUP

Jennifer H. Doherty[1], Emily E. Scott[2], Karen Draney[3], Jinho Kim[3], and Charles W. Anderson[2]
[1]University of Washington, [2]Michigan State University, [3]University of California Berkeley

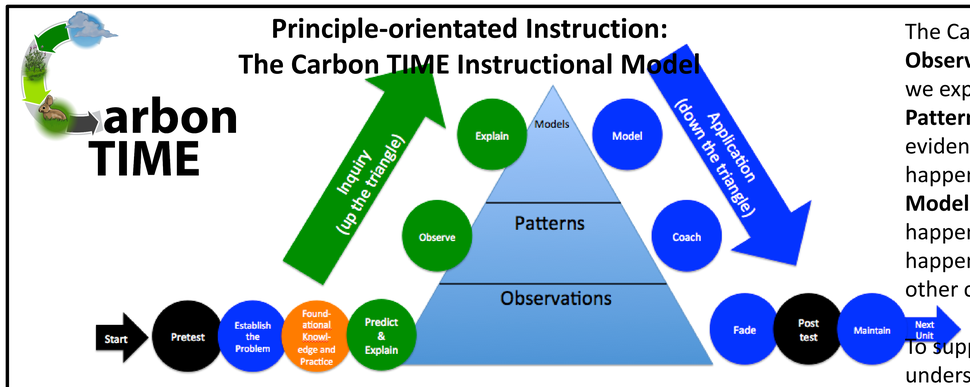
MICHIGAN STATE UNIVERSITY
Berkeley UNIVERSITY OF CALIFORNIA

## Research Question:

While students see many differences across the systems we investigate in the Carbon TIME units (e.g., alcohol combustion, animals moving, plant growth), there are important underlying similarities (e.g., matter and energy conservation, oxidation of organic materials). In Carbon TIME we use principle-orientated instruction to support our goal of students being able to apply principled reasoning from one context (e.g., combustion) to another (e.g., plants).

**Can principle-orientated instruction help students see the underlying similarity in principles and models across contexts, despite the differences in surface features? That is, do students transfer principled reasoning learned in one unit to the next?** If this is true, we expect to see increased performance among unit pretests.

## Principle-orientated Instruction: The Carbon TIME Instructional Model




The Carbon TIME instructional model is built on the triangle:
**Observations**: The world is full of possible experiences in the physical world. When we experience these phenomena, we make observations and collect data.
**Patterns**: After we have made observations and collected data, we organize our evidence to help us identify patterns. These are generalizations about what is happening.
**Models**: Finally, we need to understand why the patterns we observe are happening. There are a few key models that we can use to explain why patterns happen. These models can sometimes be used to explain other similar patterns in other contexts. This is where the principles are.

To support student learning, the units also include elements that assess student understanding, stimulate interest, provide foundational knowledge, follow intentional activity sequences, and assess learning over time.

## Observations, Patterns, and Models to support Principle-based explanations

### Investigation: Burning ethanol

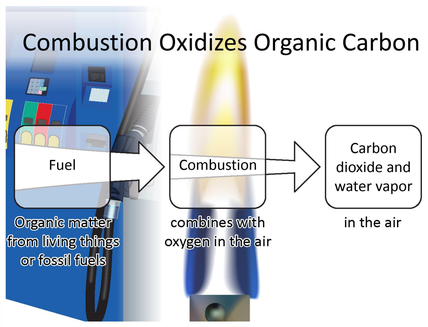
- Ethanol loses mass when it burns
- The air gains $CO_2$ (detected with bromothymol blue) when ethanol burns

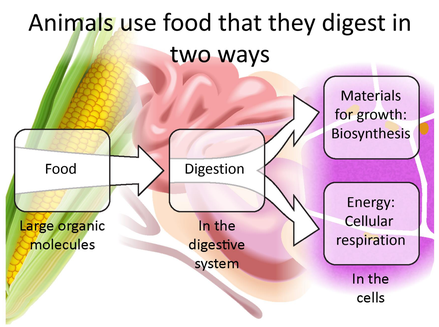
### Investigation: Mealworms eating and breathing

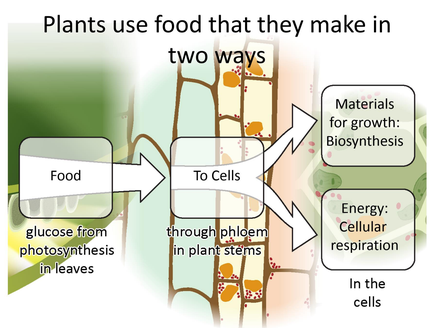
- Mealworms gain mass
- The potato loses mass
- The potato loses more mass than the mealworms gain
- Mealworms breathe $CO_2$ out into the air

### Investigation: Plants growing & gas exchange

- When plants grow, they gain more dry mass than the soil loses
- Plants absorb $CO_2$ in the light
- Plants emit $CO_2$ in the dark



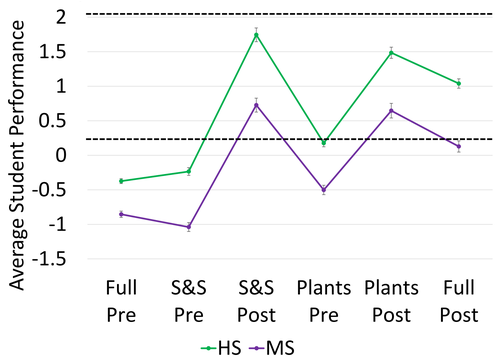



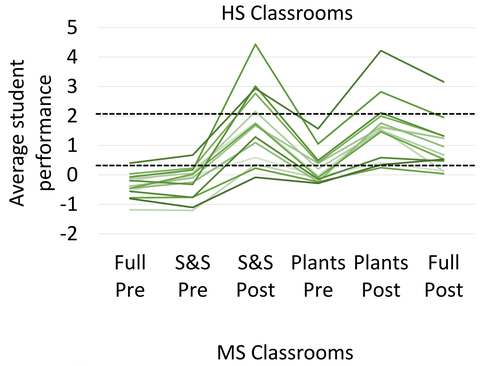




## Scaffolds for principled reasoning: The Three Questions

| Question | Rules to Follow | Evidence to Look For |
|---|---|---|
| **The Movement Question:**<br>Where are atoms moving?<br>Where are atoms moving from?<br>Where are atoms going to? | Atoms last forever in combustion and living systems<br>All materials (solids, liquids, and gases) are made of atoms | When materials change mass, atoms are moving<br>When materials move, atoms are moving |
| **The Carbon Question:**<br>What is happening to carbon atoms?<br>What molecules are carbon atoms in before the process?<br>How are the atoms rearranged into new molecules? | Carbon atoms are bound to other atoms in molecules<br>Atoms can be rearranged to make new molecules | The air has carbon atoms in $CO_2$<br>Organic materials are made of molecules with carbon atoms (e.g., Foods, Fuels, Living and dead plants and animals). |
| **The Energy Question:**<br>What is happening to chemical energy?<br>What forms of energy are involved?<br>How is energy changing from one form to another? | Energy lasts forever in combustion and living systems<br>C-C and C-H bonds have more stored chemical energy than C-O and H-O bonds | We can observe indicators of different forms of energy (e.g., Organic materials with chemical energy, Light, Heat energy, Motion) |

**Analysis and Findings:** We analyzed the Full, S&S and Plants pre and post written assessments from the classrooms of 19 teachers (14 HS, 5 MS) with 17-33 students each. These 19 teachers taught Animals in between S&S and Plants but we have not finished analysis of those assessments. The Full assessment contains items from all six units and was administered before and after all Carbon TIME instruction. Unit assessments are focused on a specific context and were administered immediately before and after each unit. We scored each assessment using previously developed learning progression scoring rubrics and reliability procedures. We used item response theory (IRT) analysis to control for any variation in assessment difficulty.



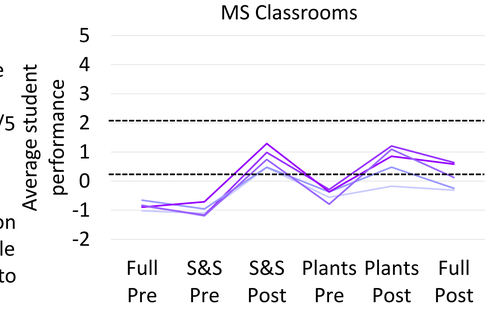




**Figure above:** Data presented are mean ± 95% CI by grade band, HS or MS. **Figures right:** Data presented are means by classroom. S&S and Plants Pre performances have non-overlapping CIs for 6/14 HS classrooms and 2/5 MS classrooms with. Dotted lines (on both graphs) represent the Level 2/3 and Level 3/4 thresholds.

**Conclusions and Implications:** Increased performance on pretests supports our hypothesis that students were able to transfer their principled reasoning from one context to another. However, more detailed analyses show large differences among teachers with significant trends for some teachers but not others. We look forward to analyzing if these trends are associated with differences in principle-based teaching practices (see Poster 6).

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