Components of Productive Level 3 Reasoning

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Levels of Achievement

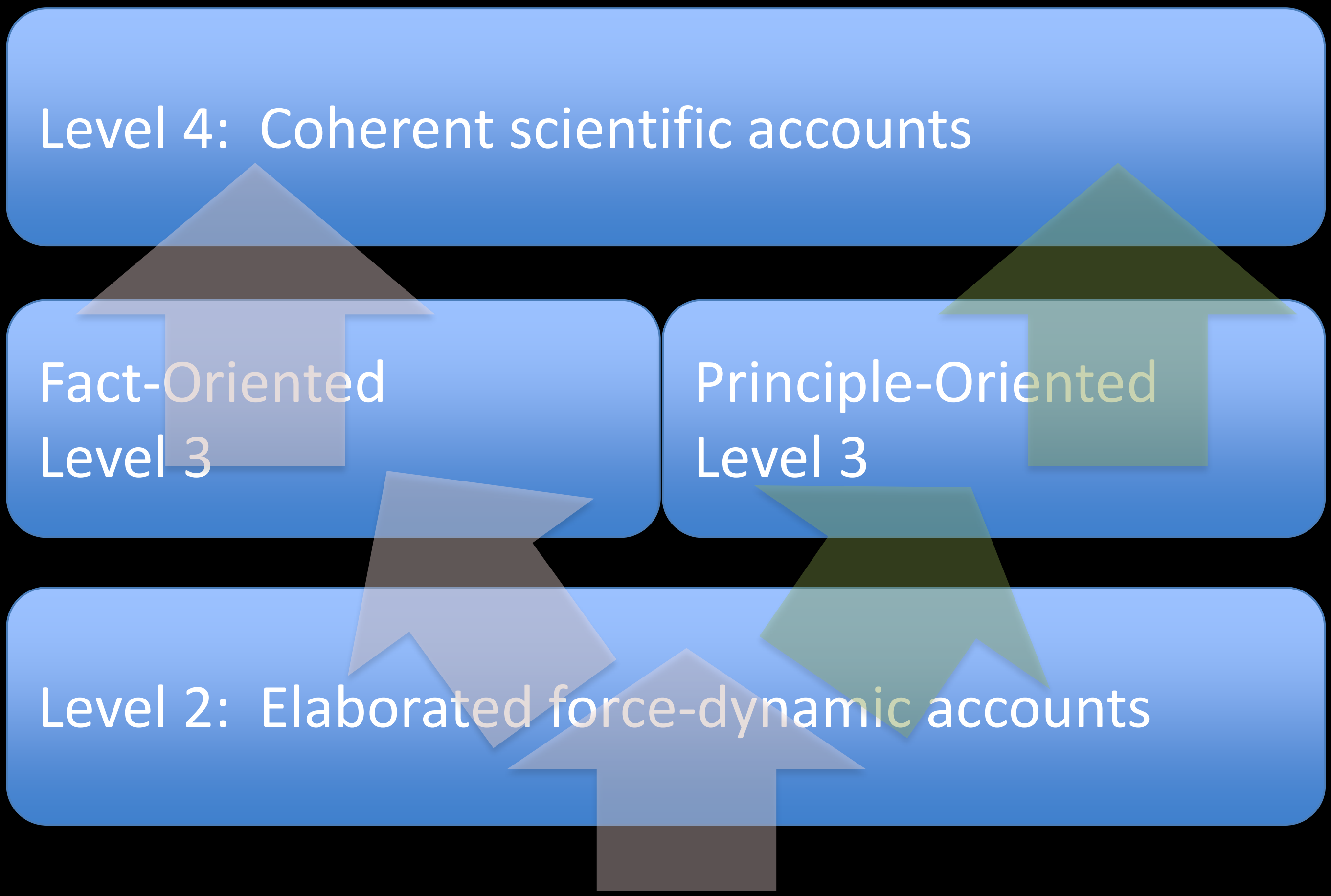
The Problem: We intend Level 3 to be a *transitory* space, but evidence suggests that Level 3 is a *dead end* for many students (grades 6-16).

Level 4: Coherent scientific accounts

Level 3: Incomplete or confused scientific accounts (the "messy middle")

Level 2: Elaborated force-dynamic accounts

The Hypothesis: PL3 students are better positioned to move to Level 4 reasoning than FL3 students.



Progress Variables (2013)

Context-specific knowledge

Orientation towards principles of matter and energy

Precision in use of matter and energy words

Data

- 25 pre/post interviews

Participants

- Secondary (6-12) science students
- Different classes across country

Intervention

- Carbon: Transformations in Matter and Energy (Carbon TIME)
- Three units over 1 year

Interview protocol items

Tree Grow
What does a tree need to grow?

Pound of Wood
How does a tree build biomass?

Card Sort
How are these alike in terms of matter and energy?

Ecosphere
How do matter and energy cycle/flow in an ecosystem?

Leaf Close-up
What is in a leaf at different scales?

Context-specific knowledge: details about photosynthesis

Scale: chemical energy stored in bonds

Precise use of matter and energy words

Principles: matter and energy are separate entities

A

Interviewer: So how does the tree use air to grow?

Student A: **The tree takes in CO_2 and uses it with water for a process called photosynthesis and sunlight triggers this. Basically, what it does is it transforms those items into food for itself with the sunlight going into chemical energy.**

Interviewer: And where does that energy go inside the tree?

Student A: The energy is stored in the cells, well, the tree cells.

Interviewer: Is it still energy when it's stored there?

Student A: Well, **it's in the chemical bonds of the tree** and the chemical bonds of the different parts inside the tree.

Interviewer: Do you think that the tree needs energy?

Student A: **The tree needs the energy from some and to go into the chemical bonds of the glucose.**

Context-specific knowledge: details about photosynthesis

Scale: chemical energy stored in bonds

Principles: matter turns into energy

Imprecision in matter and energy words

B

Interviewer: So where does, say, carbon dioxide go once it's in the leaf cell?
Student B: **It stays next to the chloroplast and then water also gathers near there so when the sun like has its chemical reaction with the chloroplast it makes the CO_2 and then the H_2O and then gets rid of O_2 and then creates glucose.**

Interviewer: Where does that energy go inside the tree?
Student B: It spreads throughout, through the entire tree.
Interviewer: Is it still energy?
Student B: Yes.
Interviewer: Does it change into other things and how?
Student B: …when **it has C-C and C-H bonds it does have a chemical energy**, **but when it changes into glucose** with the chloroplast and the sun chemical change then it goes out through the tree and then it goes through a glucose just **providing nutrients** for the rest of the tree.

Framework (2013)

	Learning Progression Level	Orientation Towards Principles of Matter and Energy	Precision in Matter and Energy Word Use
Principle-Oriented Level 3 (PL3)	PL3 students use confused or incomplete scientific accounts that lack some context-specific knowledge needed to develop a complete account of the phenomenon in question.	PL3 students employ the principles of matter and energy as a reasoning framework to interpret familiar and unfamiliar natural phenomena. They apply these principles *consistently* across contexts.	PL3 students make clear distinctions between matter words (*matter, materials, atoms*, and *molecules*) and energy words (*energy, forms of energy*, and *energy transformation*).
Fact-Oriented Level 3 (FL3)	Like PL3 students, FL3 students also use confused or incomplete accounts that lack some context-specific knowledge needed to develop a complete account of the phenomenon in question.	Unlike PL3 students, FL3 students treat the principles of matter and energy as "facts to be memorized" rather than "rules to be followed" when interpreting natural phenomena. They apply these principles *inconsistently* across contexts.	Unlike PL3 students, FL3 students conflate the meanings between matter words (*matter, materials, atoms*, and *molecules*) and energy words (*energy, forms of energy*, and *energy transformation*).

Revised Framework (2014)

	Context-specific knowledge	Orientation toward principles of matter and energy	Precision in matter and energy word use	Movement between scales
Level 4 (Most Productive)	**Code: L4** - Level 4 students offer accounts of carbon transforming processes that include chemical change to explain context-specific phenomena. The level of context-specific knowledge is fairly consistent with the NGSS performance expectations.	**Code: More Productive** - More productive student accounts employ the principles of conservation of matter and energy as a reasoning framework to interpret familiar and unfamiliar natural phenomena. They apply these principles *consistently* across contexts.	**Code: More Productive** - student accounts make clear distinctions between matter words (*matter, materials, atoms, element, nutrient,* and *molecules*) and energy words (*energy, forms of energy,* and *energy transformation*).	**Code: L4** - students offer accounts of carbon-transforming process at multiple scales, and are able to move from large scale to macroscopic to cellular to atomic-molecular scales to explain carbon-transforming processes.
Level 3 (More Productive)	**Code: L3** - Level 3 students' accounts offer confused or incomplete explanations, and lack some context-specific knowledge needed to develop a complete story of the phenomenon in question.			**Code: More Productive** – students provide accounts at an atomic-molecular scale, with varying degrees of detail of the role of matter and energy at this scale. In terms of matter, they begin to tell a story of atoms breaking apart and recombining to form molecules, but may be missing details about how this happens, or how energy is involved in the chemical change.
Level 3 (Less Productive)		**Code: Less Productive** - Student accounts treat the principles of matter and energy as "facts to be memorized" rather than "rules to be followed" when interpreting natural phenomena. They apply these principles *inconsistently* across contexts to explain phenomena.	**Code: Less Productive** - student accounts conflate the meanings between matter words (*matter, materials, atoms, element, nutrient,* and *molecules*) and energy words (*energy, forms of energy,* and *energy transformation*).	**Code: Less Productive** - student accounts either 1) stay only at the macroscopic scale, or 2) use vocabulary of the atomic-molecular scale, but in ways that ascribe macroscopic properties to atomic-molecular objects (e.g., they may use the names of molecules and atoms, but not as a means of describing chemical change).
Level 2 (Least Productive)	**Code: L2** - Level 2 students' accounts focus on actors, enablers, and natural tendencies of inanimate materials.	**Code: L2** - Level 2 students' accounts may include a re-stating of the principles (e.g., "atoms last forever") but they do not use or apply the concepts matter and energy to explain phenomena. They take a force-dynamic approach to question about matter and energy.		

Student A Pre (L2)

	Context-specific knowledge	Orientation toward principles of matter and energy	Precision in matter and energy word use	Movement between scales
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Student A Post (PL3)

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Student B Pre (L2)

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Student B Post (FL3)

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Implications

- **We know:** two progress variables are progressing before others
- **We don't know:** how to help students progress on *all* variables

Future Directions

- **Research:** new data sets
- **Curriculum and Instruction:** to address *all four* variables
- **Professional Development:** to support teachers in using *all four* variables as indicators of productive progress

Thank you

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