

Components of Productive Level 3 Reasoning

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College of Education Department of Teacher Education The Problem: We intend Level 3 to be a transitory space, but levels of get the Vermeint 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?

Contextspecific 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.

Contextspecific 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 \underline{s}_0 once it's in the leaf collocation 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 CO₂ and then the H₂O and then gets rid of O₂ 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 <i>consistently</i> across contexts.	PL3 students make clear distinctions between matter words (<i>matter</i> , <i>materials</i> , <i>atoms</i> , and <i>molecules</i>) and energy words (<i>energy</i> , <i>forms</i> <i>of energy</i> , and <i>energy</i> <i>transformation</i>).
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 <i>inconsistently</i> across contexts.	Unlike PL3 students, FL3 students conflate the meanings between matter words (<i>matter</i> , <i>materials</i> , <i>atoms</i> , and <i>molecules</i>) and energy words (<i>energy</i> , <i>forms of energy</i> , and <i>energy transformation</i>).



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: 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: L2 - Level 2 students' accounts focus on actors, enablers, and natural tendencies of inanimate materials.	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 <i>consistently</i> 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: 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 <i>inconsistently</i> across contexts to explain phenomena.	Code: Less Productive - student accounts conflate the meanings between matter words (<i>matter, materials,</i>	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
Level 2 (Least Productive)		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.	atoms, element, nutrient, and molecules) and energy words (energy, forms of energy, and energy transformation).	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).

ASSET

Student A Pre (L2)

	Context-specific knowledge	Orientation toward principles of matter and energy	Precision in matter and energy word use	Movement between scales	
Level 4 (Most Productive)	Cale: L4 - Lovel 4 students offer account of carbon transforming processes that include chosmical change to explain context-specific pleasament. The level of context- specific hascoellegie in fainly consistent with the NTSS performance expectations.	Cade Marc Productive - Marc productive date Marc Productive - Marc productive date account and references date account and by the principles of the principles of	Cade 1.4 - students offer accounts of cades trans forming process at undigite scales, and are able to move from large scale to successory in to collular to achimic- undecadar scales to explain cades- transforming processes.		
Level 3 (More Productive)	Calle 1.3 - Level 5 students' accurate offer confused or incomplete explanation, and lack tone context projectic hardwelge needed to develop a complete indep of the phenomenon in question.	Converse to integrate from the first of a first first of a standard by the second standard by the second standard by a second standard	with (near), means and come, downer, means and medaculae) and energy worth (concept, frame, of energy, and energy is confermation)	Code: Marce Productive — students provide account at an atomic subcentar node, with varying degrams of deal of the node of matter and energy at this node. In forms of analytic, they happed hold at atomy of a constart, they happed hold at atomy of another the stranges of the student nodes they hyperterpies in single deals show how the hyperterpies in subced in the chemical change.	
Level 3 (Less Productive)		Order Leen Productive -Student accounts from the principles of matter and energy at "Each to be municated" rather than "take to be follower?" when interpreting satural phenomena. They apply these principles increasionable account contexts to explain phenomena.	Cade: Less Productine- stations' account could be worth (unstre, material, cities, advance, material, cities, advance, material, advance), and concept worth (anogge, form of anogge, adv anogge to could be advance).	Chelse Loss Pendersing - disider account offer 10 day only at the macroscopic reals, or 20 per vectorized provides an endocuter acidy, but in ways that another macroscopic properties to data macroscopic data and data provides and address and advant, but out an another of describing channel (change).	
Level 2 (Least Productive)	Calle 1.2 - Level 2 statients' accounts form on actors, embles, and satural tendencies of insuinate anticide.	Order L2 - Level 2 strelests ¹ accounts may include a re-stating of the principles (e.g., "atom Inf Genero") but fleryd on others or apply the concepts matter and energy to explain phenomena. They later a force-dynamic approach to specifics about matter and energy.			

Student A Post (PL3)

		Context-specific knowledge	Orientation toward principles of matter and energy	Precision in matter and energy word use	Movement between scales
-	Level 4 (Most Productive)	Carlet L4 - Level 4 andenin offer account of carbon transforming processes that include chemical change to captain context-specific phenomen. The level of context- specific havordege in fairly consistent with the NTSS performance expectation.	Cale and the set of the principles of the set of makes and energy as a reconstruc- nel to interpret families and a calm like a phenomena. They apply these principles minimum areas contexts.	Cale: More Pro- aided acce Pro- diate accession between matter worth (matter matterial, et an, denner, material, et an, denner, material, et an, denner, material, et ange, form of energy, and mangg it confirmation)	Code 1.4 - indicato offer accounts of carlos fram Similar process at undirate radies, and are able to move from large scale to manoscopic to collast to status- understar scales to captain carbon- randoming processes.
	Level 3 (More Productive)	Caller 1.3 Lower accessing of the new code and the complete accessing of the complete accessing			Coller the state of the state o
	Level 3 (Less Productive)		Codes Leen Productive -Student accounts (not the principles of multier and energy at "Each to be municitys") rather than "take to be follower!" when interpreting student pleasaness. They apply these principles incornationally account contexts to explain pleasaness.	Calles Loss Productive- nucleat accounts confinite the maxing's between author worth (matter, matteriate,	Calle Less Productive - student account either 1) stay only at the macroacque acate, or 2) me vocabulary of the atomic-ordencedur acate, but in ways that a mothe macroacque
	Level 2 (Least Productive)	Calle L2 - Level 2 students' accords focus on actors, emblers, and actoral tendencies of insuinate materials.	Code: L2 - Level 2 stylests' accorais may include a re-stating of the principles (eg., "atom Inf forever") the floy do notice or apply the concepts matter and energy to captain phenomena. They there a fore-objamic approach to question about matter and energy.	etcom, element, nationat, and medecules) and energy work (energy, from Grossy, and energy transformation)	properties to attainic molecular objects (e.g., they may use the name of molecular and atom, bottoch a name of describing chemical change).

Student B Pre (L2)

	Context-specific knowledge	Orientation toward principles of matter and energy	Precision in matter and energy word use	Movement between scales	
Level 4 (Most Productive)	Cale: L4 - Level 4 indexis offir account of carbon transforming processes that include chemical change to caption context-specific phenomen. The level of context- specific have/edge in faily consistent with the NTSS performance expectation.	Chain Marce Productive - Marc productive elected accounts employ the principles of conservation of matter and empty an arcmaning framework to integrate familiar and tradinitiar natural phenomena. They apply these principles constitutedy access contexts.	Casle: Mare Productive- student accounts make clear distinctions before a matter	Code L4 - statesti offer account of cates transforming process at undigite notes, and are able to move from large code to successorie to collutar to admini- understar acides to cogstain cabra- transforming processes.	
Level 3 (More Productive)	Carles 1.3 - Loved 9 students' account offer confused or incomplete explanation, and lack some context application of the student medial to develop a complete indep of the planetuments in question.		with (near), many and an of one, observations, making and medication) and energy worth (energy, frame, of energy, and many is confermation)	Code: Marce Productive — stationic provide account at an atomic subcolar acide, with varying degrams of detail of the sole of mather and energy at this rate. In terms of mather, they high to lead a stays of atomic molecules, but mary be mining details about here of the largence, or here energy is involved in the chemical change.	
Level 3 (Less Productive)		Order: Leex Productive - Student accounts treat the principles of matter and energy at "Each to be measured" rather than "take to be follower?" when integrating natural phenomena. They apply these principles increasively account contexts to explain phenomena.	Code: Less Productive- nholest accounts conflate the meanings between matter worth (matter, matterials,	Code: Less Productive - student account editor 1) stay only at the macroscopic scale, or (2) me vocabulary of the atomic-succeeding scale, but in ways that a rothe macroscopic	
Level 2 (Least Productive)	Calle: L2 - Level 2 students' accounds form on actors, emblers, and natural tendencies of imminute materials.	Coder L2 - Level 2 atrictus' accessite may include a re-stating of the principles (e.g., "atom bat Govers") but fley do not use or apply the concepts mather and encey to coghin phenomena. They take a force-dynamic approach to question abcommatter and energy.	eterne, element, ratrient, and melecules) and energy worth (energy, forms of energy, and energy to englarmation)	properties to attain employable actual objects (e.g., they may not the names of molecules and atom, bott scare a norm of describing chemical change).	

Student B Post (FL3) Context-specific Orientation toward principles Precision in Movement between scales knowledge of matter and energy matter and energy word use Calles L4 - Level 4 moderate office n of carbon transform Code L4 - students offer accounts Level 4 uer flat include chemica ing precen at unlifp scales, and are able to move from large scale (Most mena. The level of centeral Productive) idecitar i calei to explain carb o Cale: Mare Productiv Level 3 (More Productive) Level 3 (Less **Productive** Cool s L2 - Level 2 mindemin' acco ayuse the names of m Level 2 Cale: L2 - Level 2 students include a re-stating of the principles (e.g., *.t forever") but they do not use or apply on, botnet as a means of i accounts form on actors, enical change). (Least atter and energy to explain a. They take a force-dynamic Productive) ic annoact

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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