Student Interview Answers: Probes about individual events

Cards showing events:
- Corn plants growing in the sunlight (photosynthesis)
- A child running (cellular respiration)
- A car climbing a hill (combustion)
- A tree decaying (decomposition, cellular respiration)

Ask questions about each card:

Structure: Molecular composition of the organic substances – To what extent, can the student identify organic carbon?
Tracing matter: Chemical Reaction – To what extent, can the student identify *gas* as reactants/products in the reaction and/or identify carbon transformation?
Tracing energy: Energy sources; transformation; dissipation – heat)

Corn plants growing in the sunlight

Structure:
- Can you identify any of the substances or materials that are changing during this event? What are they?
- Do any of the substances you named contain carbon? What are they?

Process:
- Will this process change the weight of the corn plants?
- What happens to the materials you identified during this event? How do they change?
- Does this event change the air? How? What is in the air that does not change?
- Does this event produce any new materials? What are they? Where do they come from? How are they formed?
- How are the atoms and molecules changing in the materials that you identified?

Energy:
- Does this event involve energy?
- Can you identify an energy source for this event? What is it?
- Why is it important for the corns to have sunlight?
- What happens to the energy from sunlight?
- Where does the energy go when the event ends? Can the energy be used again? Why or why not?

A child running

Structure:
- Can you identify any of the substances or materials that are changing during this event? What are they?
- Do any of the substances you named contain carbon? What are they?

Process:
- Will this process change the weight of the child?
- What happens to the materials you identified during this event? How do they change?
- Does this event change the air? How? What is in the air that does not change?
- Does this event produce any new materials? What are they? Where do they come from? How are they formed?

- How are the atoms and molecules changing in the materials that you identified?

Energy:

- Does this event involve energy?
- Can you identify an energy source for this event? What is it?
- Why is it important for the runner to eat food?
- What happens to the energy from runner?
- Where does the energy go when the event ends? Can the energy be used again? Why or why not?

A car climbing a hill

Structure:

- Can you identify any of the substances or materials that are changing during this event? What are they?
- Do any of the substances you named contain carbon? What are they?

Process:

- Will this process change the weight of the car?
- What happens to the materials you identified during this event? How do they change?
- Does this event change the air? How? What is in the air that does not change?
- Does this event produce any new materials? What are they? Where do they come from? How are they formed?
- How are the atoms and molecules changing in the materials that you identified?

Energy:

- Does this event involve energy?
- Can you identify an energy source for this event? What is it?
- Why is it important for the car to have gasoline?
- What happens to the energy of the gasoline?
- Where does the energy go when the car stops? Can the energy be used again? Why or why not?

A tree decaying

Structure:

- Can you identify any of the substances or materials that are changing during this event? What are they?
- Do any of the substances you named contain carbon? What are they?

Process:

- Will this process change the weight of the tree?
- What happens to the materials you identified during this event? How do they change?
- Does this event change the air? How? What is in the air that does not change?
- Does this event produce any new materials? What are they? Where do they come from? How are they formed?
- How are the atoms and molecules changing in the materials that you identified?

Energy:

- Does this event involve energy?
- Do you think the dead tree contains energy?
- What happens to the energy of the dead tree?
- Can the energy be used again? Why or why not?

	Plants growing	Child running	Car climbing hill	Tree decaying
Student 1	The sunlight is energy. The energy is used and transformed. The CO_2 and water are used to make glucose molecules. Use glucoses to grow. They use energy in the glucose like ATP to grow. The light energy goes into the bonds of glucose molecules.	He takes in oxygen and lets out CO_2. O_2 goes into cells for cellular respiration and produces CO_2. I guess you are losing carbon, so a little bit. C in CO_2 comes from glucose. The glucose molecules are broken and energy released. Some energy is released as heat, some as ATP.	I don't know the chemical formula of gasoline. But, I think gasoline is transformed. Its bonds are broken and release energy. The gasoline itself may transformed into other substances. It probably needs oxygen to burn. The gasoline has potential energy. It transforms into kinetic energy. "Is there any other forms of energy involved?" I don't know whether there is any other form of energy. "When car stops, where does the potential energy of gasoline go?" - I have no idea. (Finally,) - There may be heat. Mostly heat.	It is cellular respiration. The carbon transforms into CO_2 and H_2O.

	Corn plants growing	Child running	Car climbing hill	Tree decaying
Student 2	Corn changes CO_2 in its cells plus photosynthesis (from leaves) to produce glucose and O_2 Glucose contains CO_2 and then releasing it in the air Corn plants will gain weight because the glucose is in the cells It does change the air because taking CO_2 from the air and producing other gases No new materials produced (just recycling); carbon is breaking down to produce glucose (different bonds & extra molecules) It involves energy called ATP; energy source is sunlight; energy cannot be used	The child is breathing O_2 & glucose and exhaling CO_2 running cellular respiration Materials changed and contained carbon Losing weight because of exercising: consuming glucose Changing the air because CO_2 came out from the child Cellular respiration is making atoms and molecules different in the cells Energy came from food; energy goes to the cells of the body when the event ends; make body structure; energy can be used again	Carbon from pipe of the car using gasoline It does not change the weight; carbon dioxide from the gasoline changes the air Molecules and atoms convert by the heat to produce carbon dioxide The energy source is gasoline; energy goes into the air when the car stops and it cannot be used again	The tree decaying is tree matters from decomposing. The carbon dioxide goes in to the air to help other molecules change The tree is losing weight because the materials are different; the decomposing becomes many the tree smaller (physical event); the air is changing because carbon dioxide left It does not produce new materials, just left out some materials ; atoms and molecules just convert to different forms to become oxygen like carbon dioxide transforming in the air back and forth The event does not involve energy; it is not using energy because the tree is dead; the energy cannot be used again

	Corn plants growing	Child running	Car climbing hill	Tree decaying
Student 3	Sunlight makes it grow so that we can eat; leaves and stalks contain carbon… It gains weight because it has more water into body; I don't know if this event change the air; water is the one that does not change; Water, nutrition, and carbon dioxide; they are from the air; I don't know how they are formed; I don't know how the atoms and molecules are changing… It involves energy because it gave plants to grow; the energy source is from sunlight; the energy goes into ground and it can be used again because it transformed into ground so that trees can grow...	He is losing heat because he is sweating when running *"Can you identify any of the substances or materials that are changing during this event?"* Water & carbon dioxide *"Will this process change the weight of the child?"* No *"What happens to the materials you identified during this event?"* They just come out *"Does this event change the air?"* No *"Does this event produce any new materials?"* No *"How are the atoms and molecules changing in the materials that you identified?"* I don't know The energy source is the food he eats. The food can keeps him running. The food breaks down and gives energy for him to run. Energy will be lost into H_2O & carbon so it cannot be used again	The air, the carbon dioxide, is changing during this event It produced carbon, water, oxygen, and hydrogen *"Will this process change the weight of the child?"* No *"What happens to the materials you identified during this event?"* They go into the air. Carbon into the air may pollute the air The new material is carbon dioxide. It comes from the car because of burning gas *"How are the atoms and molecules changing in the materials that you identified?"* Doing arrange, in the air, I guess. The energy source is the engine *"Why is it important for the car to have gasoline?"* Because it can move	Carbon, oxygen, and water are the substances that are changing during this event This process change the weight of the tree because it loses mass This event does not change the air This event does not produce any new materials The tree is breaking down because it is dying This event does not involve energy

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Student 4	Water, sunlight, and nutrients from soil are necessary. Plants are making themselves food so the weight changes. Don't know how the materials change. The nutrients go up the stems and the sunlight goes into the leaves and that's where they make food. They let out oxygen and take in CO_2. Doesn't know what does not change. New materials: corns, oxygen, food for bugs. I don't know how they come from. Maybe minerals and nutrients are changing but don't know. Air and maybe nutrients have carbon in it but don't know. Sunlight is the energy source. Energy goes into the leaves and I don't know.	Kid will take in oxygen and take out heat and breathe out CO_2. Kid will lose weight if he runs a lot. *New materials?* I don't know. If you breathe out CO_2 then there's carbon in the body but I don't know. Energy source: muscles. Food and water give you energy. Energy: you get tired when you run. I don't know.	Air will change around the car. Car is polluting the air. Bad gases. Car needs gasoline and power. The weight does not change. The gasoline goes on and out into the air and it stays there. It pollutes air but I don't know. It does not change the air. Air will be changing, fresh air if you don't have any cars, cars let out the gasoline in the air and it pollutes but I don't know how it pollutes. Air and gasoline contains carbon. Motor in the car, gasoline are the energy source. Don't know what happens to the energy. The energy left over in the car, you can use that but the energy that you used you cannot use it again.	Tree dies and trees stop letting out oxygen. You need a lot of water, sunlight, nutrients in sunlight. Less weight because it falls apart and goes away. Don't know how it changes. Trees are not letting out oxygen anymore. New materials: no. Substances and materials: wood, tree trunk are changing-decaying. Doesn't involve energy. Dead tree does not have energy. Don't know what happen to the energy. Energy disappears. No energy anymore.

	Corn plants growing	Child running	Car climbing hill	Tree decaying
Student 5	Corn plants in the sunlight they can get too much heat and die? Water, sunlight and dirt are necessary. Weight does not change. Water dries up but glaciers are melting so it will balance out. Plants growing creates more air: oxygen. New materials: radiation. Corn gets drier. Dirt will be drier, less moisture, Water will be less. The plant does not contain carbon it just produces it, Water has it and sunlight has it. Energy source: sun. Energy from sunlight goes inside the corn. When it hits the dirt it is wasted.	His heart is pumping harder, breathing faster, everything gets faster, gets exhausted. Food, water, sleep and shoes are necessary. Using his energy storage, he loses weight. Water is sweated out and stays in the body. The food is mostly wasted. Pooping, and farting changes the air. New material: sweat. Made of water, evaporating from the skin. Don't know things that are changing. Energy source: food. Important because nutrients, calcium, protein are needed for certain parts of body. Energy is being used up, burned up.	Car exhausts. Gasoline is necessary. The gasoline is burned up slowly. It's used for the car to give energy and the bi-product, CO_2, of the gases goes into the air. New materials: gas. Gasoline is transferred throughout the car but don't know exactly. Air is changing. Air contains carbon. Energy source: gasoline.	Wood changes. The tree could fall and kill stuff. Tree needs to grow first to decay. The weight decreases because its parts are falling off. It is losing energy so it can't support itself anymore and falls apart. It's changing the air because it is not producing CO_2 anymore. Wood, air are changing. Both contain carbon. The dead tree has the energy. Nothing happens to the energy of the dead tree. Don't know if the energy can be used again.

Notes about student levels and patterns in their responses

Student 1 – Level 5

Qualitative model-based reasoning

Separate accounting for matter and energy

Student 2 – Level 4-5

Qualitative model-based reasoning about matter

School science narratives about energy: Confusion about forms of energy (especially chemical potential energy) prevents meaningful use of conservation of energy for tracing energy

Student 3 – Level 4

School science narratives: processes changing matter and energy

Confusion about substances and forms of energy prevents meaningful use of conservation laws to trace matter or energy

Student 4 – Level 3-4

School science narratives about matter: Stories of events use mostly common-language names for materials without meaningful accounting for how matter is conserved or transformed

Gas exchange (O_2 and CO_2) is separate from accounts of what happens to food, fuel, and energy

Energy is used in ways consistent with common cultural models (energy in sunlight, muscles, motor of car, not in decaying tree), but not in ways that give it any power as an explanatory concept

Student 5 – Level 2-3

Descriptions focus on observable macroscopic events and use mostly informal names for materials

No clear distinction among materials, conditions, and forms of energy in accounts of events

Occasional reference to internal mechanisms, components of materials