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Initials

Environmental Literacy Carbon Assessment: --- High School Level, Form C ---

Science is easier to understand if you can make connections between what you know now and the new ideas that you are studying. This is a test that will help us to understand what you know now. Please answer these questions as carefully and completely as you can. If you are not sure of the answer, please write about any thoughts that you have. If you can help us to understand how you think about these questions, then we can do a better job of explaining science in ways that make sense to you.

Please put your initials (not your full name) in the boxes

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First Middle Last

Date _____

Class _____ Teacher _____

1. Your body needs heat to keep its normal temperature. Where does the heat mainly come from? Please choose ONE answer that you think is best.

- The heat mainly comes from sunlight.
- The heat mainly comes from the clothes you are wearing.
- The heat mainly comes from the foods you eat.
- When people exercise, their bodies create heat.

Please explain why you think that the answer you chose is better than the others. (If you think some of the other answers are also partially right, please explain that, too.)

Purpose: *The purpose of this item is to understand how students reason about body heat. While the scientific reasoning includes identifying cellular respiration as the process releasing heat for humans to maintain body temperature, students may construct their explanations based on their daily experiences of feeling warm in sunshine or when wearing heavy clothes.*

Sophisticated Answer: *A sophisticated explanation identifies organic substances of foods as energy source to keep body temperature and describes energy degradation (heat dissipation) in cellular respiration – In cellular respiration, all the chemical potential energy will finally dissipates as heat. The heat released from cellular respiration is used to keep the body temperature. We expect that most students who understand this explanation will answer “c,” although choice “a” could also be justified with a good explanation.*

Naïve Answers: *Based on their daily experience, students tend to think that heat comes from environment such as sunlight and air. Some students tend to think that heat is produced when people exercise. Or, younger children may think that heat comes from wearing heavy clothes.*

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2. A scientist made three groups A, B, and C, like the following:

- A. Sugar, meat, bread
- B. Water, limestone, sand
- C. Coal, gasoline, wood

a) What makes each group go together?

Purpose: *The purpose of this item is to know whether students can identify foods and fuels as energy-rich materials.*

Sophisticated Answer: *The sophisticated answer recognizes a) that group A are foods, B are materials do not contain energy, and C are fuels; b) that group A are energy-rich materials, but water is not energy-rich, so water does not go with sugar and meat. c) that A and C are both energy-rich materials – they contain high-energy bonds: C-C and C-H.*

Naïve Answer: *Students may use “function of materials” for reasoning (i.e., people use different materials for different purposes.) and may not identify the similarity between foods and fuels.*

b) Why would water go with limestone and sand rather than sugar and meat?

See above

c) Does it seem to you that groups A and C have anything in common? Yes / No

Please explain your answer. If no, explain why you think these groups are different. If yes, explain what the groups have in common.

See above

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3. When you are riding in a car, the car burns gasoline to make it run. Eventually the gasoline tank becomes empty.

a) What happened to the **matter** the gasoline was made of?

Purpose: The purpose of this question is to know how students reason the event of car consuming gasoline for moving and whether they can identify matter transformation in combustion of gasoline.

Sophisticated Answer: Sophisticated answer explains matter transformation in combustion of gasoline – the gasoline reacts with oxygen and produce carbon dioxide and water. So, the gasoline becomes gases and is released into the air after the reaction.

Naïve Answers: Based on their experience with car running, many students understand that gasoline is used to provide energy for car running, but they usually do not understand combustion in terms of chemical reaction. They may think that gasoline becomes energy to make the car run.

b) When the gasoline tank becomes empty and the car stops, what happens to the **energy** of gasoline? Where does it go? Do you think the energy of gasoline still exists somewhere? Please explain your answers.

Purpose: The purpose of this question is to know how students reason the event of car consuming gasoline for moving and whether they can use energy degradation in combustion for reasoning.

Sophisticated Answer: Sophisticated answer explains energy degradation in combustion – in combustion, a small part of the chemical potential energy of gasoline transforms into kinetic energy for car running and most chemical potential energy of gasoline dissipates as heat into the environment. The kinetic energy of car moving will finally transforms into heat into the environment. So, all the energy of gasoline finally dissipates into the environment as heat.

Naïve Answers: Based on their experience with car running, many students understand that gasoline is used to provide energy for car running. But, they usually do not identify combustion as the process underlying the event or do not understand energy transformation or degradation in combustion. As the result, they tend to think that energy of gasoline is used up to make the car run. Or, they may also think that energy always goes with matter and since gasoline becomes exhaust, energy must exits from the tailpipe with exhaust. Due to traditional ways of teaching energy and “work” in physics, we also expect some students think that energy of gasoline becomes “work” of car running. This idea does not recognize “work” as a process variable and has no meaning when the process ends.

c) Do cars need air in order to run? Yes / No

Please explain your answer.

Purpose: The purpose of this question is to know whether students can identify all the reactants in combustion of gasoline.

Sophisticated Answer: Sophisticated answer describes matter transformation in combustion of gasoline and recognizes oxygen as one reactant – the gasoline reacts with oxygen and produce carbon dioxide and water. So, the car needs oxygen in the air to run.

Naïve Answers: Based on their experience with car running, many students understand

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that gasoline is used to provide energy for car running, but they usually do not understand combustion in terms of chemical reaction. They may not recognize that oxygen is one of the reactants in combustion. They may think that gasoline becomes energy to make the car run.

4. A tropical rainforest is an example of an ecosystem. Which of the following statements about matter and energy in a tropical rainforest is the most accurate? Please choose ONE answer that you think is best.
- Energy is recycled, but matter is not recycled.
 - Matter is recycled, but energy is not recycled.
 - Both matter and energy are recycled.
 - Both matter and energy are not recycled.

Please explain why you think that the answer you chose is better than the others. (If you think that some of the other answers are partially right, please explain that, too.)

Purpose: *The purpose is to understand students' idea about energy degradation in food chain. There is always energy lost into environment as heat, when energy flow from one organism to another.*

Sophisticated Answers: *The correct answer is b. Sophisticated explanation should include the following two parts: 1) Matter recycling – Matter transforms and recycles among organisms and atmosphere: Although matter transforms between organic and inorganic forms, it is always useful for certain organisms. In the ecosystem, the total amount of matter conserves and will not be lost. 2) Energy transforms and degrades among organisms and physical environment: Organisms transform chemical energy of organic materials to other forms of energy for their metabolic needs. This part of energy will ultimately dissipate into environment as heat and thus becomes unavailable for any other organisms. Although the products of decomposition – carbon dioxide and water, can be used by plants, the energy of dead organic body will be released as heat after decomposition and thus cannot be used by plants or any other organisms.*

Naïve Answers: *Energy recycles, because energy cannot be destroyed. Or, energy recycles, because it flows in the food chain from plants, to animals, to decomposers and then goes to the soil and absorbed by plants again.*

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5. A burning candle is put into an air-tight container. After some time, the candle stops burning.



a) How does the air change while the candle is burning?

Purpose: The purpose is to understand students' idea about matter transformation in burning.

Sophisticated Answers: The sophisticated answer explains the matter transformation in burning – the wax of the candle reacts with oxygen in the air and produces carbon dioxide and water. Thus, the air is having less oxygen and more carbon dioxide and water vapor.

Naïve Answers: Students usually cannot identify all the reactants and products of combustion.

b) As the candle burns, it gets shorter in height. What happens to the matter in the wax after it melts and is burned? Please explain your answer.

Purpose: The purpose is to understand students' idea about matter transformation in burning.

Sophisticated Answers: The sophisticated answer explains the matter transformation in burning – the wax of the candle reacts with oxygen in the air and produces carbon dioxide and water. Thus, the air is having less oxygen and more carbon dioxide and water vapor.

Naïve Answers: Students usually do not understand burning candle as a chemical reaction and may think it as physical change such as melting or evaporation.

c) Where does the energy for burning come from? Please explain your answer.

Purpose: The purpose is to understand students' idea about energy transformation in burning.

Sophisticated Answers: The sophisticated answer explains the energy transformation in burning – when the candle is burning, the chemical potential energy of the wax is transformed into heat and light energy releasing into the environment. So, the energy of burning comes from the chemical potential energy of wax. Although, part of energy of burning also comes from energy of oxygen, we do not expect students to mention that, since our research focuses on chemical potential energy of organic substances.

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Naïve Answers: Students may think that burning create energy or comes form the energy used to initiate the burning.

6. Compared with incandescent light bulbs, fluorescent light bulbs have higher energy efficiency and can save 66% to 75% of the energy that the bulb uses. Do you think that using fluorescent light bulbs instead of incandescent light bulbs can contribute to slowing global warming? Yes / No



Incandescent light bulb



Fluorescent light bulb

Purpose: The purpose of this item is to understand whether students recognize that energy consumption contributes to global warming.

Sophisticated Answer: Sophisticated explanation recognizes that most electricity comes from burning fossil fuels, which emits large amount of carbon dioxide into the atmosphere and further causing global warming. Using fluorescent light bulb consumes less electricity and thus slows global warming.

Naïve Answers: Students may not recognize that energy consumption is related to burning fossil fuels.

7. Where does your body store energy for later use? Please choose the ONE answer that you think is best.

- Energy is stored in the form of matter.
- Energy is stored in the form of chemical energy.
- Energy is stored in the cell, but is separated from the matter of the cell.
- Energy is stored among the cells.
- The body does not store energy. Energy is produced when you need it.
- Other _____

Please explain why you think that the answer you chose is better than the others. (If you think some of the other answers are also partially correct, please explain that, too.)

Purpose: The purpose of this item is to investigate how students understand energy stored in animal/human body.

Sophisticated Answer: The correct answer is b. A sophisticated explanation recognizes that energy exists in animal/human body in the form of chemical potential energy and that chemical potential energy is stored in organic materials such as fat (lipids) and carbohydrates. Some students may mention protein as the material storing

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energy. This is also correct response, although energy stored in protein will be used only when carbon-containing organic materials are not enough to provide energy. So, if students only mention protein but not mention any carbon-containing organic substances, their understanding is not sophisticated enough.

Naïve Answers:

8. A tree falls in the forest. After many years, the tree will appear as a long, soft lump barely distinguishable from the surrounding forest floor.



a. The mass of the lump on the floor is less than the mass of the original tree. Where do you think that the mass that is no longer in the lump has gone? In what form?

Purpose: *The purpose of this question is to understand students' ideas about how matter changes in the event of decay and whether they identify the process of cellular respiration (decomposition) and trace matter in that process.*

Sophisticated answers: *A sophisticated answer identifies the process of decomposition – bacteria, termites, and fungi decompose the organic compound of the dead tree. The organic compound of the dead tree is first broken into simpler forms. Then, in the process of cellular respiration, the matter further reacts with oxygen and produce carbon dioxide and water. So, most mass of the dead tree is released as gases into the environment.*

Naïve answers: *Students may use the word “decomposition” in their explanation, but many of them cannot successfully trace matter in decomposition – they usually do not recognize that most mass of the tree becomes gases, carbon dioxide and water vapor. An example of naïve answers is that decomposers eat up the dead tree. Students may also think that the mass of the tree simply disappeared, or was absorbed directly by surrounding plants.*

b. What caused the changes in the wood? How did those changes happen? Give as many details as you can about what is breaking the wood down, and how.

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Purpose: The purpose of this question is to assess whether students identify decomposers in this event.

Sophisticated answers: Sophisticated answers should indicate that decomposers such as termites, bacteria and fungi decompose the remains of the tree: The organic compound of the dead tree is first broken into simpler forms. Then, in the process of cellular respiration, the matter further reacts with oxygen and produce carbon dioxide and water.

Naïve answers: Students often possess a limited understanding of the role of decomposers in an ecosystem. They may assume that the tree decomposed naturally or was eaten up by decomposers. It is also possible that some students may attribute decomposition to non-biological processes, such as rain or heat.

c. Do you think that the process of decay involves energy? How?

Purpose: The purpose of this item is to uncover how students reason decay and whether they can identify the process of cellular respiration (decomposition) and trace energy in this process.

Sophisticated answers: A sophisticated explanation describes energy transformation and degradation in cellular respiration (decomposition) – in cellular respiration, bacteria use the energy of the dead tree for metabolism and heat is released at the same time. Finally the energy used for metabolism will also dissipate into environment in the form of heat.

Naïve answers: Students tend to reason based on their living experience with decay. They usually do not identify the process of cellular respiration underlying the event of decay. They tend to think that the energy always goes with matter: The matter of the dead tree becomes soil when the tree is decaying, so the energy of the dead tree must also go into the soil. They may also think that later other plants will get this part of energy by their roots.

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9. Grandma Johnson had very sentimental feelings toward Johnson Canyon, Utah, where she and her late husband had honeymooned long ago. Because of these feelings, when she died she requested to be buried under a creosote bush in the canyon. Describe below the path of a carbon atom from Grandma Johnson's remains, to inside the leg muscle of a coyote. **NOTE:** The coyote does not dig up and consume any part of Grandma Johnson's remains.



Purpose: The purpose of this question is to understand students' ideas about how carbon transforms between organic and inorganic forms in ecosystem and atmosphere through decomposition, photosynthesis, and digestion.

Sophisticated answers: Sophisticated answers should include how carbon transforms between organic and inorganic forms through decomposition, photosynthesis, and digestion. It should include: 1) In the process of decomposition, the organic carbon in Grandma Johnson's remains transforms into inorganic carbon in carbon dioxide. 2) In the process of photosynthesis, the creosote bush makes sugar molecules from carbon dioxide and water and then synthesizes sugar molecules to build its body structure. In this process, the inorganic carbon in atmosphere transforms into organic carbon in creosote bush or another plant. 3) When a herbivore such as a rabbit ate the plant, the organic compounds of creosote bush were digested and synthesized to build the rabbit's body structure. 4) When the coyote ate the rabbit, organic compounds in the rabbit were digested and reassembled into organic molecules in the coyote, including those in the coyote's leg muscle.

Naïve answers: Students that possess a limited understanding of the cycling of carbon in an ecosystem may leave out one or more steps in the expected answer. For example, they may omit the role of decomposers in breaking down the complex carbon molecules in the remains of Grandma Johnson. Students who make this error may assume that the creosote bush is able to absorb carbon from her remains directly and incorporate them in its tissues. Students may also assume that the carbon in her remains would enter the atmosphere directly without the intermediary step of bacterial decomposition. Naïve answers may also indicate that students do not understand that bacterial decomposition uses the process of cellular respiration to break down complex organic molecules and release carbon dioxide. Furthermore, students may not understand that plants absorb carbon dioxide during the process of photosynthesis.

An example of naïve answer is:

The creosote bush absorbed the Grandma remains, so the carbon in Grandma's remains moved to the bush. When a herbivore eats the bush, the carbon in bush then moves to the herbivore, and from there to the coyote's leg muscle.

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10. Do you think that a muscle cell is a mixture of different substances? YES / NO

Please explain your ideas about what makes up a muscle cell.

Purpose: *The purpose of this item is to know whether and how students understand the atomic/molecular structure of cells.*

Sophisticated Answer: *The correct response is yes. Sophisticated answer explains that cell is a mixture of various substances and should identify some major substances including organic carbon-containing substances (such as lipids or carbohydrates) and water.*

Naïve Answers: *Students usually do not recognize that cell has atomic/molecular structure and .*

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11. An apple is eaten by a child and digested in his body.

a) What happens to the substances in the apple when it is digested?

Purpose: The purpose of this item is to know how students understand digestion in human body.

Sophisticated Answer: The sophisticated answer recognizes that digestion happens in the child's body after he eats the apple. The apple is digested and its organic substances, most of which is sugar, are broken down into simpler molecules such as glucose.

Naïve Answers: Students may not have limited knowledge on digestion and thus do not recognize that the substances of apple is broken down into simpler molecules by enzyme.

b) How can the child's body use the substances in the apple to help his feet grow?

Purpose: The purpose of this item is to know how students understand biosynthesis in human body.

Sophisticated Answer: The sophisticated answer recognizes that after digestion, the process of biosynthesis happens to synthesize substances from food into human body structure – after digestion, the simpler organic molecules are reassembled into more complex molecules such as fat molecules.

Naïve Answers: Students usually do not recognize biosynthesis or cannot identify it from digestion. They tend to think that things the child eats will become part of the child's body, but they may not know why and may not identify the matter transformation in the processes of digestion and biosynthesis.

12. Explain how are the following living things connected with each other:

- (a) Grass.
- (b) Cows.
- (c) Human beings.
- (d) Decomposing bacteria.

Please tell as much as you can about matter and energy in your explanation.

Purpose: The purpose of this item is to know students' ideas about matter transformation in food chain.

Sophisticated Answer: The sophisticated answer recognizes matter transformation in food chain: the grass produce organic matter through photosynthesis. The organic matter is digested and synthesized into the cows' body when the cows eat plants. When humans eat beef, the organic matter of beef is digested and synthesized into human body structure. After plants, cows, and humans die, the organic matter of their dead body is used by decomposing bacteria through decomposition – the organic matter is first broken down into simpler molecules and then these molecules react with oxygen and produce carbon dioxide and water (cellular respiration); the energy released in cellular respiration is used by decomposition bacteria for body function and activities.

Naïve Answers: Students usually understand food chain in terms of eating relationship, but usually do not recognize that matter undergoes different chemical reactions in food chain. They also tend to hold intuitive ideas about decomposition and think

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decomposition is the same as the process of digestion and biosynthesis.

13. Three batches of radish seeds, each with a starting weight of 1.5g (dry) were placed in Petri dishes and provided only with light or water or both, as shown in the photo. After 1 week, the material in each dish was dried and weighed. The results (masses after drying) are shown below.



a) Which of the following processes contributed the MOST to the increased dry mass of the “Light, Water” treatment?

- a) Absorption of mineral substances by the roots.
- b) Absorption of organic substances by the roots.
- c) Absorption of carbon dioxide gas from the air by green leaves.
- d) Absorption of water by roots.
- e) Absorption of sunlight by leaves.

b) Explain why you think your choice contributed the most to the increase in mass. (If other processes also contributed to the mass, explain which ones they are, too.)

Purpose: The purposes of this question are to discover whether students can identify the conditions for plants to conduct photosynthesis and cellular respiration and to understand students’ ideas about matter transformation and energy transformation in photosynthesis and cellular respiration.

Sophisticated answers: The correct choice is c. Sophisticated answers should recognize that in the light and water treatment, the radish seeds undergo both photosynthesis and cellular respiration and photosynthesis contributes to the weight gain. In photosynthesis, carbon dioxide reacts with water and produce organic carbon-containing matter of plants and oxygen. From this chemical equation, we can find that the most increased matter of plants is in the form of organic carbon, which comes from carbon dioxide.

Naïve answers: Students may identify photosynthesis is involved in the light and water treatment, but they usually do not recognize that organic carbon constitute the major increased mass and that organic carbon is from carbon dioxide. They tend to think that

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the major increased matter comes from the substances absorbed through plants' roots.

c) The "No Light, Water" treatment lost mass (from 1.50g to 1.17g). What do you think happened to the mass that was lost?

Purpose: The purposes of this question are to discover whether students can recognize that plants are doing cellular respiration all the time.

Sophisticated answers: Sophisticated answer should recognize that in the no light and water treatment, the radish seeds only undergo cellular respiration, which contributes to the weight loss. In cellular respiration, the organic matter of the radish seeds reacts with oxygen to produce carbon dioxide and water. Thus, some organic matter becomes gases releasing into the air.

Naïve answers: Students usually do not think that plants also do cellular respiration, so they often do not know why the weight of the seeds is lost.