SECONDARY SCHOOL ITEMS (Answer Key)

PHOTOSYNTHESIS

ENERPLNT (MH)

Which of the following is/are energy source(s) for plants? Circle yes or no for each of the following:

a. Water	Yes / No
b. Light	Yes / No
c. Air	Yes / No
d. Nutrients in soil	Yes / No
e. Plants make their own energy.	Yes / No

Explain your answers.

Purpose: *The purpose of this item is to know whether and how students can identify light as the only energy source for plants.*

Sophisticated Answer: *The correct response is yes for b and no for all the other choices. Sophisticated explanation identify light as the only energy source and explains energy transformation in photosynthesis – In photosynthesis, plants transform light energy into chemical potential energy of "foods" – carbon-containing organic substances (e.g. glucose). Water and carbon dioxide are involved in photosynthesis, but they are not the energy source, because the chemical energy of glucose is transformed from the light energy. Minerals and Nutrients are not energy sources, because they are not involved in photosynthesis – the only process of plant harnessing energy into body structure.*

Naïve Answers: *Students tend to hold the idea that everything plants take in is energy source for plants. Thus, they usually identify things plants absorb from soil as energy sources. Students are familiar with the statement that plants make their own foods, but many interpret this statement as plants make their own energy.*

LIGHTEN (EMH) – High school version

Sunlight helps plants to grow. Where does light energy go when it is used by plants? Please choose the ONE answer that you think is best.

a. The light energy is converted into glucose of the plants.
b. The light energy is converted into ATP in the plants.
c. The light energy is used up to power the process of photosynthesis.
d. The light energy becomes chemical bond energy.
e. The light energy does not go into the plants' body.

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.)

How does light help plants to grow? Please explain your answers. Tell as much as you can about PROCESSES happening in the plants' body.

	Purpose: *The purpose of this item is to know how students reason the event of plants using sunlight.* ***Sophisticated answer:*** *A Sophisticated explanation describes energy transformation in photosynthesis – In photosynthesis, plants transform*

	*light energy into chemical potential energy of "foods" – carbon-containing organic substances (e.g. glucose).* ***Naïve answers:*** *Students usually do not distinguish light from conditions of living such as being healthy or warmth. Students at higher levels can recognize that light provides energy for plants to make foods, but many tend to think that light energy is used up to power the process of photosynthesis.*

LIGHTANPLT (EMH) (Light for animals and plants)
Do you think animals and plants use sunlight in the same way? Please explain your answer.

Purpose: *The purpose of this item is to identify whether students use their intuitive reasoning – light is a living requirement for all organisms. It is possible that even when students have learned that light is involved in plant photosynthesis they may still use intuitive reasoning when the question is asked in a way triggering their intuition.*

Sophisticated answer: *The correct response is No. A sophisticated explanation recognizes that plants use sunlight for photosynthesis while animals cannot use sunlight for photosynthesis. It also describes plant energy transformation in photosynthesis – In photosynthesis, plants transform light energy into chemical potential energy of "foods" – carbon-containing organic substances (e.g. glucose). It is possible that students may explain that animal body needs sunlight to keep healthy such as sunlight helps body absorb vitamin D. However, this is not our focus and thus is not required.*

Naïve answers: *Students usually do not distinguish light from conditions of living such as being healthy or warmth. Although students from middle and high schools may know that light is required for plants to do photosynthesis, they may, at the same time, still hold the idea that light is the living condition for all animals.*

THINGTREE (Middle/High school version)
A small oak tree was planted in a meadow. After 20 years it has grown into a big tree, weighing 250 kg more than when it was planted.


the small oak tree


The big oak tree weighing 250 kg more than it was planted

a. Where did MOST of the extra 250 kg come from? Please circle the ONE source that contributed most to the tree's weight gain.

a. Soil
b. Air

c. Sunlight
d. Water
e. Minerals in soil
f. Other (Please list _____)

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.) Try to explain what happens inside the tree as it grows wood and leaves.

Purpose: *The purpose of these questions is to understand students' reasoning about plant growth and foods for plants.*

Sophisticated Answer: *The correct response is b. The sophisticated answer explains organic carbon production through photosynthesis – the increase in weight comes primarily from conversion of carbon dioxide and water into organic matter as a result of photosynthesis. Water and soil minerals also contribute some to the tree's mass (but only about 10-15% of the tree's total mass).*

Naïve Answers: *Students may not recognize that photosynthesis is the primary process enabling plants to build body structure. They may think that, plants, like people, gain their foods by taking in various solid and liquid materials such as nutrients in the soil, water, and so on. Students may also see sunlight as plant food, which is aligned with their idea about foods for humans. Students also tend to confuse minerals with organic substances produced in photosynthesis such as carbohydrates. Students who hold these alternative conceptions usually do not believe the scientific idea that CO_2 (a gas) can contribute to the weight gain of plants.*

b. Where did the oak tree get energy to grow and change? Please circle Yes or No for each of the following and explain your choices.

a.	Air	Yes	/	No
b.	Sunlight	Yes	/	No
c.	Water	Yes	/	No
d.	Minerals in soil	Yes	/	No
e.	Nutrients in soil	Yes	/	No
f.	Plants make their own energy	Yes	/	No

Please explain your answers. In particular, explain why the ideas you circled "No" for are NOT sources of energy for the tree.

Purpose: *The purpose of this item is to know whether and how students can identify light as the only energy source for plants.*

Sophisticated Answer: *The correct response is yes for b and no for all the other choices. Sophisticated explanation identify light as the only energy source and explains energy transformation in photosynthesis – In photosynthesis, plants transform light energy into chemical potential energy of "foods" – carbon-containing organic substances (e.g. glucose). Water and carbon dioxide are involved in photosynthesis, but they are not the energy source, because the chemical energy of glucose is transformed from the light energy. Minerals and Nutrients are not energy sources, and they are not involved in photosynthesis – the only process of plant harnessing energy into body structure.*

Naïve Answers: *Students tend to hold the idea that everything plants take in is energy source for plants. Thus, they usually identify things plants absorb from soil as energy sources. Students are familiar with the statement that plants make their own foods, so many students interpret this statement as plants make their own energy.*

SEEDGAIN

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 the major increased matter comes form 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.

DIGESTION & BIOTHYNTHESIS

INFANTNEED (EMH) – Middle/High school version

When the baby was five months old, she weighed 22 lb. After 7 years, the tiny baby has grown into a big girl, weighing 50 lb.

	
The baby weighed 22 lb when she was 5 months old.	The baby has grown into a big girl, weighing 50 lb.

a. The baby gained more and more weight as she grew. Where did her weight come from? Please circle Yes or No for each of the following and explain your choices.

a.	Sunlight	Yes	/	No
b.	Water	Yes	/	No
c.	Air	Yes	/	No
d.	Nutrients	Yes	/	No
e.	Foods	Yes	/	No
f.	Exercises	Yes	/	No

Please explain your answer. Try to explain what happens inside the girl's body to each of the materials that you circled "Yes."

Purpose: *This purpose of this question is to explore the students' ideas about human growth and foods for humans.*

Sophisticated Answer: *The correct response should circle yes for foods and no for all the other choices. A sophisticated explanation addresses organic matter transformation in digestion and biosynthesis – organic compounds of foods are broken down into simpler compounds and go through digestive system and blood circulation to cells in different parts of human body. Then, these simpler organic compounds will be reassembled into more complicated organic compounds (e.g., fat), which are the building blocks for human body growth.*

Naïve Answers: *Students may hold the idea that everything taken in will contribute to the weight increase. They usually do not recognize organic carbon-containing substances as the major building blocks of human body. Thus, they may think that air and water become the body structure. They may recognize digestion, but they usually do not identify biosynthesis as the process involved in the event of animal and human growth. They may also think that the carbs/lipids/protein go directly to parts of the body without being broken down and reassembled.*

ENERPEOP (MH)

b. The baby stored energy in her body. Where did she gain that energy? Please circle Yes or No for each of the following and explain your choices.

a.	Sunlight	Yes	/	No
b.	Water	Yes	/	No
c.	Air	Yes	/	No
d.	Food	Yes	/	No
e.	Exercise	Yes	/	No

Please explain your answers. How does each material that you circled "Yes" for supply energy for the girl?

Purpose: *The purpose of this item is to investigate how students identify energy source for humans.*

Sophisticated Answer: *The correct answer is yes for d and no for all of the other choices. A sophisticated explanation describes digestion & biosynthesis as the process of humans gain energy from organic materials – Digestion and biosynthesis convert organic compounds of foods from one form to another, keeping most energy as chemical potential energy associated with organic substances (e.g. carbohydrates, fat, etc.) in human body.*

Naïve Answers: *Students tend to think that humans gain energy from multiple sources such as water, air, and sunlight. They also tend to think that energy is created in some events such as humans doing exercises.*

STOREEN (MH)

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

a. Energy is stored in the form of matter.
b. Energy is stored in the form of chemical energy.
c. Energy is stored in the cell, but is separated from the matter of the cell.
d. Energy is stored among the cells.
e. The body does not store energy. Energy is produced when you need it.
f. 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 right, 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 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 other carbon-containing organic substances, their understanding as sophisticated.*

Naïve Answers: *Students may hold the idea that energy is distributed somewhere in*

human body and is separated from matter. Or, they may hold the idea that after food goes to the human body, it stores food in the form of energy.

BREADEN (MH)

White bread contains high energy. After you eat a slice of white bread, where does its energy go? Please tell as much as you know about substances and chemical processes.

Purpose: *The purpose of this item is to understand how students account for energy in human eating food – whether they can identify digestion and biosynthesis and how they account for energy in these processes.*

Sophisticated Answer: *A sophisticated answer identifies the processes of digestion and biosynthesis and describes energy transformation in these processes: The organic molecules of the bread (starch) are broken down into simpler molecules (sugar) and reassembled into complex molecules (fat) to build human body structure. In this process, energy keeps the same form – chemical potential energy contained in organic substances.*

Naïve Answers: *Students may hold the idea that energy is distributed somewhere in human body and is separated from matter. Or, they may hold the idea that after food goes to the human body, it stores food in the form of energy.*

EATAPPLE (NEW)

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' 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?

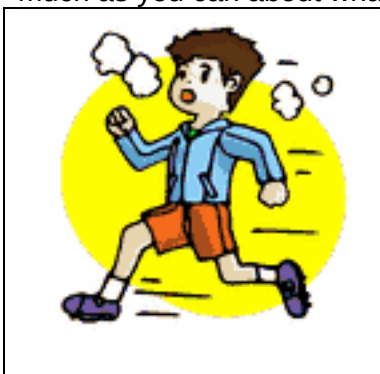
Purpose: *The purpose of this item is to know how students understand biosynthesis in human body.*
Sophisticated Answer: *The sophisticated answer recognizes that after digestion, the process of biosynthesis happens to synthesize substances from food into human body structure – after digestion, the simpler 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 becomes 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.*

CELLULAR RESPIRATION

RUNENER (EMH) (Middle/High version)

The child needs energy to run. Where does the energy for running come from? Tell as much as you can about what happens to energy inside the child's body.



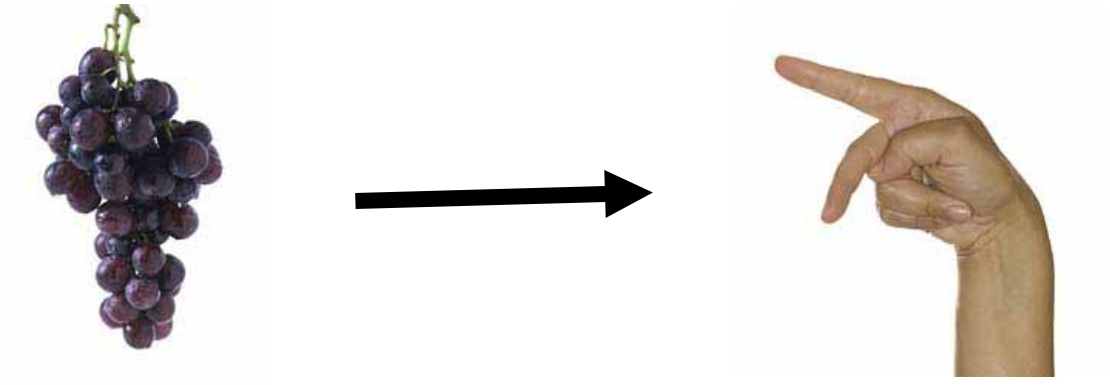
Purpose: *The purpose of this item is to know whether students can identify the process of cellular respiration and explain energy transformation in the process.*

Sophisticated Answer: *A sophisticated explanation describes energy transformation in cellular respiration: In cellular respiration, the chemical potential energy of organic substances (carbohydrates, fat, etc.) in the child's body are transformed into kinetic energy of the child's body movement.*

Naïve Answers: *Many students can identify foods as energy source due to their living experiences, but they usually cannot successfully explain how foods provide energy for running. Some students tend to identify substances such as nutrients as energy source. Usually, students can identify digestion as the process involved in the event of child eating foods to gain energy for running, but they often cannot identify cellular respiration as the core process of transforming potential energy into kinetic energy of moving. They also tend to use matter-energy conversion for explanation: Foods go to the body and turns into energy for running.*

GLUGRAPEa (MH)

The grape you eat can help you move your little finger.



a. Please describe how the substances from the grape provide energy to move your little finger. Describe as many intermediate stages **and** processes as you can.

Purpose: *The purpose of this item is to investigate how students account for human body activities: whether students can identify the process of cellular respiration and whether they can explain matter transformation and energy transformation in cellular respiration. Although blood circulation is also involved, it is not the focus of this item.*

Sophisticated Answer: *The sophisticated explanation describes both blood circulation and cellular respiration – the substances (glucose) go through blood circulation to the cell of the little finger. Then, through cellular respiration, the chemical potential energy of glucose is transformed into kinetic energy of finger movement.*

Naïve Answers: *Students may identify blood circulation, but cellular respiration is much harder for them to identify. Even some students who recognize that there must be some chemical reactions happening, so that substances in the body can provide energy for finger movement, they usually cannot successfully explain energy transformation in cellular respiration. Usually, students tend to use matter-energy conversion for reasoning – the substances of grape are converted into energy to make the little finger move.*

b. Do you think the substances of the grape can also help you to keep your body warm at the same time when they are used to move your little finger? Please explain your answer.

Purpose: *The purpose of this item is to know whether students can identify energy degradation in cellular respiration – heat is released from cellular respiration and the heat help people keep their body temperature.*

Sophisticated Answer: *Sophisticated answer addresses energy degradation in cellular respiration – In cellular respiration, only a small part of the chemical potential of the glucose molecule is transformed into kinetic energy. Most chemical potential energy dissipates as heat to increase our body temperature.*

Naïve Answers: *Students may not believe that the same molecule can provide energy for both finger movement and body temperature.*

WTLOSS (MH)

When a person loses weight, what happens to some of the fat in the person's body? Please choose ONE answer that you think is best.

a. The fat is broken down and leaves the person's body as water and gas.
b. The fat is converted into energy
c. The fat is burned up providing energy for the person's body functions
d. The fat is broken down and leaves the person's body as feces and urine

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 these questions is to understand whether and how students conserve mass when explaining changes in body weight in human beings.*

Sophisticated Answer: *The sophisticated answer to the questions would be choice "a" with the explanation that the fat reacts with oxygen in cellular respiration and produce water and carbon dioxide. So, fat becomes gases – carbon dioxide and water vapor.*

Naïve Answers: *Many students tend to believe that food is converted into energy or "goodness". Some students may think of loss of weight as a process where usable energy is extracted out of body fat, and then the 'energy-less' 'used' fat is excreted out of the body as feces. Such students are likely to pick "d". Some students may select the correct choice "a" but they may not use chemical reaction for explanation. Instead, they tend to construct an explanation based on observation: People lose weight by doing*

exercise. When people are doing exercise, they sweat and breathe heavily.

AIRNBODY

How is the air you breathe out different from the air you breathe in? Where does it change and how does it change?

Purpose: *The purpose of this item is to know how students understand cellular respiration as the chemical reaction underlying breathing.*
Sophisticated Answer: *The sophisticated explanation recognizes cellular respiration underlying breathing and explains matter transformation in cellular respiration – humans inhale oxygen, which reacts with the organic substances of our body structure and produce carbon dioxide and water. Thus, the air we breathe out has more carbon dioxide and water vapor but less oxygen.*
Naïve Answers: *Students may not recognize that air we breathe in is different from the air we breathe out. Or, they may understand breathing as a process of gas exchange – oxygen becomes carbon dioxide and thus do not recognize that the air we breathe out has more water vapor.*

BODYTEMP (MH)

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.

a. The heat mainly comes from sunlight.
b. The heat mainly comes from the clothes you are wearing.
c. The heat mainly comes from the foods you eat.
d. When people exercise, their bodies create energy.

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.*

APPLEDECAY (EMH) – Middle/High school version

An apple was put on the table. After several weeks, it got rotten. Where does its energy go? In what form?

Purpose: *Most middle and high school students recognize that food contains energy. The purpose of this item is to understand how students account for energy when the food is decaying.*

Sophisticated Answer: *A sophisticated answer identifies cellular respiration in the event of apple rotting and explains energy transformation and degradation in cellular respiration (decomposition) – in cellular respiration, bacteria use the energy of the apple 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. Their understanding of decay is usually context dependent. For example, when apply rots, its matter and energy goes to the air. But when tree decays, its matter and energy becomes soil. Students 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 apple must go to the air somehow, so the energy of the apple must also go to the air. Some students might also liken decomposition to rusting or evaporation.*

TREEDECAY (EMH) – Middle/High school version

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.

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.*

APLDECAY

When an apple is left outside for a long time, it rots.

a) What causes the apple to rot?

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 bacteria decompose the apple: The organic compound of the apple 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. They may assume that the apple 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.*

b) The weight of the apple decreases as it rots. What do you think happens to the mass/stuff that was once in the apple?

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 decompose the organic compound of the apple. The organic compound of the apple 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 apple 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 apple. Students may also think that the mass of the apple simply disappeared, or was absorbed directly by soil.*

c) Do you think that energy is involved when the apple rots? Yes / No
Please explain your answer.

Purpose: *Most middle and high school students recognize that food contains energy. The purpose of this item is to understand how students account for energy when the food is decaying.*

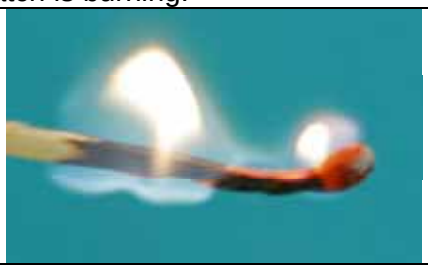
Sophisticated Answer: *A sophisticated answer identifies cellular respiration in the event of apple rotting and explains energy transformation and degradation in cellular respiration (decomposition) – in cellular respiration, bacteria use the energy of the apple for metabolism and heat is released at 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. Their understanding of decay is usually context dependent. For example, when apply rots, its matter and energy goes to the air. But when tree decays, its matter and energy becomes soil. Students 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 apple must go to the air somehow, so the energy of the apple must also go to the air.*

COMBUSTION

BRNMATCH (EMH) Middle/High school version

The picture shows that a match is burning.



Why does a match lose weight as it burns? Choose the ONE answer that you think is the best explanation.

a. It releases CO_2 and water into the air.
b. It turns to ashes and smoke which are lighter.
c. It is burned up by the flame.
d. It turns into energy.

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 question is to uncover students' understanding of the event of burning and whether they understand combustion as a chemical reaction and trace matter in combustion.*

Sophisticated Answer: *The correct choice is "a". The sophisticated answer to this question recognizes combustion as the underlying process and explains combustion in terms of chemical reaction – the matter of the wood reacts with oxygen and produce CO_2 and H_2O. As the result, the match loses weight. The wood of the match becomes CO_2 and water vapor.*

Naïve Answers: *Many students do not attribute weight to gases. Some of them may know that carbon dioxide is released from this event, but they usually do not believe that the mass of solid wood can be accounted for by gaseous carbon dioxide. More often than not, students tend to explain loss of weight as that matter "disappears" or "goes away". Or, they may think matter of the wood is turned into smoke or ashes, because these are observable "products".*

WOODBURN (EMH)

b. Wood can burn, but sand cannot. Why? Please tell as much as you can about substances and chemical processes.

Purpose: *The purpose of this item is to know how students understand the difference between energy-rich materials and non energy-rich materials.*

Sophisticated Answer: *Sophisticated answer distinguishes between wood and sand in terms of chemical bonds. Wood is energy-rich, because the major compound of wood – cellulous – contains high-energy bonds – C-C and C-H.*

Naïve Answers: *Students tend to explain the difference in terms of function of materials: People burn wood but not sand. Older students may think that wood has "specific chemicals", so that it can burn, but they often do not recognize that wood is energy-rich.*

Some students can recognize that wood contains energy, but they usually cannot explain that in terms of chemical bonds.

CARHILL (MH)

The picture below shows that a car is climbing up the hill. When the car is moving, it has energy. Where does the energy of motion come from?

a. The energy is created by the engine.
b. The energy comes from the gasoline in the tank.
c. The energy comes from the person who is driving the car.
d. The energy comes from the wheels turning and pushing the cars.

Please explain your answer.

Purpose: *The purpose of this item is to understand how students account for the event of car running and whether they can identify the energy source for car running.*

Sophisticated Answer: *The correct choice is b. A sophisticated explanation recognizes that gasoline's major component is hydrocarbons (octane), which contains high-energy bonds C-C and C-H.*

Naïve Answers: *Students may recognize that running car contains energy, but they may hold the idea that energy is created when the car is moving.*

ENERGAS (EMH) – Middle/High school version

Tom's family went to Chicago on vacation. When they came back, Tom's dad found that their car consumed 50 gallons of gasoline for the trip.

a. Where did the 50 gallons of gasoline go?

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

Sophisticated Answer: *A sophisticated answer explains matter transformation in combustion: Gasoline reacts with oxygen and produces carbon dioxide and water- so the gasoline is found as CO_2 and water vapor in the air.*

Naïve Answers: *Students may not understand combustion as chemical reaction. Some students may use matter-energy conversion for reasoning – gasoline was turned into energy to move the car. Some students may explain that gasoline evaporates or becomes smoke.*

b. Where did the energy of the gasoline go? Does the energy of the gasoline still exist somewhere? Please choose the ONE answer that you think is best.

a. The energy of the gasoline was burned up and does not exist anywhere.
b. The energy of the gasoline was turned into heat in the environment.
c. The energy of the gasoline was stored in the engine.
d. The energy went out the tailpipe with the exhaust.
e. Other _____

Please explain your answer. Tell as much as you can about intermediate stages and processes.

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.*

GAS_MT

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 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.*

GASWATER (EMH) – Middle/High school version

Why do people use gasoline instead of water to run their cars? Please tell as much as you can about substances and chemical processes.

Purpose: *The purpose of this item is to uncover students understanding about the difference between gasoline and water and whether they recognize gasoline is energy-rich material.*

Sophisticated Answer: *A sophisticated answer recognizes that gasoline is energy-rich material since gasoline's major component is hydrocarbons (octane), which contains high-energy bonds C-C and C-H.*

Naïve Answers: *Students may use function for reasoning – people use gasoline to run car, because gasoline lasts longer or because water will destroy the engine. Some students may recognize that gasoline and water have different chemical composition, but they may not recognize that is related to energy (e.g., gasoline has special chemicals).*

HOTTHINGS (EMH)

When the car runs for some time, the front part of it will become hot. When you are running for a while, you also feel very hot. When the wood is burning, it makes the air around it very hot. Why is heat released in these events? Do you think they have the same cause? Please explain why.

Purpose: *The purpose of this item is to uncover students understanding about energy degradation in various events.*
Sophisticated Answer: *A sophisticated answer identifies the chemical reactions underlying all the events (i.e., combustion and cellular respiration) and recognizes heat dispersion in all the processes.*

Naïve Answers: *Currently, we do not know enough what students would respond.*

AIRBURN, WAXBURN, WAXEN

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.*

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

Context

ENECO (MH)

What is the ultimate energy source for an ecosystem? Please explain your answer.

Purpose: *This item is usually used in school science. The purpose of using this item in the assessment is to compare students' responses of this item with their responses of ECOSPHERE.*

Sophisticated Answer: *A sophisticated explanation recognizes that sunlight is the ultimate energy source for ecosystem, since plants gain their energy from sunlight and animals gain their energy either directly or indirectly from sunlight.*

Naïve Answers: *We expect that many students can give correct answer, since this is a common school science question.*

ECOSPHERE (MH)

NASA scientists invented the EcoSphere – inside a sealed glass container, there are air, water, gravel, and three living things – algae, shrimps, and bacteria. Usually, these three living things can stay alive in the container for two or three years until the shrimps become too old to live. The picture above shows an EcoSphere and its inside part. The EcoSphere is a closed ecosystem and has no exchange of matter with the outside environment.

Do you think the EcoSphere has energy exchange with the outside environment?

Circle one: YES / NO

If your answer is NO, why the living things can stay alive without energy exchange with the outside world?

If your answer is YES, what are the energy input and output of the EcoSphere? Please explain the forms of energy.

Purpose: *The purpose of this item is to uncover students' understanding of energy in ecosystem – whether they can recognize energy degradation in ecosystem.*

Sophisticated Answer: *The correct choice is YES. Although the closed ecosystem has no exchange of matter with the outside environment, it must have energy exchange with the outside world. A sophisticated explanation recognizes both energy transformation and degradation in ecosystem: On the one hand, energy flows in food chain – shrimps and bacteria gain their energy from photosynthetic algae. On the other hand energy always degrades – the living things in the ecosystem are constantly doing cellular*

respiration to keep normal body function and physical activities and in cellular respiration, there is always part of energy lost as heat and becomes unavailable for the organisms to use. Thus, the useful energy of the ecosystem always degrades and the ecosystem requires constant energy input from outside to keep the organisms living. That energy comes from algae harvesting light energy through photosynthesis. In brief, the input energy is the sunlight energy and the output energy is heat released from cellular respiration.

Naïve Answers: *Students may think that energy always goes with matter. Thus, when there is no matter exchange with the outside world, there should not be energy exchange with the outside world. Students may also hold the idea that, since energy cannot be destroyed, the closed ecosystem does not require extra energy from outside world. This reasoning does not recognize that the total quantity of energy conserves, but the quality of energy decrease – the available energy degrades.*

TROPRAIN (MH)

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?

a. Energy is recycled, but matter is not recycled.
b. Matter is recycled, but energy is not recycled.
c. Both matter and energy are recycled.
d. Neither matter nor energy are recycled.

Explain your answer:

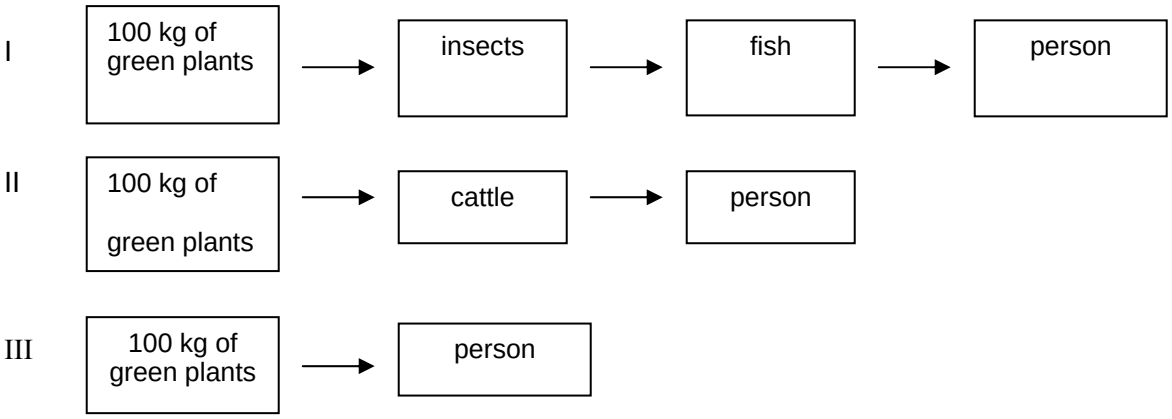
Purpose*: The purpose is to understand students' idea about energy degradation in food chain. There is always energy lost into environment as heat, when energy flow from one organism to another.*

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*: Some students may say 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.*

ENPYRAMID (H)

Consider the three diagrams below. They represent three situations in which 100 kg of green plants serve as the original source of food for each of the food chains. In situation II, for example, cattle eat 100 kg of green plants and then people eat the beef that is produced by the cattle as a result of having eaten the plants.



In which of the three situations is the most energy available to the person?

a. I
b. II
c. III
d. Situations I and II will roughly tie for the most energy.
e. The same amount of energy will be available to the person in all three situations.

Please explain your answer.

Purpose: *The purpose of this item is to understand students ideas about matter transformation and energy transformation in ecosystem and the physical environment. In particular, we want to know how they understand the following two aspects: 1) Matter recycles because, although it transforms, it can always be used by organisms. 2) Energy degrades because, when energy transform, there is always part of the energy lost as heat and cannot be used by any organisms.*

Sophisticated Answers: *The correct choice is a. Sophisticated answers should include the idea of energy degradation in each tropic level. That is, each organism on the food chain requires energy for metabolic functions. This part of energy comes from the chemical energy of their body structure and will be ultimately dissipate into environment as heat. Thus, at each of the trophic levels, only a small part of energy will be passed on to the next trophic level.*

An example of sophisticated answer is:
In all of the three situations, the amount of incoming energy is the same – the energy contained in 100 kg green plants. In situations I and II, insects, fish, and cattle will use a large part of the incoming energy for their metabolic function. This part of energy will ultimately dissipate into environment as heat and thus will not be passed on to the person. So, only in situation III, the food chain loses the least amount of energy to environment and thus passes on the largest amount of energy to the person.

Naïve answers:
1. a). I. b). Energy accumulates in food chain/web. In situation I, the person can gain the largest amount of energy, because energy accumulates along the food chain. The more organisms on the food chain, the more energy the top organism can gain.
2. a). II b). In situation II, because cow is bigger than fish and grass, so it contains more energy than fish and grass and thus can pass on more energy to the person.

DEERWOLV (H)

A remote island in Lake Superior is uninhabited by humans. The primary mammal populations are white-tailed deer and wolves. The island is left undisturbed for many years. Select the best answer(s) below for what will happen to the average populations of the animals over time.

_____a. The deer will all die or be killed.
_____b. The wolves will all die or be killed.
_____c. On average, there will be a few more deer than wolves.
_____d. On average, there will be a few more wolves than deer.
_____e. On average, there will be many more deer than wolves.
_____f. On average, there will be many more wolves than deer.
_____g. On average, the populations of each would be about equal.
_____h. None of the above. My answer would be: _____
_____
_____

Please explain your answer to what happens to the populations of deer and wolves.

Purpose: *The purpose of the question is to understand students' conception about food chain and feeding relationships between species in an undisturbed ecosystem. To figure out the population of the species, students need to understand how food chain and energy trophic pyramid constrain the number of organisms.*

Sophisticated answer: *The answer for question 3 is e. Wolves feed on white-tailed deer, so the matter and energy of deer transfers to wolves. Deer and wolves are at different trophic levels in food chain and a food chain can be represented quantitatively (with numbers) in the form of a pyramid. Over time, there must be much fewer wolves than deer, because when one wolf eats one deer, the wolf only get about 10% energy from the deer and thus one wolf requires many deer to get enough energy to survive.*

Naïve answers: *Wolves eat deer and there are less deer than wolves or no deer. Students may not realize that the predator-prey relationship between wolves and deer has implications for the relative size of the populations.*

GRANJOHN

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.

CONNLIFE

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

ENRESLAMP (EMH)

When you open the lamp, you can see the light. Where does the light energy come from? Trace the energy back as far as you can. You may or may not fill up all of the spaces in each table.

	What form of energy was it? Where was it?
	Light energy of the light
Before that…	
Before that…	
Before that…	
Before that…	
Before that…	

Purpose: *The purpose of the question is to understand to what extend, students trace energy back to energy resources.*

Sophisticated answer: *The sophisticated answer recognizes that light energy of the lamp comes from the electrical energy of the wires. Most electrical energy is transformed from the chemical energy of fossil fuels in power plants. Chemical energy of fossil fuels came from plants and animals living millions of years ago. That energy was transformed from the light energy of sunlight.*

Naïve answers: *Students may have difficulty tracing energy back to its resources. They may not have the knowledge that most electricity comes from burning fossil fuels.*

DIFEVENTS (EMH) – similar or different events?

		
A. Eating a hamburger	B. Filling up a car with gasoline	C. Watering plants

The pictures above show that three things are happening. Are they alike or different? Please explain your answer.

A scientist says that A and B are similar events, but picture C is different from A and B. Do you know why? Please explain why C is different from A and B.

Purpose: *The purpose of these two items is to understand whether students can identify that plants gaining energy from sunlight while humans and car gain energy directly from energy-rich materials.*

Sophisticated Answer: *A sophisticated answer recognizes that A and B are similar events in the sense that both people and car gain energy from energy-rich materials (i.e., food and gasoline) and C is a different event since plants cannot gain energy from water. Plants need water to make organic materials, but the energy of plants comes from sunlight.*

Naïve Answers: *Students tend to think that these events are similar since they all gain things from outside to make them function properly. They may also think that A and C are similar because they are about living systems, as opposed to B, which is about nonliving systems.*

AIRCOICE (MH)

How are the three things related to each other: a person plugs in an air conditioner in US, trees grow in Amazon forest, ice in Antarctica melts?

Purpose: *The purpose of this item is to understand how students make connections among these events and whether they can identify and explain carbon cycling through the two processes – photosynthesis and combustion.*

Sophisticated answer: *A sophisticated answer to this question explains the connection of the events in terms of carbon cycling: On the one hand, using air conditioner consumes electrical energy, most of which comes from combustion of fossil fuels. Combustion of fossil fuels releases a large amount of carbon dioxide into the atmosphere, causing global warming over time. As the result, ice in Antarctica melts. On the other hand, underlying the event of trees growing in Amazon is the process of photosynthesis: Trees use carbon dioxide in the atmosphere and water to make organic substances for their body structure. When the plants remove the carbon dioxide from the atmosphere, they help to slow global warming.*

Naïve answers: *Students usually do not recognize the connection in terms of carbon*

cycling at atomic/molecular scale. They may also address connection at macroscopic scale. For example, heat released from air conditioner can be the reason for ice melting in Antarctica.

LBULB (MH)

Compared with incandescent light bulb, fluorescent light bulb has higher energy efficiency and can save 66% to 75% energy. Do you think your personal behavior of using fluorescent light bulb instead of incandescent light bulb can contribute to slowing global warming? Please explain your answers.

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.*

ENERRICH (EMH)

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 them go together?
b) Why would water go with limestone and sand rather than sugar and meat?
c) Does it seem to you that groups A and C have anything in common? If yes, what are in common? Please explain your answers.

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.*

EVENTS (EMH)

Do you think the following events have cause? Please circle yes or no for each event and explain your answers.

Events	Does something cause this event? (Circle one)	If your answer is "yes", what is the cause?
Tree growing	Yes No	
Apple decaying	Yes No	
Person gaining weight	Yes No	
Person losing weight	Yes No	
Match burning	Yes No	
Car running	Yes No	
Child running	Yes No	

Person keeping his body temperature	Yes No	

Purpose: *The purpose of this item is to investigate how students account for the causes of these events and whether students will use a same reasoning to account for different environmental events.*

Sophisticated Answer: *A sophisticated answer identifies chemical processes involved in each event (i.e., photosynthesis, digestion & biosynthesis, and oxidation) and successfully explains energy transformation and degradation in each process: Energy determines whether the process will happen or not. In tree growing, light energy transforms into chemical potential energy of plants' body and thus make plant growth possible. In apple decaying, chemical energy of the apple degrades into the environment as heat and thus cause the apple decay. In person gaining weight, the organic molecules of the foods break down into simpler molecules and reassembles into complex molecules to build body structure. In this process, energy of food goes to the person's body structure and keeps the same form – chemical potential energy. This causes human body growth. The cause of person losing weight, match burning, car running, and child running is that in oxidization processes, chemical potential energy of organic materials transforms into other forms of energy – kinetic energy and heat – to make these events happen. In keeping body temperature, the heat released from cellular respiration cause people to keep their body temperature.*

Naïve Answers: *Students may not distinguish energy from other causes such as intention cause or material cause.*

STRUCTURE

Carbon exists in different molecules or substances in nature. Please explain where carbon might exist in a forest. Complete the table below.

Question:	YES or NO	If YES, what substances or materials in these locations contain the carbon?
Do you think you would find carbon in trees?		
Do you think you would find carbon in the soil?		
Do you think you would find carbon in animals, like deer and wolves?		
Do you think you would find carbon in bacteria in the soil?		
Do you think you would find carbon in the air?		
Where else might you find carbon?		

***Purpose**: The purpose of this question is to understand students' ideas about the inorganic and organic compounds in which carbon is stored. Often, students will overlook certain forms in which carbon is stored. This leads to a greater misunderstanding of the carbon cycle. Organic carbon is stored sugar, starch, and cellulose that compose plants' body structure. Organic carbon is also stored in humus of plants/animals in the soil, but the minerals in soil do not contain carbon. Carbon is also stored as carbohydrates and lipids in the body structure of animals. Sugar is the most common form for bacteria to store carbon. Carbon is stored in the air in the form of carbon dioxide.*

***Sophisticated answers:** Sophisticated answers should indicate that carbon is stored in all organic matter (living or dead) as organic form and in the atmosphere as inorganic form. Furthermore students should indicate how carbon is stored in each of the options listed in the question.*

***Naïve answers:** Students that possess a limited understanding of how carbon is stored in an ecosystem may answer "NO" to any of the questions. Furthermore, students may not understand that carbon can be stored in the molecules that make up organisms or as a gas in the atmosphere.*

Do you think that wood is a mixture of different things? (Circle one) YES / NO

Please explain your ideas about what materials or substances are in wood.

Purpose: *The purpose of this item is to know whether and how students understand the atomic/molecular structure of wood.*
Sophisticated Answer: *The correct response is yes. Sophisticated answer explains that wood is a mixture of various substances and should identify some major substances including organic carbon-containing substances (such as cellulous) and water.*
Naïve Answers: *Students may recognize that wood is mixture but they usually cannot identify organic carbon-containing substances as the major component of wood.*

MUSCMIX

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 .*

ENERRICH

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