Common Student Ideas about Energy and Energy Transfer

Common Student Idea(s)	Scientific Explanation
Energy is a "thing," a material object.	Energy is a concept scientists use to explain changes in everyday objects. Some examples are picking up a toddler, boiling water for oatmeal, hitting a tennis ball, blowing on a spoonful of hot soup, and stretching a rubber band around a ponytail. In the world around us, we can measure differences in distance, temperature, velocity, and even color between objects. When these measurable quantities change, energy is involved. We can't see the actual energy, but we can see the changes or differences that energy causes. Energy isn't a concrete "thing," but it's always associated with an object or a system of objects.
Energy is the same thing as force and power.	It's common for some words to be used interchangeably in everyday language, but in science, words tend to have very precise meanings. Energy, force, and power are all abstract concepts. A *force* is energy expressed as a push-or-pull action. If that push or pull results in some sort of measurable difference, then energy flowed into or out of the system. *Power* refers to how fast or slow energy flows into or out of a system. A car racing around a track has energy of motion. Where did that energy come from? The chemical energy in the race car's gasoline was converted to heat energy and motion energy that moved the car around the track.
If an object isn't part of some action, it has no energy.	The primary categories or forms of energy are potential and kinetic. *Kinetic energy* is associated with motion. *Potential energy* is associated with the composition or position of an object relative to another object. For example, a pencil lying on a table is in a higher position relative to the floor. Because of the pull of gravity, the pencil has the potential to fall from the higher table to the lower floor. Even if it isn't moving, the pencil has energy. The key science idea here is that both kinetic energy and potential energy are energy. We measure the amount of energy differently once we determine the category of energy, but both categories are still energy, just as someone wearing a Halloween costume is still the same person.
Energy has human qualities like want or desire.	It's common to use everyday language to explain scientific phenomena. Students might say, "Heat *wants* to moves from hot to cold," or "The marble *likes* being at the bottom of the ramp," or "The packing peanut *needs* to stop." But inanimate objects don't have human qualities like love, hate, desire, need, or intent. Human qualities don't affect the laws of nature.
Energy can be used up or destroyed.	Energy can't be used up or destroyed. The law of energy conservation states that energy is neither created nor destroyed. Energy can, however, change from one form to another. For example, potential energy can change to kinetic energy when a rock rolls down a hillside. The rock had potential energy at the top of the hill, and when it began to roll down the hill, the potential energy changed to kinetic energy. Energy can undergo other types of changes as well. The chemical energy (potential energy held in chemical bonds) in your car's gasoline can change into the motion of your car, the roar of the engine, the heat the engine produces, and the heat the tires produce as they grip the road. Through all of these changes, the amount of energy stayed the same—no more, no less. When a battery goes "dead," your electronic device didn't use up the battery's energy. Rather, the potential energy stored in the battery (because of the relative positions of charged particles in the atoms inside the battery) transformed into the energy to power your device. This potential energy transformed into the

Common Student Idea(s)	Scientific Explanation
	sound coming from your digital music device or the light coming from your flashlight, to name a couple of examples. Additionally, some energy is always transformed into heat that isn't useful to us. You know this if you've felt the heat coming from a cell phone or a laptop computer after you've used it for several minutes.
Energy can be created.	Energy isn't created. It doesn't instantly spring into existence, and yet it does change. Change, however, isn't the same thing as creation. The fact that some energy isn't directly visible doesn't mean that energy creation is involved when it transforms into a visible form. For example, the motion of air molecules that we call *wind* isn't easily observed. Yet it can transfer to the motion energy of a flag. Similarly, thermal energy can't be seen directly, and yet when heat transfers to water through conduction, we can feel the warmth of the water or see the water start to boil.
Energy transformations and transfers can happen 100% efficiently.	No system is 100% efficient. Whenever energy moves from object to object or from place to place, or whenever it changes in any way (such as a light turning on or a bell ringing), some of the energy changes to heat. Not all of the energy from a battery is used to power a flashlight, for example. Some of the energy transforms into heat. But inefficiency related to energy transfers and transformations doesn't mean that energy is destroyed. The total amount of energy remains constant. Energy can, and often does, change in ways that make it not as useful, such as a lightbulb changing some of the electrical energy into heat.
Gravitational potential energy is the only type of potential energy.	An object at the top of a hill has potential energy because gravity is pulling on it. But this is only one category of potential energy. Several other common categories of potential energy exist as well. Elastic, chemical, and electromagnetic energy are all forms of potential energy. Each category of potential energy is a way of storing energy so that it can be transformed into other categories of energy. For example, a stretched rubber band stores elastic potential energy; gasoline stores chemical potential energy; and opposite electrical charges separated by some distance store electromagnetic energy.
Motion energy depends only on speed, not mass.	The amount of kinetic energy (energy of motion) depends on an object's motion or velocity (v) and mass (m). You can see this from the mathematical way of expressing the relationship between energy, mass, and velocity. $Kinetic\ energy = \frac{1}{2}mv^2$ For example, if two marbles collide with a piece of Styrofoam at the same speed, the heavier marble will move the Styrofoam farther. Thus, mass is a factor affecting the amount of kinetic energy.
Only objects that feel warm or hot have thermal energy.	All objects have some thermal energy because they're made of molecules in motion. Thermal energy is a way of describing the movement of molecules in a substance. For example, two cups of water, one warm and one cold, both have thermal energy. The molecules in the warmer water are moving, on average, faster than the molecules in the colder water. If both cups contained the same amount of water, the warm water would have more thermal energy than the cold water.
Only visible things have energy.	It's common to think that energy requires a visible agent to express it. For example, a hammer hits a nail. The hammer is a visible agent of motion (kinetic) energy. But invisible objects are also agents of energy transfers and

Common Student Idea(s)	Scientific Explanation
	transformations. Infrared radiation (heat waves) is invisible, and yet it warms objects. For example, heat lamps at a buffet restaurant keep the food warm until it's served.
Elastic potential energy happens only during stretching, not compression.	Elastic objects, like springs, are characterized by two types of movement: compression (squeezing) and expansion (stretching). Both movements cause elastic potential energy to change. Bedsprings are compression springs, and bungee cords are expansion springs. But both store potential energy.
Objects have energy in them that gets used up as the object moves.	Objects have energy that can be transferred or transformed, but the total amount of energy remains constant (conserved). The term *used up* might convey the idea that energy can be destroyed. Instead, the energy transfers to another object or transforms into another form. For example, a rolling marble has kinetic energy, but many tiny collisions called *friction* that occur between the marble and the floor (or the marble and the air) cause the marble to slow down and eventually stop. These tiny collisions resulted in the marble's kinetic energy transferring to the floor as heat. If the marble collides with another marble, some of the motion energy of one marble transfers to motion energy of the next marble, while some is also transformed into the sound of the marbles hitting each other or a small amount of heat being produced. But in all of these transfers and transformations, the total amount of energy is conserved.
Energy transfers from one object to another only if there is a collision.	Certainly, both macroscopic and microscopic collisions transfer energy. But energy can move from place to place or object to object in other ways as well. Electromagnetic radiation (anything from radio waves to microwaves to visible light to gamma rays) is another way energy can be transferred. For example, when sunlight strikes our skin, no collision is involved. Instead, light energy causes the skin to tan, and it transforms into heat energy, which we feel as warmth.