MIDDLE SCHOOL PHYSICAL SCIENCE: THERMAL ENERGY

Standards Bundle:

Standards are listed within the bundle. Bundles are created with potential instructional use in mind, based upon potential for related phenomena that can be used throughout a unit.

MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. (SEP: 2; DCI: PS1.A, PS3.A; CCC:Cause/Effect) [Clarification Statement: Emphasis is on qualitative molecular-level models of solids, liquids, and gases to show that adding or removing thermal energy increases or decreases kinetic energy of the particles until a change of state occurs. Examples of models could include drawing and diagrams. Examples of particles could include molecules or inert atoms. Examples of pure substances could include water, carbon dioxide, and helium.]

MS-PS1-6 Design, construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. (SEP: 6; DCI: PS1.B, ETS1.B, ETS1.C; CCC: Energy/Matter) [Clarification Statement: Emphasis is on the design, controlling the transfer of energy to the environment, and modification of a device using factors such as type and concentration of a substance. Examples of designs could involve chemical reactions such as dissolving ammonium chloride or calcium chloride.] [*Assessment Boundary: Assessment is limited to the criteria of amount, time, and temperature of substance in testing the device.*]

MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. (SEP: 6; DCI: PS3.A, PS3.B, ETS1.A, ETS1.B, ; CCC: Energy/Matter) [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

MS-PS3-4 Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample. (SEP: 3; DCI: PS3.A, PS3.B; CCC: Scale/Prop.) [Clarification Statement: Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

Content Overview

This section provides a generic overview of the content or disciplinary core ideas as an entry point to the standards.

Gases and liquids are made of molecules or atoms that are moving about relative to each other. The molecules in a liquid are constantly in contact with each other, whereas in a gas, the molecules are widely spaced except when they happen to collide. In a solid, atoms are closely packed and vibrate in position, but do not change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g. crystals). The changes of state that occur with variations in temperature or pressure can be described and predicted using models of matter.

The term “heat” as used in everyday language refers to both thermal energy (the motion of atoms or molecules within a substance) and energy transfers by convection, conduction, and radiation (particularly infrared and light). In science, heat refers to flow of thermal energy when two objects or systems are at different temperatures. Temperature is the measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

Phenomena

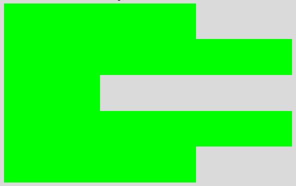
Phenomena can be used at varying levels of instruction. One could be used to anchor an entire unit, while another might be more supplemental for anchoring just a unit. Please remember that phenomena should allow students to engage in the SEP and use the CCC/DCI to understand and explain the phenomenon.

- My tire pressure light comes on when the temperature dramatically drops.
- Chocolate melts in your hand.
- The handle of a metal spoon in a hot bowl of soup becomes hot.
- Observe the spread of food coloring in a glass of hot water versus a glass of cold water.
- If you are outside on a hot day, you will sweat. When your sweat evaporates you feel cooler.
- My bag of frozen vegetables will enlarge while being heated in the microwave.

Storyline

This section aims to decode not only the DCI connections, but also the SEP and CCC in a detailed account of how they possibly fit together in a progression for student learning, including both rationale and context for the bundle.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models ● Develop a model to predict and/or describe phenomena. **Constructing Explanations and Designing Solutions** ● Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.	**PS1.A: Structure and Properties of Matter** ● Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. ● In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. ● The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. **PS3.A: Definitions of Energy**	**Cause and Effect** ● Cause and effect relationships may be used to predict phenomena in natural or designed systems. **Energy and Matter** ● The transfer of energy can be tracked as energy flows through a designed or natural system.

● Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. **Planning and Carrying Out Investigations** ● Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.	● The term “heat” as used in everyday language refers both to thermal energy (the motion of atoms or molecules within a substance) and the transfer of that thermal energy from one object to another. In science, heat is used only for this second meaning; it refers to the energy transferred due to the temperature difference between two objects. ● The temperature of a system is proportional to the average internal kinetic energy and potential energy per atom or molecule (whichever is the appropriate building block for the system’s material). The details of that relationship depend on the type of atom or molecule and the interactions among the atoms in the material. Temperature is not a direct measure of a system's total thermal energy. The total thermal energy (sometimes called the total internal energy) of a system depends jointly on the temperature, the total number of atoms in the system, and the state of the material. **PS1.B: Chemical Reactions** ● Some chemical reactions release energy, others store energy. **PS3.A: Definitions of Energy** ● Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present. **PS3.B: Conservation of Energy and Energy Transfer** ● Energy is spontaneously transferred out of hotter regions or objects and into colder ones. ● The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment.	**Scale, Proportion, and Quantity** ● Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. 

The state of matter (solid, liquid, gas) of a pure substance is related to the particle motion (kinetic energy) within that substance. Students should understand that the temperature of matter is really a measurement of the average kinetic energy of the particles within the matter, not the total thermal energy. The level of particle motion, and therefore kinetic energy, in matter increases as the matter moves from a solid state to a liquid state, and to a gas state. In a solid state, particles of matter are in a fixed position and may vibrate, but will not change location. Particles of matter in a liquid state are more free to move, can change location, and are constantly in contact with other liquid particles. In a gas state particles of matter are spaced out and may only come in contact with each other upon random collisions.

Matter that goes through a change in internal temperature or pressure, can undergo a phase (state) change. To change the internal temperature of a substance, thermal energy is either added or released from the substance. If matter is in a solid state, and its internal temperature is increased (or the pressure is decreased or both), the matter will transform into a liquid (called the melting point). If thermal energy continues to be added (and thus kinetic energy) to the matter (or further decrease pressure), the matter will reach its boiling point and it will begin the process of vaporization; changing from a liquid into a gaseous state. If the particles in matter change directly from a solid state to a gaseous state the process is called sublimation. The reverse process to sublimation is deposition; the process of changing directly from a gas to a solid. Condensation occurs if the internal temperature of matter is decreased (energy released) when changing from a gas to liquid. When matter changes from a liquid to a solid state, it has reached its freezing point. To create a solid from a liquid, you might have to decrease the temperature by a large amount and then add pressure.

The term heat refers to the transfer of thermal energy from one object to another due to a temperature difference between the two objects. Temperature is a measure of the average kinetic energy of the particles in a material. The more kinetic energy particles have, the higher the material's temperature will be. While temperature is proportional to the average internal energy (kinetic and potential) per particle, it is not a direct measure of a system's total thermal energy. The total thermal energy (total internal energy) depends on the temperature, total number of atoms, and the physical state of the material. As pure substances go through a phase change, their temperature remains unchanged though thermal energy continues to be added to/released from the system. Once a phase change is complete, the temperature (average kinetic energy) will once again begin to change. Students should plan an investigation to determine the relationship between the type of matter, mass, and the change in temperature when thermal energy is either added or released from various samples of matter. Students can also undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. By tracking the energy transfer associated with the system of the device, students can determine the efficiency of the device and gather evidence to support the conservation of energy in a closed system. Emphasis should be placed on controlling the transfer of the energy to the environment, and the modification of the device using factors such as type, temperature, concentration or amount of substance or the time taken for the reaction to occur.

Formative Assessment

Formative assessment is crucial because all learners benefit from timely and focused feedback from others. It promotes self-reflection, self-explanation, and social learning. It can also make learning more relevant. Each of the questions below might be used throughout the formative assessment process. Specific prompts may focus on individual practices, core ideas, or crosscutting concepts, but, together, the components need to support inferences about students' three-dimensional science learning as described in a given bundle, standard or lesson-level performance expectation.

Resources to inform your formative assessment.

http://stemteachingtools.org/brief/30

http://stemteachingtools.org/brief/41

http://stemteachingtools.org/pd/sessionb

SEP Developing and Using Models

- Develop a model to demonstrate how molecules behave when thermal energy is applied.

SEP Constructing Explanations and Designing Solutions

- Apply scientific ideas or principles to design, construct, and test a device to either heat or cool a system using chemical reactions.

SEP Planning and Carrying Out Investigations

- Plan an investigation to illustrate that mass is conserved when ice melts.

CCC Cause and Effect

- Describe the effect on the molecules in a system when thermal energy has been transferred.
- Describe the relationship between the average kinetic energy and the temperature of the system.

CCC Scale, Proportion, and Quantity

- Write an equation to express the relationship between the following quantities:
  - Kinetic energy and mass
  - Kinetic energy and speed

Performance Outcomes

These are statements of how students use knowledge and are similar to the standards in how they blend DCI, SEP, and CCC, but at a smaller grain-size. These are potential outcomes for instruction as it plays out in lessons and activities in the classroom. It is important to also think of these as smaller outcomes that build toward the larger goal of mastering the standards.

- **Design, construct, and test a device that demonstrates** what *causes* some **chemical reactions to release** *energy* **while others store** *energy.*
- **Develop a model to describe how** the *magnitude of speed* of atoms and/or molecules **is related to their physical state(**solid, liquid and gas**).**
- **Construct an argument using evidence to explain** that temperature is a *proportional* measure of the average kinetic energy contained in the particles of matter and that temperature is not a direct measure of a **system'**s total thermal energy.
- **Plan and carry out an investigation to determine** that total thermal energy *is dependent on* the physical state, type, and number of atoms in the system
- **Use mathematics and computational thinking to describe** the phenomena that the temperature of a system is *proportional* to the average internal kinetic energy and potential energy per atom or molecule.
- **Explain from evidence** that changes of state *are caused by* variations in temperature and/or pressure.
- **Plan an investigation** to observe that thermal *energy is transferred* from hotter regions or objects to colder ones.
- **Explain from evidence** that the term "heat" refers to the *transfer* of thermal energy.
- **Construct and test** a device that either minimizes or maximizes the *transfer* of heat energy between two objects or mediums.
- **Modify a design based on data analysis to improve the efficiency of a device** to *reduce or increase the amount* of energy that is transferred.