Middle School Phenomenon Model Course 1

Narrative and Rationale: This course model arranges the Performance Expectations (PEs) outlined in the first year of the middle school conceptual progressions model from Appendix K of the Next Generation Science Standards into five different bundles of PEs using a phenomenon-based arrangement. The bundles in this model follow a conceptual flow throughout the year.

The first bundle focuses on the relationship between resource availability and geoscience processes. The second and third bundles focus on energy and matter flows, and the fourth and fifth bundles focus on object interactions. Each bundle is organized around the DCIs that would help students explain a unifying phenomenon and answer a guiding question. It is important to note that the practices and crosscutting concepts described are intended as end-of-instructional unit expectations and not curricular designations. Additional practices and crosscutting concepts should be used throughout instruction toward each bundle.

Bundle 1: How important are our natural resources?" **~4 weeks**	**Bundle 2:** How does a change in thermal energy affect matter? **~4 weeks**	**Bundle 3:** What are chemical reactions? **~4 weeks**	**Bundle 4:** What happens when objects collide? **~4 weeks**	**Bundle 5:** How can objects interact at a distance? **~4 weeks**
MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. **MS-LS2-2**. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. **MS-ESS2-2**. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.[1] **MS-ESS2-3**. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions. **MS-ESS3-1**. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.	**MS-PS1-1**. Develop models to describe the atomic composition of simple molecules and extended structures. **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. **MS-PS3-3**. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer. **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. **MS-ESS2-4**. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. **MS-ESS2-5**. Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.[1] **MS-ESS2-6**. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine global climates.[1]	**MS-PS1-2**. Analyze and interpret data on the properties of substances before and after substances interact to determine if a chemical reaction has occurred. **MS-PS1-3**. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. **MS-PS1-5**. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved. **MS-PS1-6**. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes. **MS-ETS1-3**. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	**MS-PS2-1**. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.* **MS-PS2-2**. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. **MS-PS3-1**. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object. **MS-PS3-5**. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. **MS-PS4-1**. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. **MS-PS4-2**. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.	**MS-PS2-3**. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. **MS-PS2-4**. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. **MS-PS2-5**. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. **MS-PS3-2**. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. **MS-ESS1-1**. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. **MS-ESS1-2**. Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

	MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.			**MS-ESS1-3**. Analyze and interpret data to determine scale properties of objects in the solar system.

1. The bundle only includes part of this PE; the PE is not fully assessable in a unit of instruction leading to this bundle.

Middle School Phenomenon Model Course 1 Flowchart

Bundle 1

LS2.A as found in MS-LS2-1
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.
- In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction.
- Growth of organisms and population increases are limited by access to resources.

LS2.A as found in MS-LS2-2
- Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

ESS1.C as found in MS-ESS2-3
- Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches.

ESS2.A as found in MS-ESS2-2
- The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

to ESS2.C and ESS2.D in Bundle 2

ESS2.B as found in MS-ESS2-3
- Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.

ESS2.C as found in MS-ESS2-2
- Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

to ESS2.C and ESS2.D in Bundle 2 and to PS2.A in Bundle 4

ESS3.A as found in MS-ESS3-1
- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.

to ESS2.C and ESS2.D in Bundle 2

Bundle 2

PS1.A as found in MS-PS1-1
- Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms.
- Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals).

PS1.A as found in MS-PS1-4
- 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 as found in MS-PS1-4
- 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.

PS3.B as found in MS-PS3-3
- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.

PS3.A as found in MS-PS3-3 and MS-PS3-4
- 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 as found in MS-PS3-4
- 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.

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Bundle 3

PS1.A as found in MS-PS1-2 and MS-PS1-3
- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

PS1.B as found in MS-PS1-2, MS-PS1-3, and MS-PS1-5
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

PS1.B as found in MS-PS1-5
- The total number of each type of atom is conserved, and thus the mass does not change.

PS1.B as found in MS-PS1-6
- Some chemical reactions release energy, others store energy.

ETS1.B as found in MS-PS1-6
- A solution needs to be tested, and then modified on the basis of the test results in order to improve it.

ETS1.B as found in MS-ETS1-3
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.
- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.

ETS1.C as found in MS-PS1-6 and MS-ETS1-3
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.

ETS1.C as found in MS-ETS1-3
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Bundle 4

PS2.A as found in MS-PS2-1
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).

PS2.A as found in MS-PS2-2
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

PS3.A as found in MS-PS3-1
- Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.

PS3.B as found in MS-PS3-5
- When the motion energy of an object changes, there is inevitably some other change in energy at the same time.

PS4.A as found in MS-PS4-1
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

PS4.A as found in MS-PS4-2
- A sound wave needs a medium through which it is transmitted.

PS4.B as found in MS-PS4-2
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Bundle 5

PS2.B as found in MS-PS2-3
- Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.

PS2.B as found in MS-PS2-4
- Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.

PS2.B as found in MS-PS2-5
- Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).

PS3.A as found in MS-PS3-2
- A system of objects may also contain stored (potential) energy, depending on their relative positions.

PS3.C as found in MS-PS3-2
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

ESS1.A as found in MS-ESS1-1
- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models.

ESS1.A as found in MS-ESS1-2
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

ESS1.B as found in MS-ESS1-2 and MS-ESS1-3
- The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

ESS1.B as found in MS-ESS1-1
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year.

ESS1.B as found in MS-ESS1-2
- The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

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ESS2.C as found in MS-ESS2-4
- Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land.
- Global movements of water and its changes in form are propelled by sunlight and gravity.

ESS2.C as found in MS-ESS2-5
- The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns.

ESS2.C as found in MS-ESS2-6
- Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents.

to PS1.B in Bundle 3

ESS2.D as found in MS-ESS2-6
- Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography all of which can affect oceanic and atmospheric flow patterns.
- The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents.

ESS2.D as found in MS-ESS2-5
- Because these patterns are so complex, weather can only be predicted probabilistically.

ETS1.A as found in MS-PS3-3
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

ETS1.B as found in MS-PS3-3 and MS-ETS1-4
- A solution needs to be tested, and then modified on the basis of the test results in order to improve it.

ETS1.B as found in MS-PS3-3
- There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.

ETS1.B as found in MS-ETS1-4
- Models of all kinds are important for testing solutions.

ETS1.C as found in MS-ETS1-4
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.