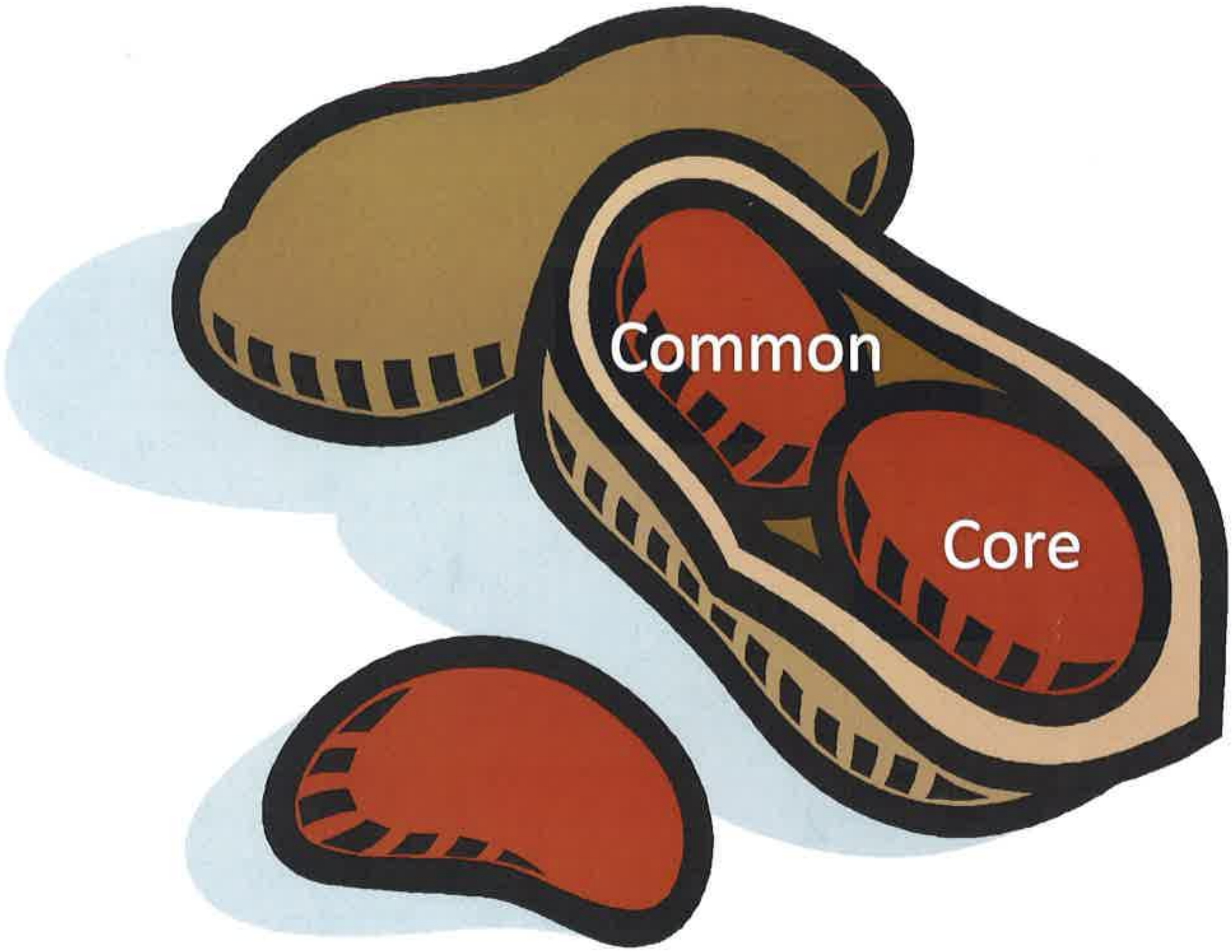


Physical Science for the 21st Century

Physical Science Progression

INCREASING SOPHISTICATION OF STUDENT THINKING

	K-2	3-5	6-8	9-12
PS1.A Structure of matter (includes PS1.C Nuclear processes)	Matter exists as different substances that have observable different properties. Different properties are suited to different purposes. Objects can be built up from smaller parts.	Because matter exists as particles that are too small to see, matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular materials.	The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.	The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter, including chemical reactions and nuclear processes. Repeating patterns of the periodic table reflect patterns of outer electrons. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy to take the molecule apart.
PS1.B Chemical reactions	Heating and cooling substances cause changes that are sometimes reversible and sometimes not.	Chemical reactions that occur when substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.	Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy.	Chemical processes are understood in terms of collisions of molecules, rearrangement of atoms, and changes in energy as determined by properties of elements involved.
PS2.A Forces and motion	Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it.	The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force.	Newton's 2nd law (F=ma) and the conservation of momentum can be used to predict changes in the motion of macroscopic objects.
PS2.B Types of interactions			Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object.	Forces at a distance are explained by fields that can transfer energy and can be described in terms of the arrangement and properties of the interacting objects and the distance between them. These forces can be used to describe the relationship between electrical and magnetic fields.
PS2.C Stability & instability in physical systems	N/A	N/A	N/A	N/A
PS3.A Definitions of energy	N/A	Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form.	Kinetic energy can be distinguished from the various forms of potential energy. Energy changes to and from each type can be tracked through physical or chemical interactions. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter.	The total energy within a system is conserved. Energy transfer within and between systems can be described and predicted in terms of energy associated with the motion or configuration of particles (objects).
PS3.B Conservation of energy and energy transfer	[Content found in PS3.D]			Systems move toward stable states.

Performance Expectations – Physical Science – Middle School

Next Generation Science Standards

<table>
<tr><th colspan="2">Forces and Interactions</th></tr>
<tr><th>Disciplinary Core Idea</th><th>Crosscutting Concepts</th></tr>
<tr><td>PS2.A: Forces and Motion
• 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). (MS-PS2-1)
• 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. (MS-PS2-2)\
• 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. (MS-PS2-2)
PS2.B: Types of Interactions
• Electrical 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. (MS-PS2-3).
• 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). (MS-PS2-4)
• Forces that act at a distance (electrical, 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, a magnet, or a ball respectively). (MS-PS2-5)</td><td>Cause and Effect
• Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3), (MS-PS2-5)

Systems and System Models
• Models can be used to represent systems and their interactions- such as inputs, processes, and outputs – and energy and matter flows within systems. (MS PS2-1), (MS-PS2-4)

Stability and Change
• Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-PS2-2)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World
• The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. (MS-PS2-1)</td></tr>
</table>

How to plan lessons around NGSS

Questions: 1) What do my students need to know? 2) What do my students need to be able to do? 3) Where do I get the material that I need to teach them what they need to know

Performance Expectations – Physical Science – High School

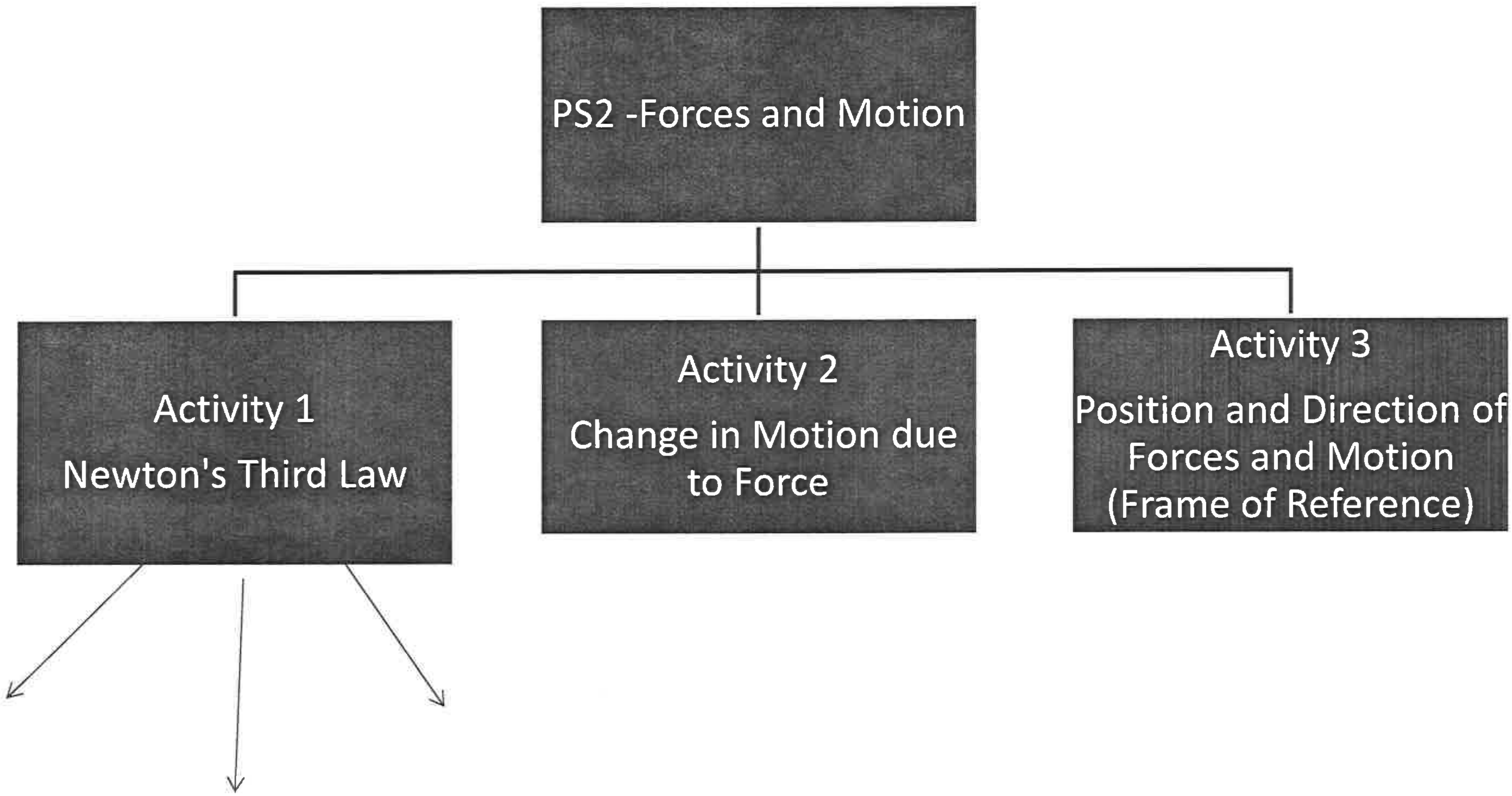
Next Generation Science Standards

<table>
<tr><th colspan="2">Forces and Interactions</th></tr>
<tr><th>Disciplinary Core Idea</th><th>Crosscutting Concepts</th></tr>
<tr><td>PS2.A: Forces and Motion
• Newton's Second Law accurately predicts changes in the motion of macroscopic objects (HS-PS2-1)
• Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2)
• If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system (HS-PS2-2), (HS-PS2-3)
PS2.B: Types of Interactions
• Newton's Law of Universal Gravitation and Coulomb's Law provide the mathematical models to describe and predict the gravitational and electrostatic forces between distant objects. (HS-PS2-4)
• Forces at a distance are explained by fields (gravitational, electrical, and magnetic) permeating space that can transfer energy through space. Magnets or electrical currents cause magnetic fields; electrical charges or changing magnetic fields cause electrical fields (HS-PS2-4), (HS-PS2-5)
PS3.A: Definitions of Energy
• "Electrical energy" may mean energy stored in a battery or energy transmitted by electrical currents. (secondary to HS-PS2-5)
ETS1.A: Defining and Delimiting Engineering Problems
• Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS2-3)
ETS1.C: Optimizing the Design Solution
• Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (secondary to HS-PS2-3)</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS2-4)

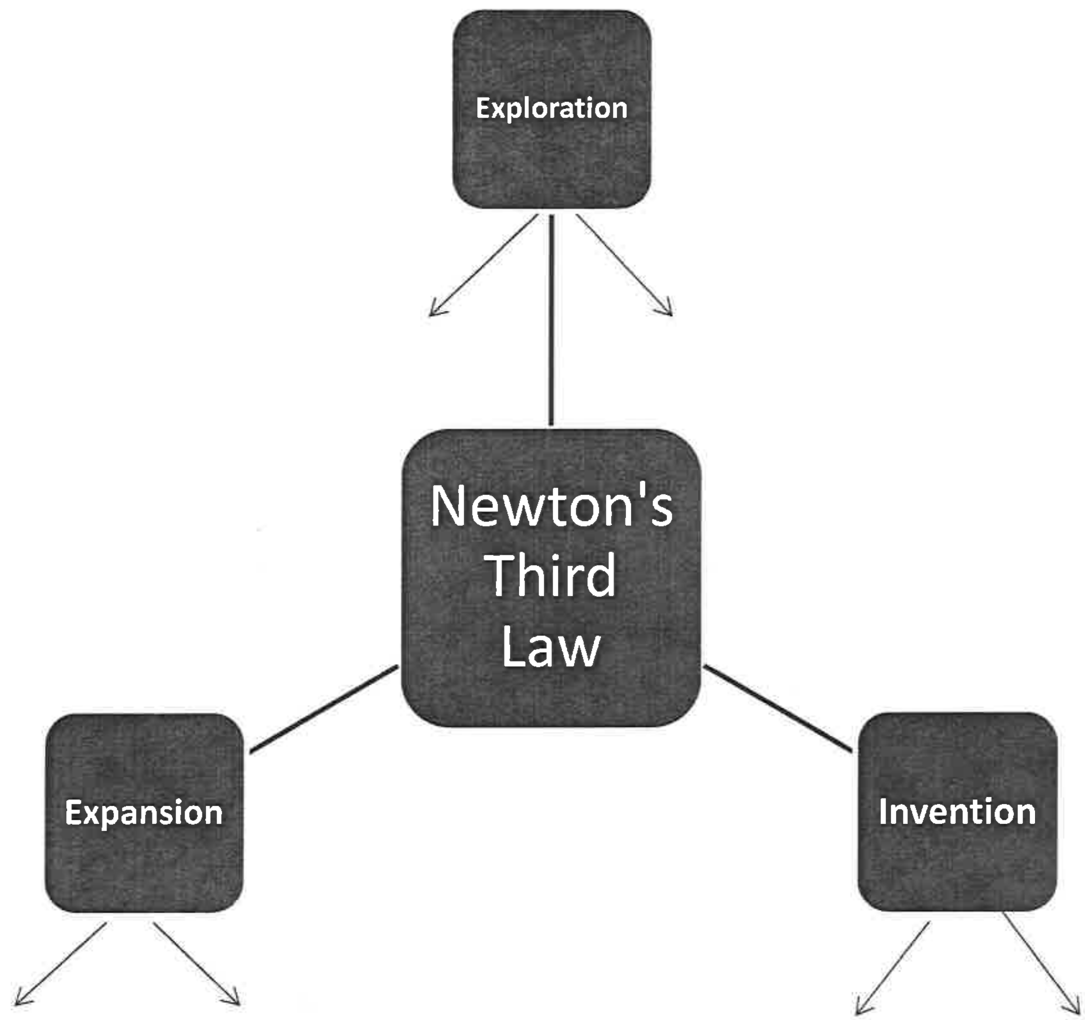
Cause and Effect
• Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1), (HS-PS2-5)
• Systems can be designed to cause a desired effect. (HS-PS2-3)

Systems and System Models
• When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)</td></tr>
</table>

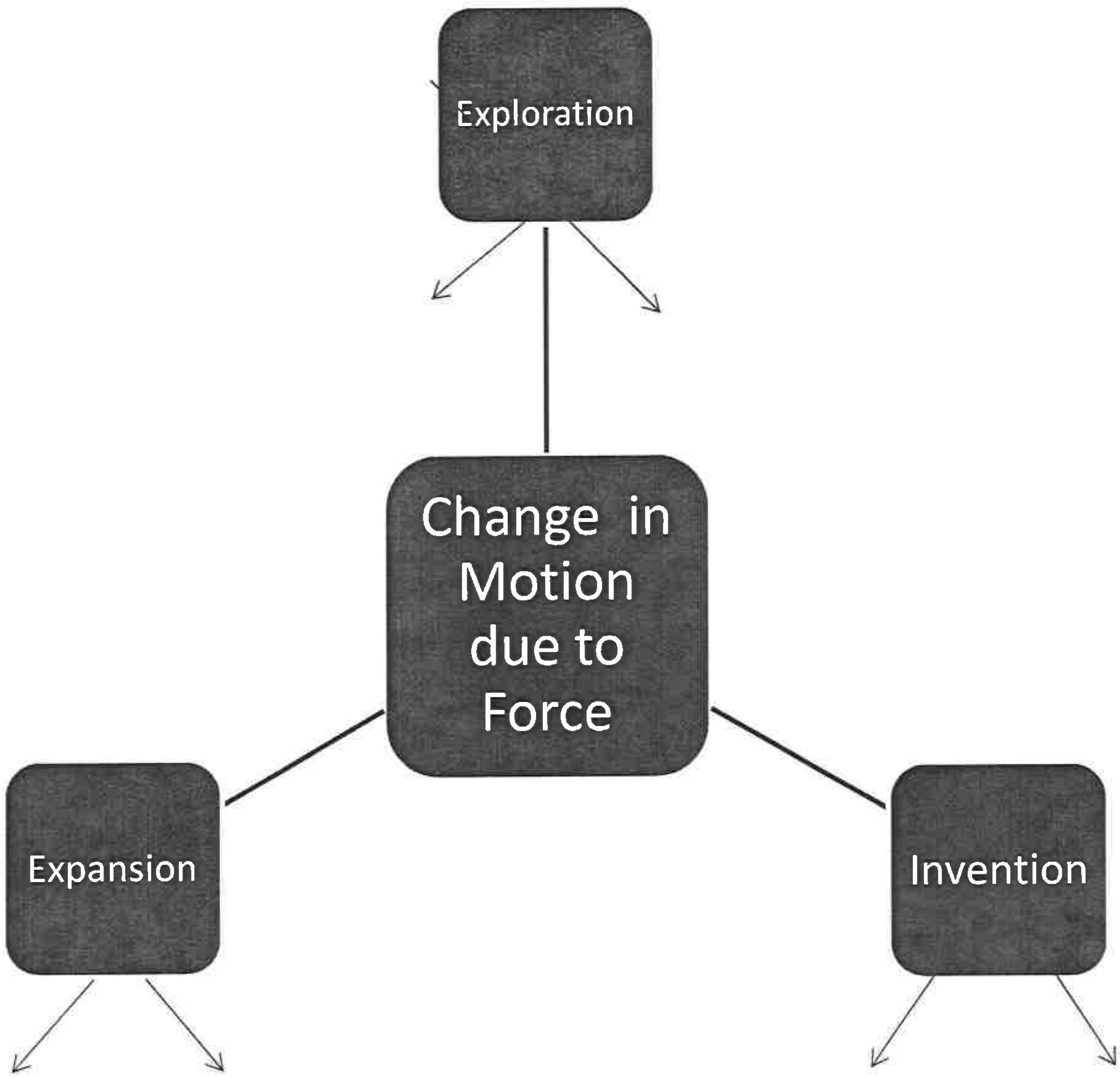
Middle/High School – Physical Science



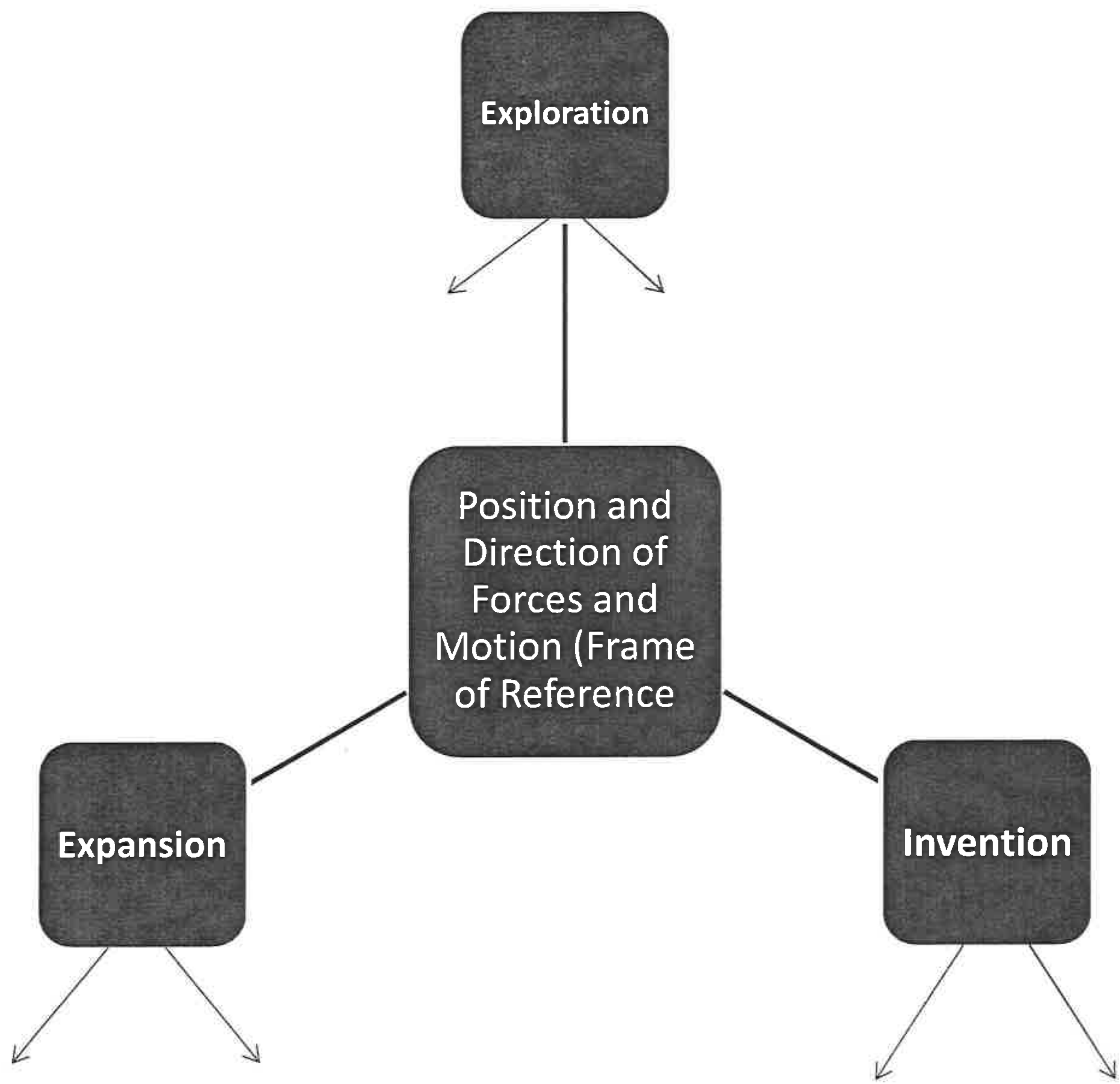
Learning Cycle – Newton's Third Law



Learning Cycle – Change in Motion Due to Force



Learning Cycle –



Performance Expectations – Physical Science – Middle School

Next Generation Science Standards

Energy	
Disciplinary Core Idea	**Crosscutting Concepts**
PS3.A: Definitions of Energy • 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. (MS-PS3-1) • A system of objects may also contain stored (potential) energy, depending on their relative positions. (MS-PS3-2) • 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. (MS-PS3-3), (MS-PS3-4) PS3.B: Conservation of Energy and Energy Transfer • When the kinetic energy of an object changes, there is inevitably some other change in energy at the same time. (MS-PS3-5) • 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. (MS-PS3-4) • Energy is spontaneously transferred out of hotter regions or objects and into colder ones. (MS-PS3-3) PS3.C: Relationship Between Energy and Forces • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. (MS-PS3-2) ETS1.A: Defining and Delimiting an Engineering Problem • 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 is likely to limit possible solutions. (secondary to MS-PS3-3) ETS1.B: Developing Possible Solutions • A solution needs to be tested and the modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (secondary to MS-PS3-3)	Scale, Proportion, and Quantity • Proportional relationships (e.g., speed as the ration of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. (MS-PS3-1), (MS-PS3-4). Systems and System Models • Models can be used to represent systems and their interactions- such as inputs, processes, and outputs – and energy and matter flows within systems. (MS PS2-1), (MS-PS2-4) Energy and Matter • Energy may take different forms (e.g., energy in fields, thermal energy, energy of motion). (MS-PS3-5) • The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-3)

Performance Expectations – Physical Science – High School

Next Generation Science Standards

<table>
<tr><th colspan="2">Energy</th></tr>
<tr><th>Disciplinary Core Idea</th><th>Crosscutting Concepts</th></tr>
<tr><td>
PS3.A: Definitions of Energy

Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy is due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-1), (HS-PS3-2)
At a macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) (HS-PS3-3)
These relationships are better understood at the microscopic scale, at which all the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2)

PS3.B: Conservation of Energy and Energy Transfer

Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. (HS-PS3-1)
Energy cannot be created or destroyed, but it can be transported form one place to another and transferred between systems. (HS-PS3-1), (HS-PS3-4)
Mathematical expressions, which quantify how the stored energy in a system depends on its configuration (e.g., relative positions of charged particles, compression of a spring) and how kinetic energy depends on mass and speed, allow the concept of conservation of energy to be used to predict and describe system behavior. (HS-Ps3-1)
The availability of energy limits what can occur in any system. (HS-PS3-1)
Uncontrolled systems always evolve toward more stable states – that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their

</td><td>
Cause and Effect

Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller-scale mechanisms within the system. (HS-PS3-5)

Systems and System Models

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models. (HS-PS3-4)
Models can be used to predict the behavior of a system but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. (HS-PS3-1)

Energy and Matter

Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3)
Energy cannot be created or destroyed – it only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2)

Connections to Engineering, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World

Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. (HS-PS3-3)

Connection to Nature of Science
Scientific Knowledge Assumes an Order and Consistency in Natural Systems

Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS3-1)

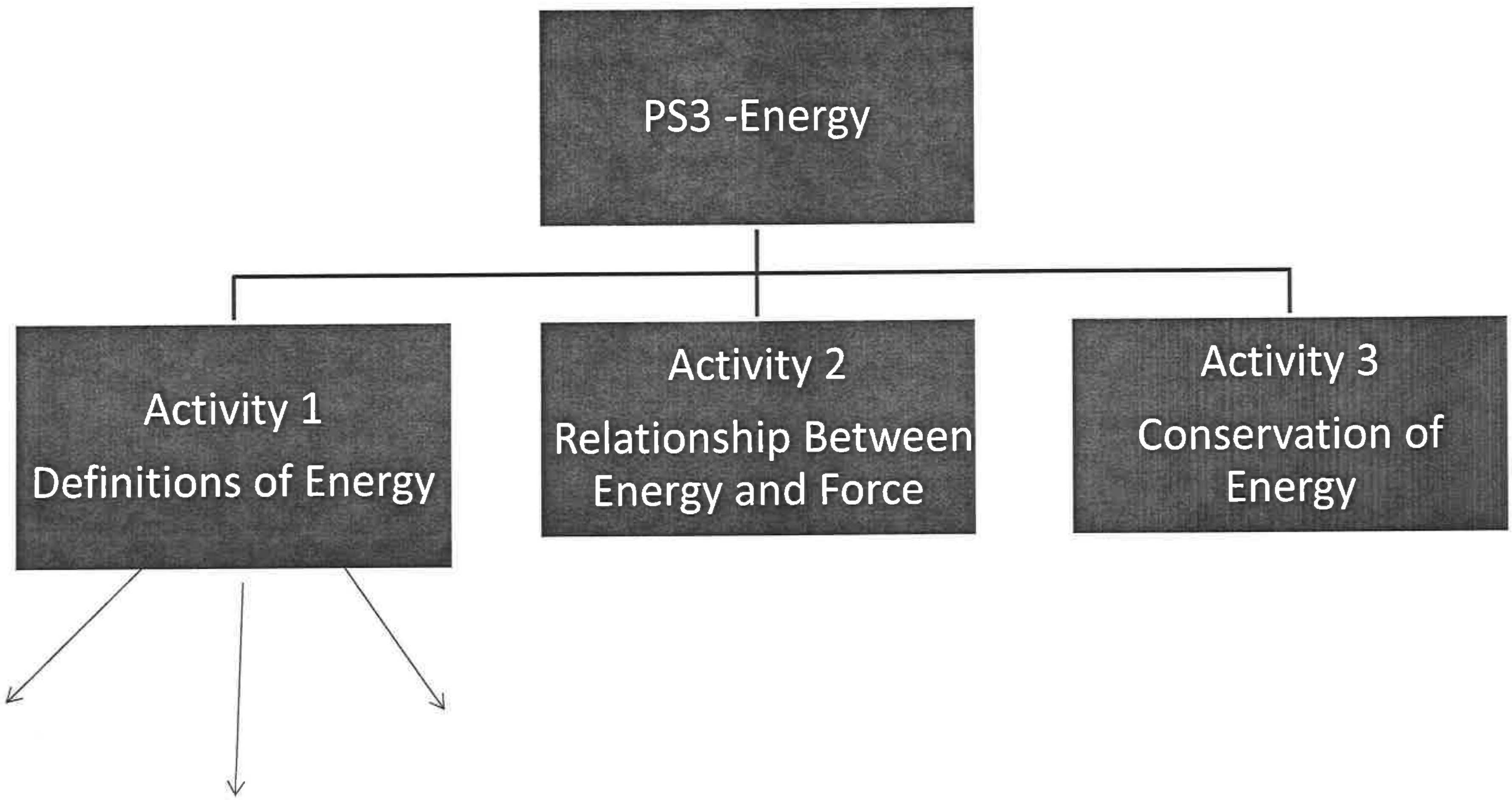
</td></tr>
</table>

surrounding environment cool down). (HS-PS3-4) PS3.C: Relationship Between Energy and Forces • When two objects interacting through a field change relative position, the energy stored in the field is changed. (HS-PS3-5) PS3.D: Energy in Chemical Processes • Although energy cannot be destroyed, it can be converted to less useful forms – for example, to thermal energy in the surrounding environment. (HS-PS3-3), (HS-PS3-4) ETS1.A: Defining and Delimiting Engineering Problems • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (secondary to HS-PS3-3)	

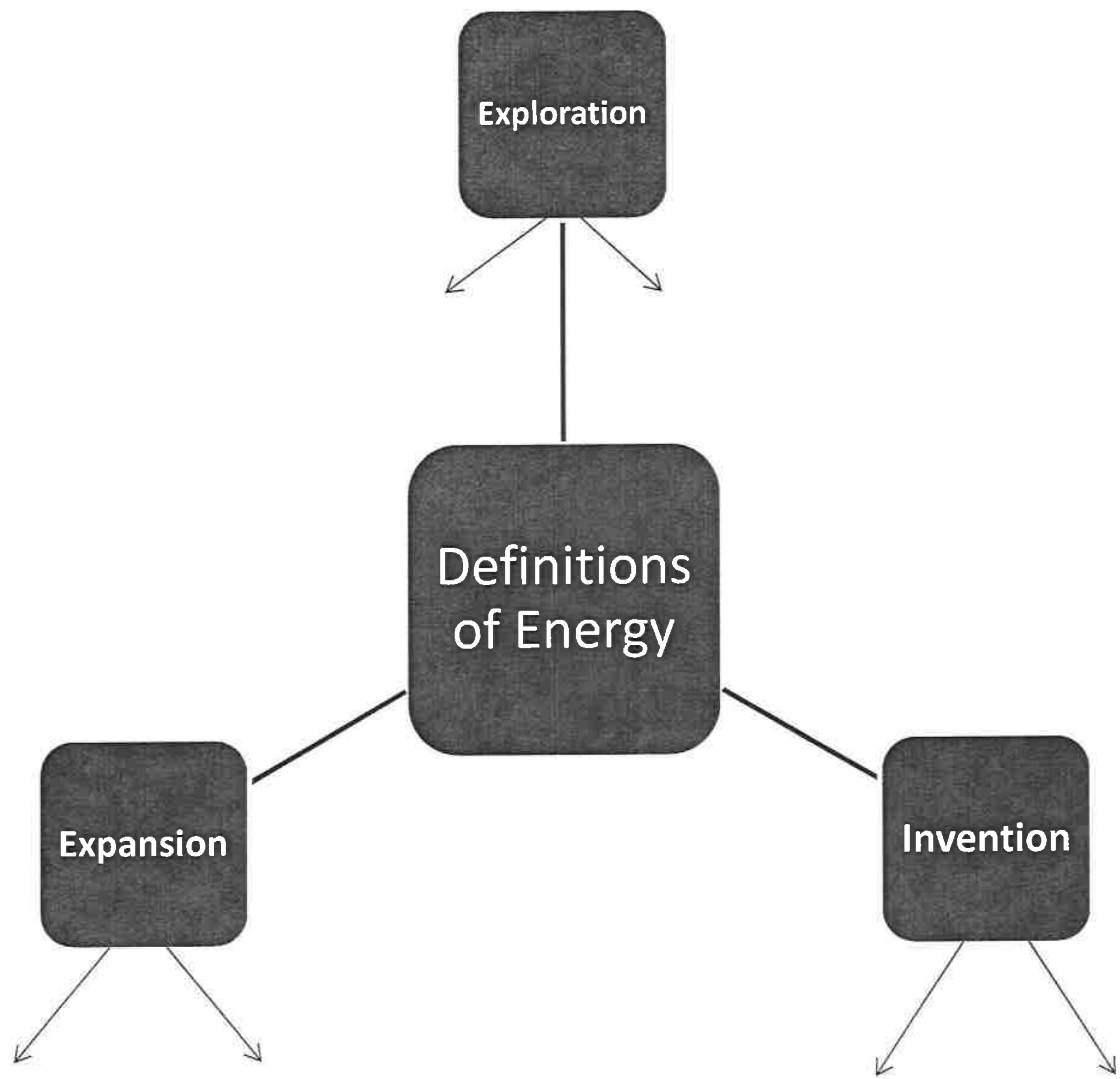
How to plan lessons around NGSS

Questions: 1) What do my students need to know? 2) What do my students need to be able to do? 3) Where do I get the material that I need to teach them what they need to know and do? 4) To what other science areas is this topic related? 5) How do I assess the content knowledge and scientific skills learned?

Middle/High School – Physical Science

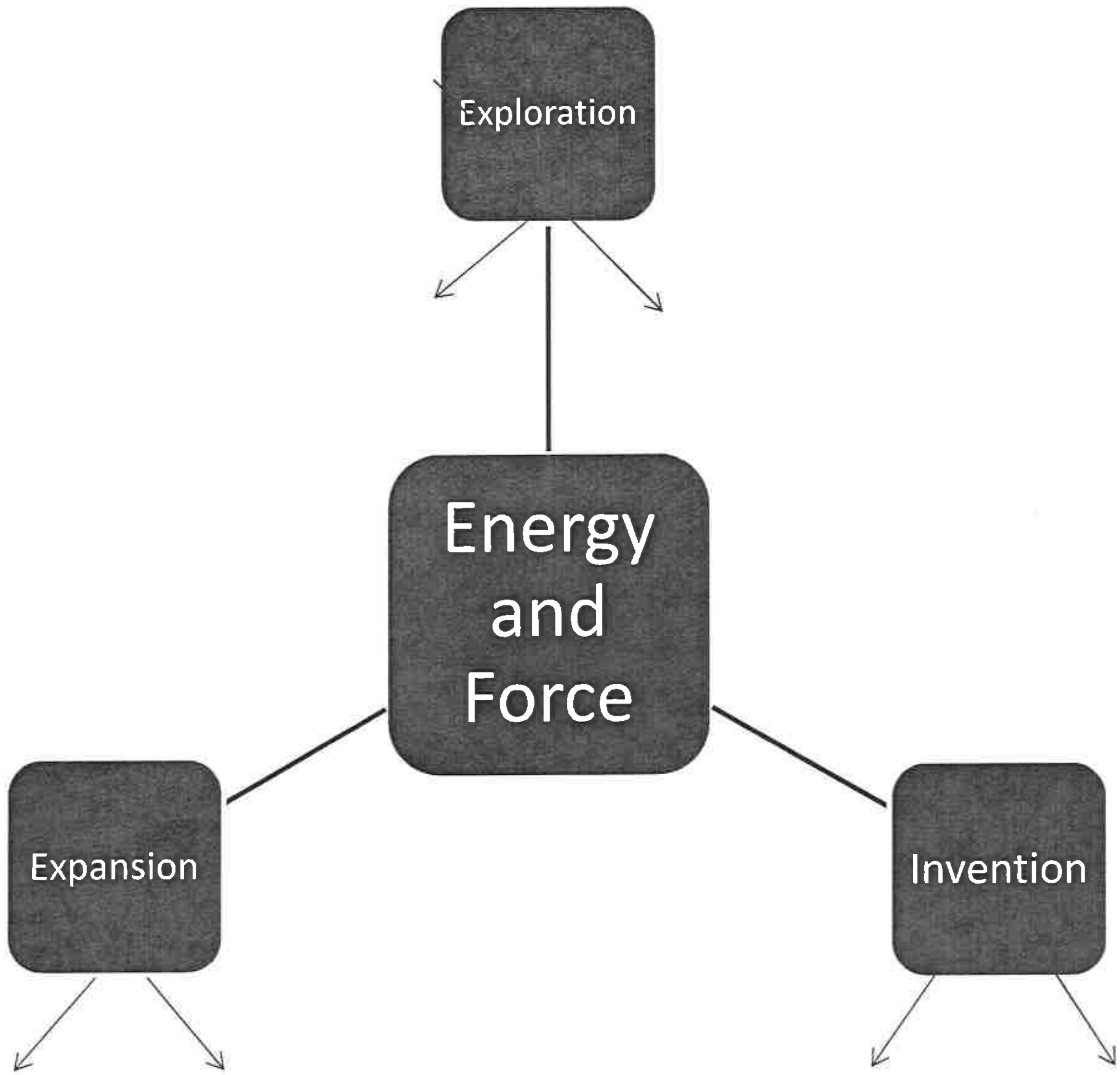


Learning Cycle – Definitions of Energy

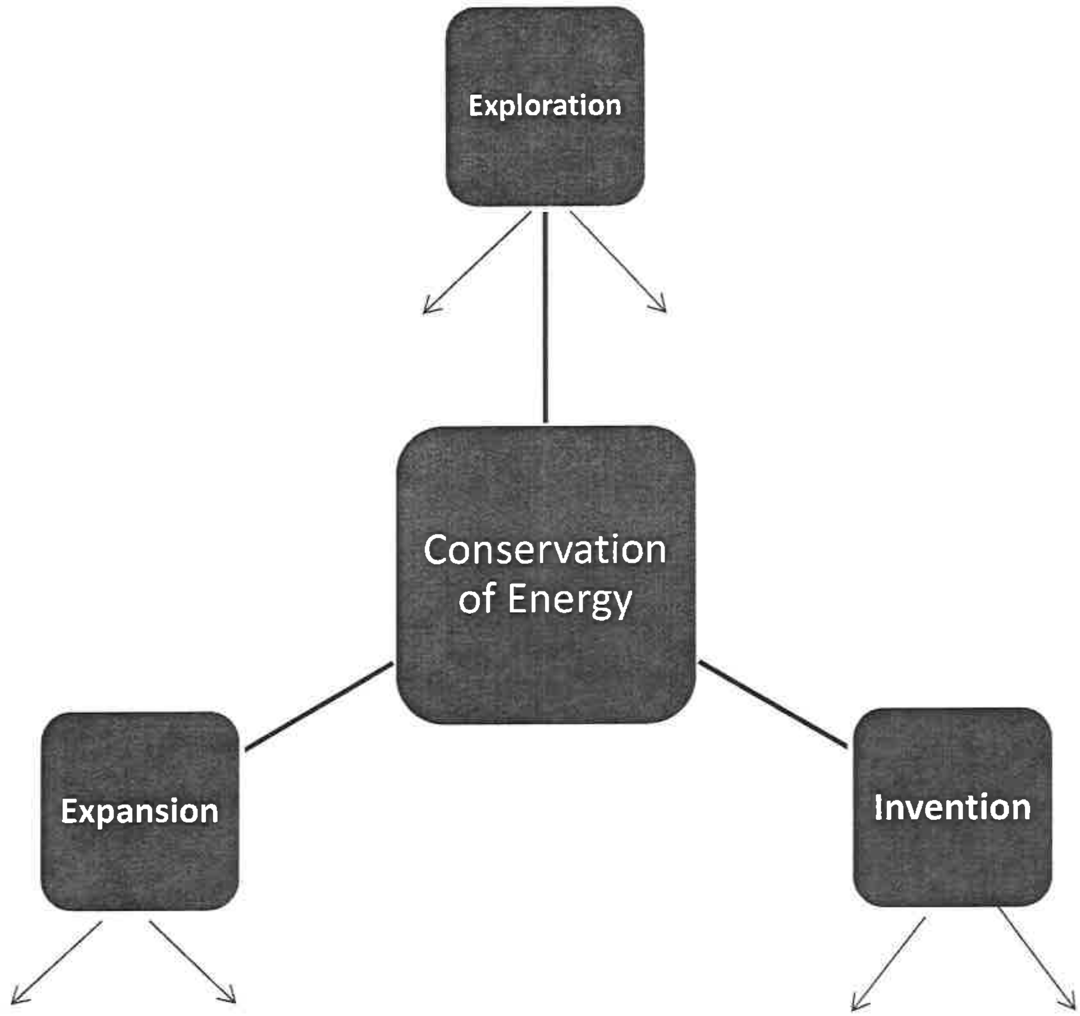


Middle/High School – Physical Science

Learning Cycle – Relationship Between Energy and Force



Learning Cycle – Conservation of Energy



Performance Expectations – Physical Science – Middle School

Next Generation Science Standards

Structure and Properties of Matter	
Disciplinary Core Idea	**Crosscutting Concepts**
PS1.A: Structure and Properties of Matter • Substances are made from different types of atoms, which combine with one another in various ways. Atoms from molecules that range in size from two to thousands of atoms. (MS-PS1-1) • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-3) • Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. (MS-PS1-4) • In a liquid, the molecules are constantly in contact with others; in a gas, they collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. (MS-PS1-4) • Solids may be formed from molecules, or they may be extended structures with repeating sub-units (e.g., crystals) • The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (MS-PS1-4) **PS1B: Chemical Reactions** • 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. (MS-PS1-3) **PS2A: Definitions of Energy** • 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 relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems (MS-PS1-4) **Scale, Proportion, and Quantity** • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1) **Structure and Function** • Structures can be designed to serve particular functions by taking into account properties of different materials and how materials can be shaped and used. (MS-PS1-3) **Interdependence of Science, Engineering, and Technology** • Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS1-3) **Influence of Science Engineering and Technology on Society and the Natural World** • The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time. (MS-PS1-3)

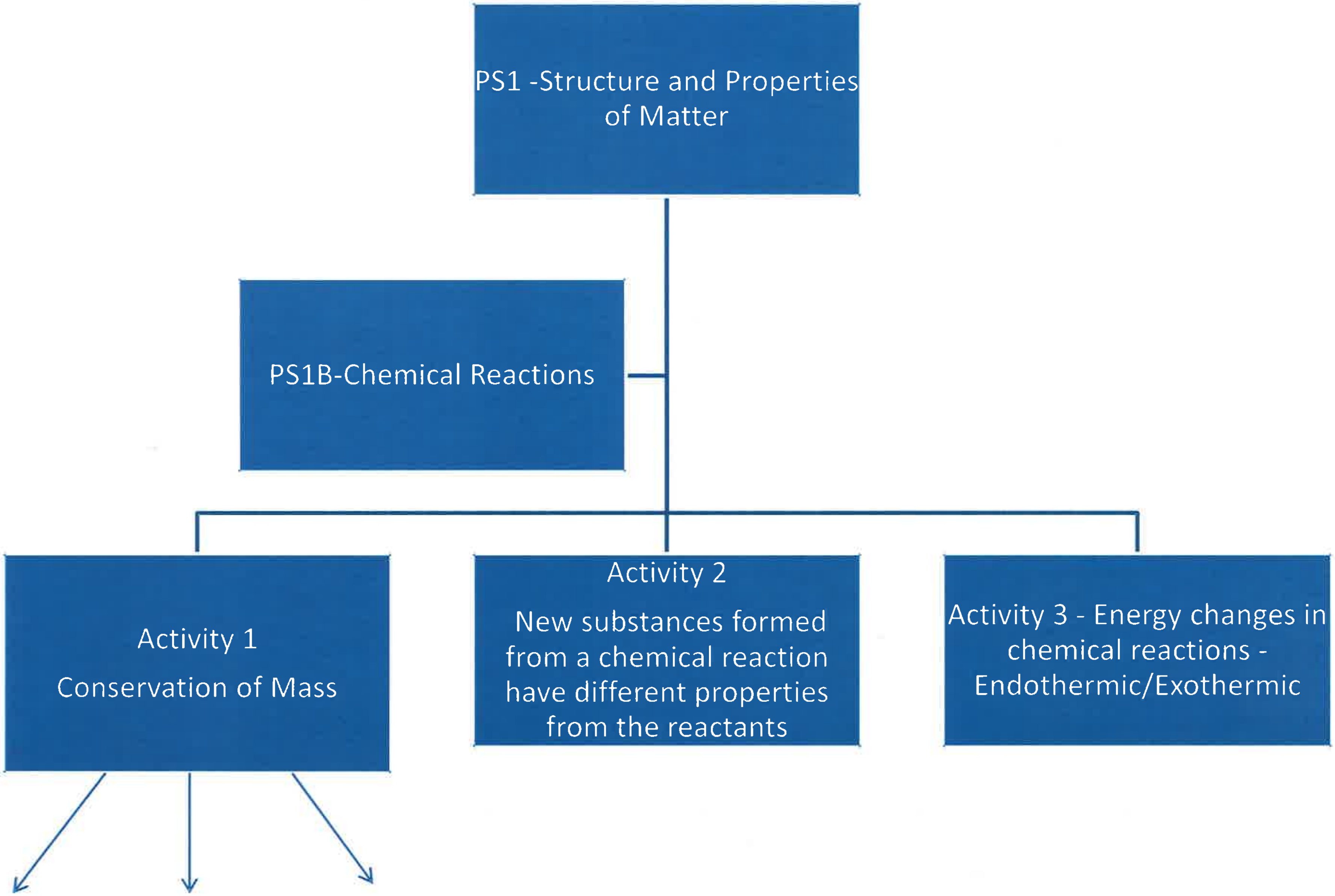
Performance Expectations – Physical Science – Middle School

Next Generation Science Standards

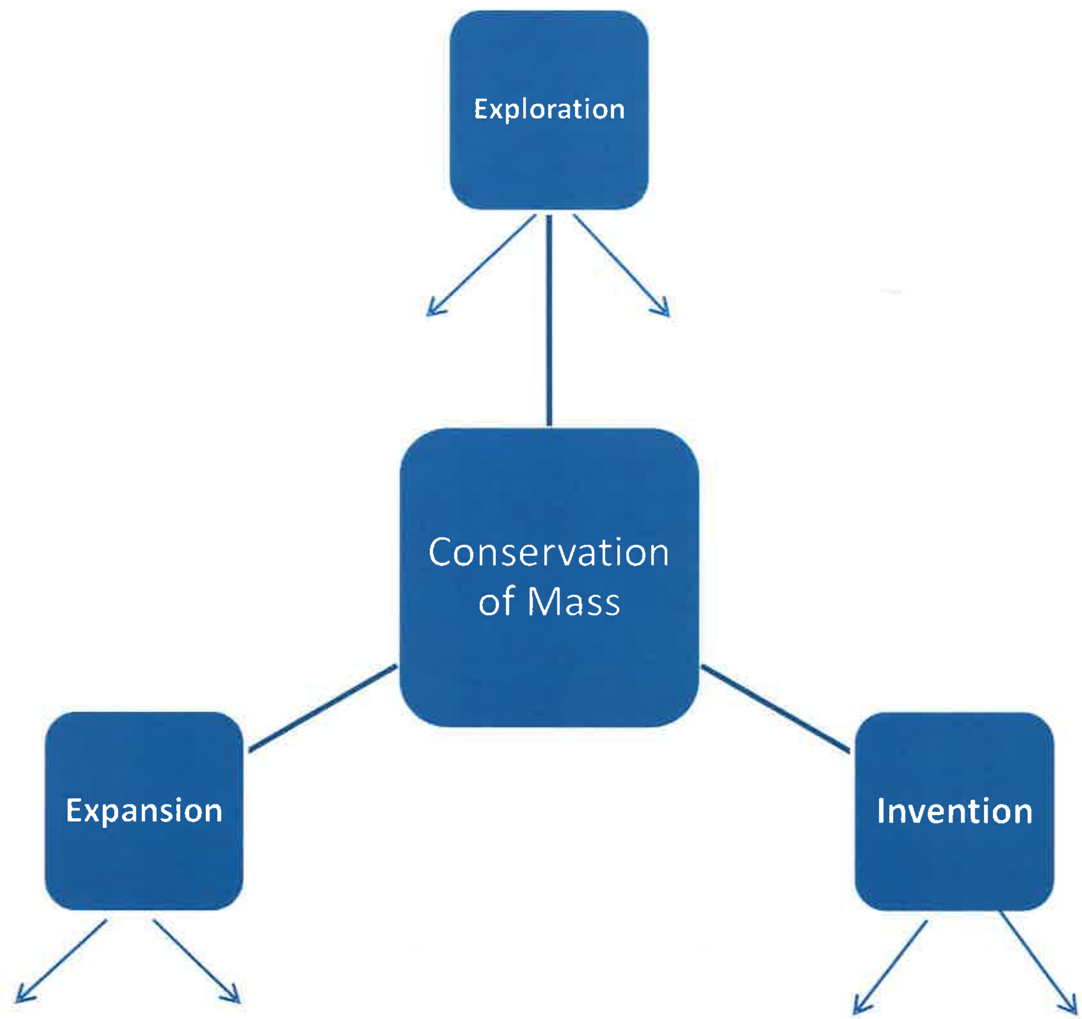
How to plan lessons around NGSS

Questions: 1) What do my students need to know? 2) What do my students need to be able to do? 3) Where do I get the material that I need to teach them what they need to know and do? 4) To what other science areas is this topic related? 5) How do I assess the content knowledge and scientific skills learned?

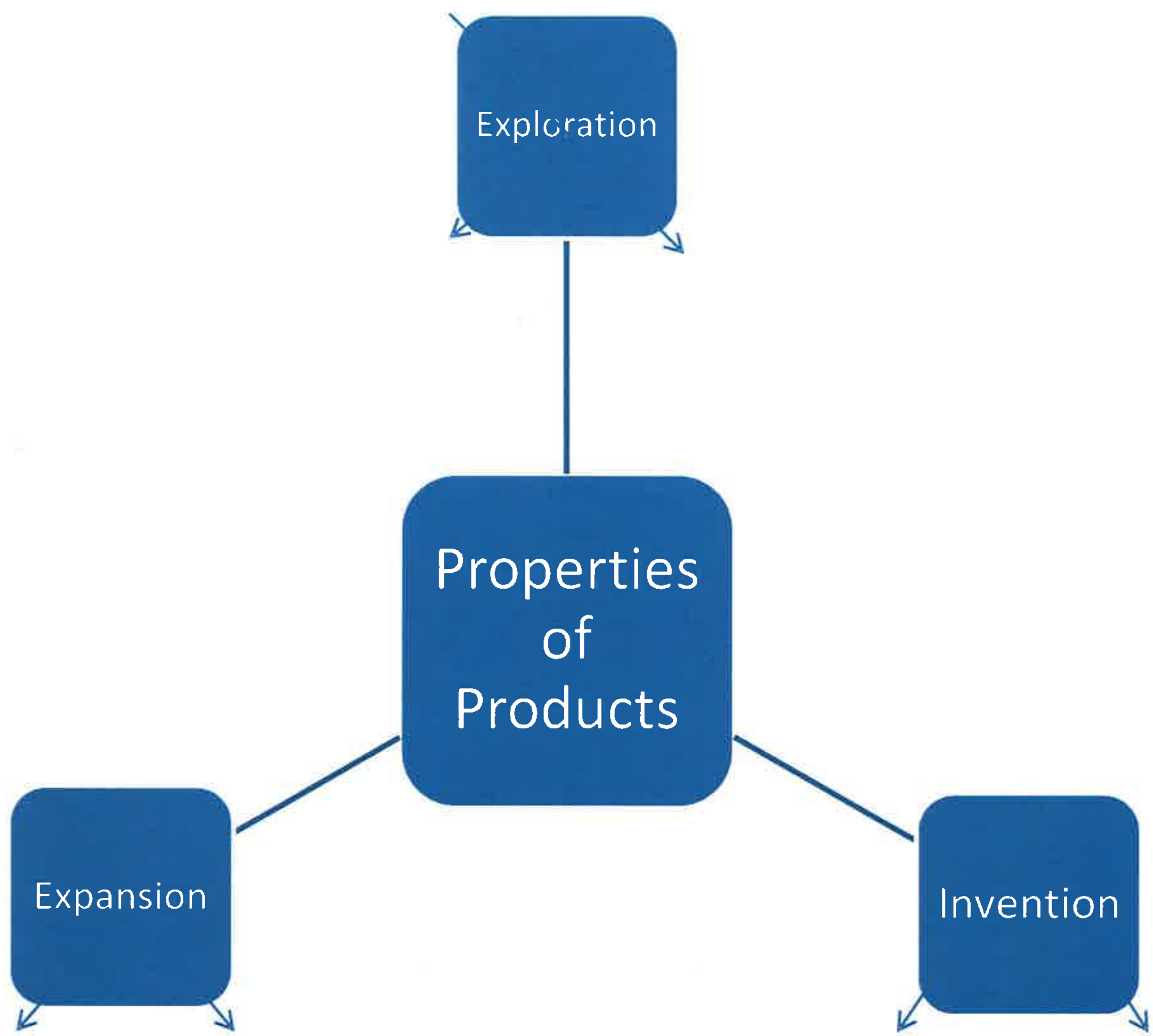
Middle School – Physical Science



Learning Cycle – Conservation of Mass

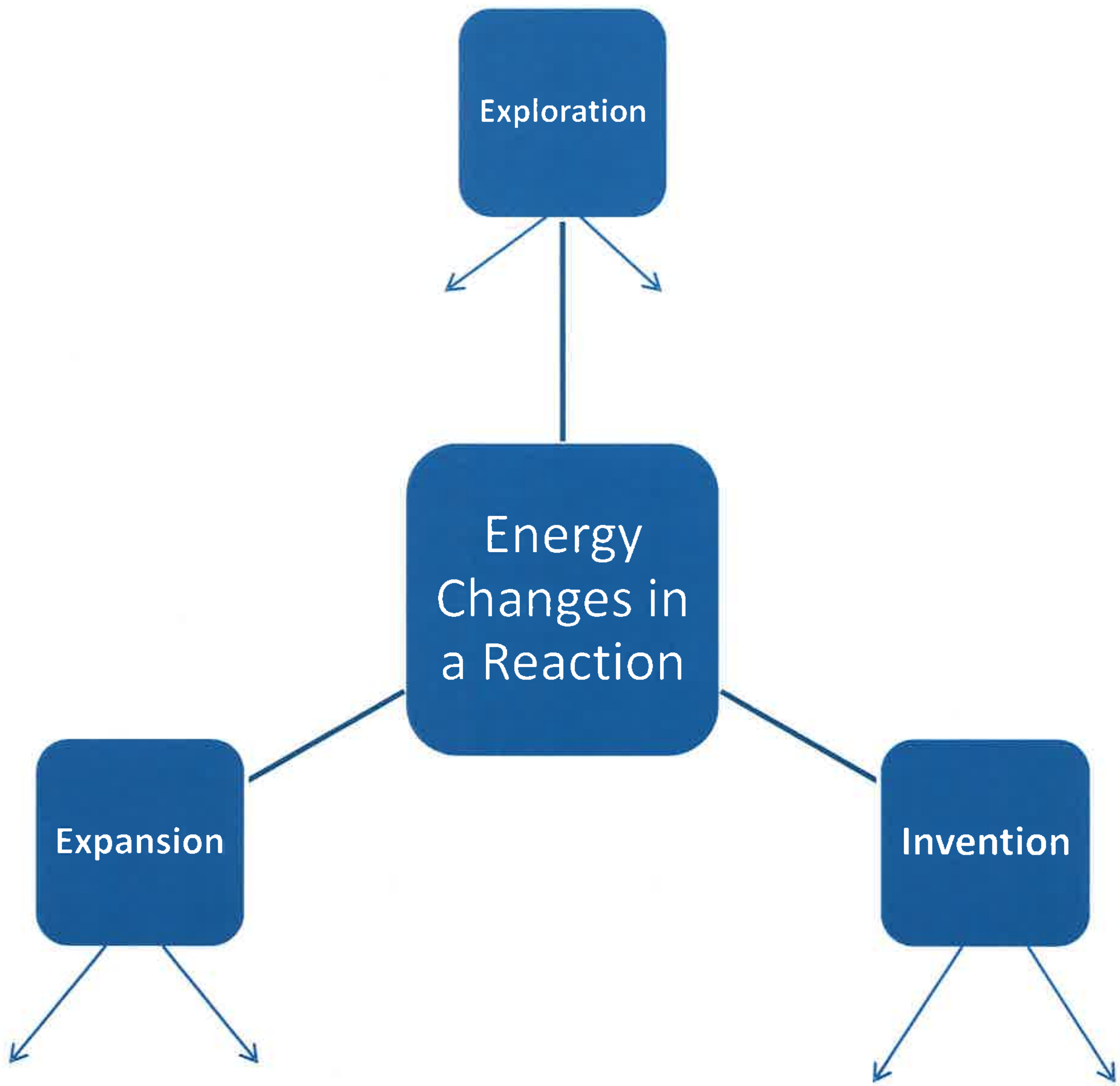


Learning Cycle – Changes in Properties of Products in a Reaction



Middle School – Physical Science

Learning Cycle – Energy Changes in a Chemical Reaction



Performance Expectations – Physical Science – High School

Next Generation Science Standards

<table>
<tr><th colspan="2">Structure and Properties of Matter</th></tr>
<tr><th>Disciplinary Core Idea</th><th>Crosscutting Concepts</th></tr>
<tr><td>HS-PS1.A: Structure and Properties of Matter
• Each atom has a charged sub-structure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons (HS-PS1-1)
• The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1), (HS-PS1-2)
• The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3) (secondary to HS-PS2-6)</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1), HS-PS1-3)</td></tr>
<tr><td>PS1.C: Nuclear Processes
• Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process. (HS-PS1-8)
PS2.B: Types of Interactions
• Attraction and repulsion between electrical charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects (HS-PS2-6)</td><td>Energy and Matter
• In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. (HS-PS1-8)
Structure and Function
• Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal the structure's function and/or to solve a problem. (HS-PS2-6)</td></tr>
<tr><td>HS-PS1.B: Chemical Reactions
• The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1), (HS-PS1-2) (Also addressed by HS-PS1-1)
• A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. (HS-PS1-4)
• Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of collisions of molecules and the rearrangements of atoms into new molecules, and with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. (HS-PS1-5)</td><td>Patterns
• Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. (HS-PS1-1), HS-PS1-3)
Energy and Matter
• The total amount of energy and matter in closed systems is conserved (HS-PS1-7)
• Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of and within that system. (HS-PS1-4)
Stability and Change
• Much of science deals with constructing explanations of how things change and how they remain stable. (HS-PS1-6)</td></tr>
</table>

Performance Expectations – Physical Science – High School

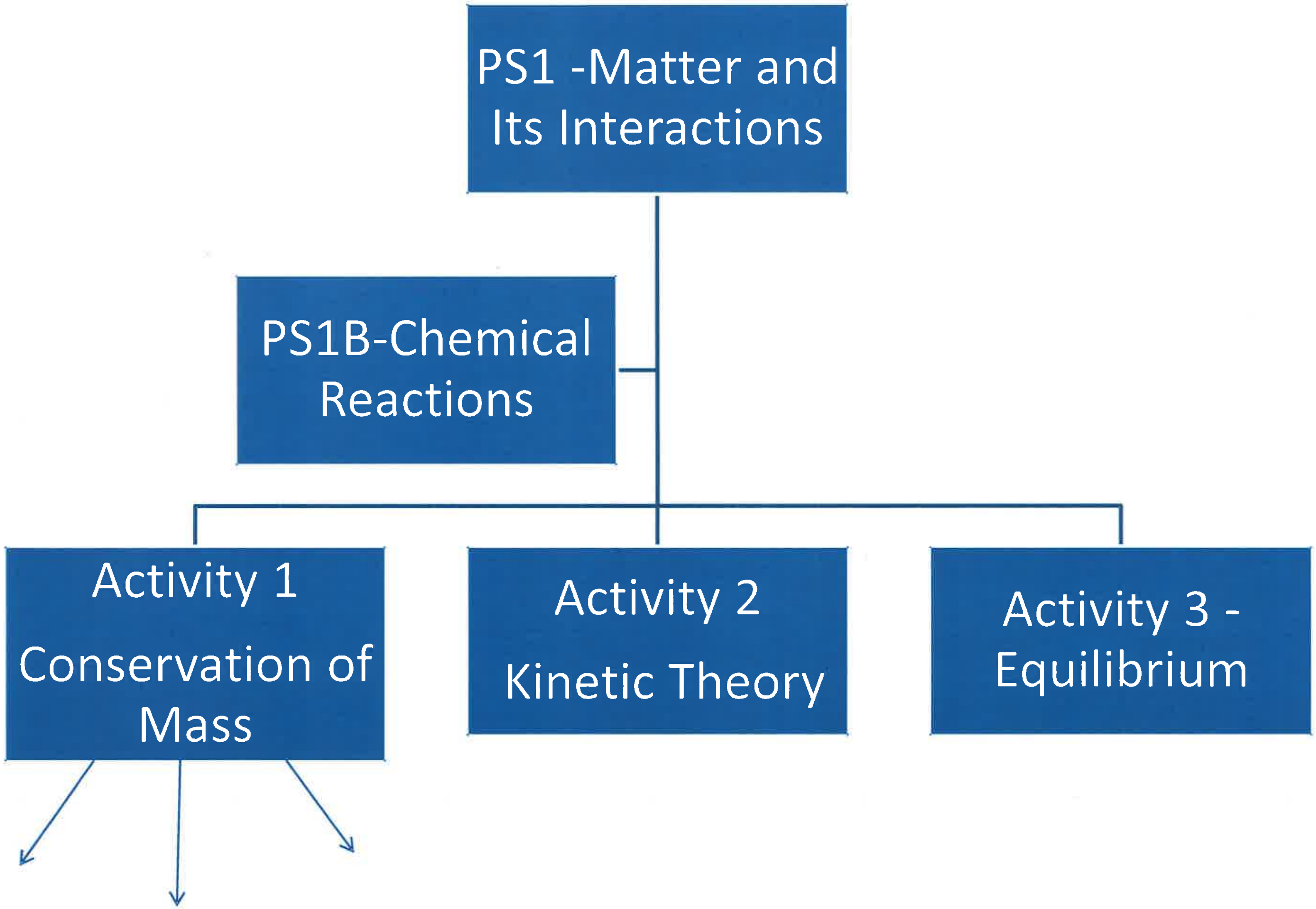
Next Generation Science Standards

HS-PS1B: Chemical Reactions	Connections to Nature of Science
• In many situations a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the number of all types of molecules present (HS-PS1-6) • The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. (HS-PS1-2), (HS-PS1-7)	Scientific Knowledge Assumes an Order and Consistency in Natural Systems • Science assumes the universe is a vast single system in which basic laws are consistent. (HS-PS1-7)

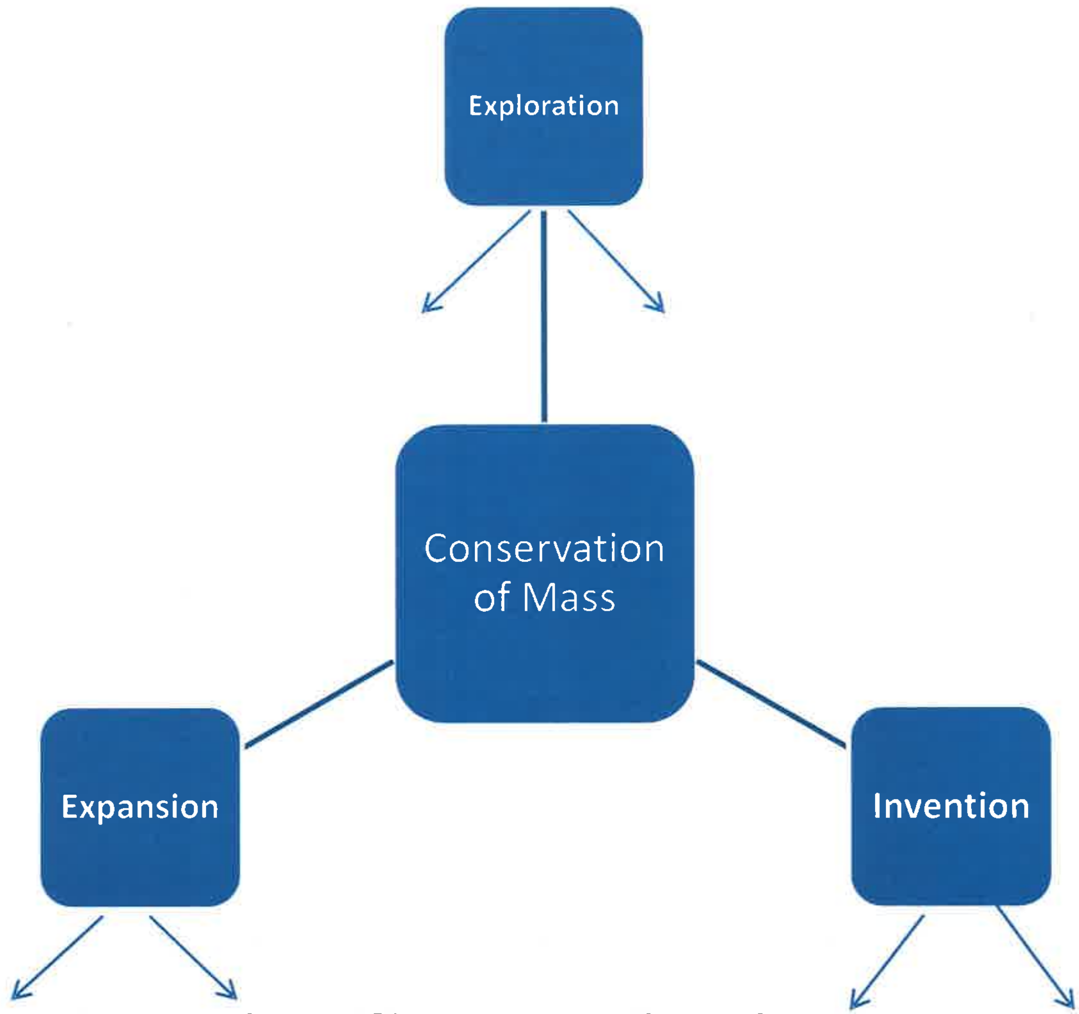
How to plan lessons around NGSS

Questions: 1) What do my students need to know? 2) What do my students need to be able to do? 3) Where do I get the material that I need to teach them what they need to know and do? 4) To what other science areas is this topic related? 5) How do I assess the content knowledge and scientific skills learned?

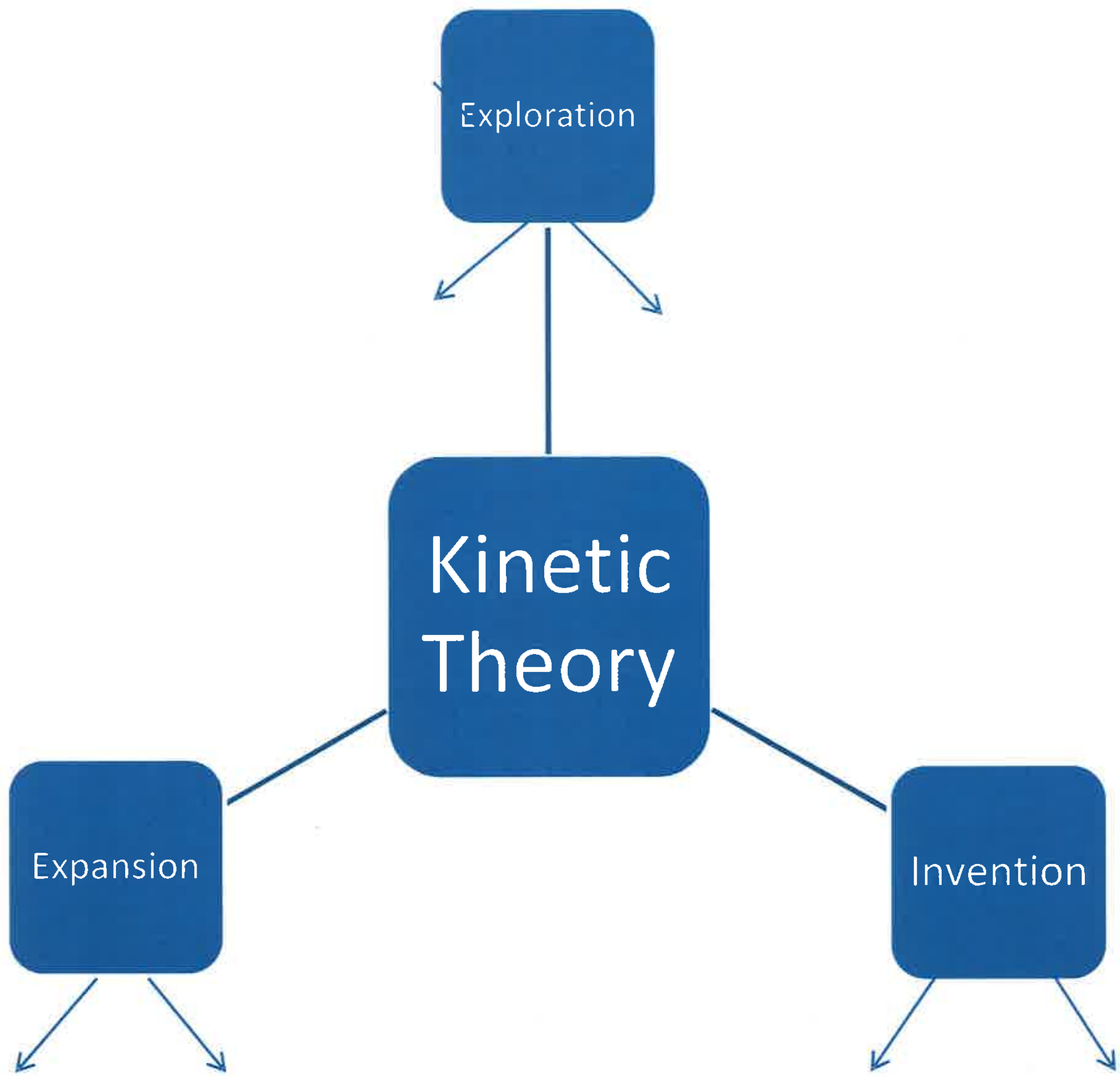
High School – Physical Science



Learning Cycle – Conservation of Mass

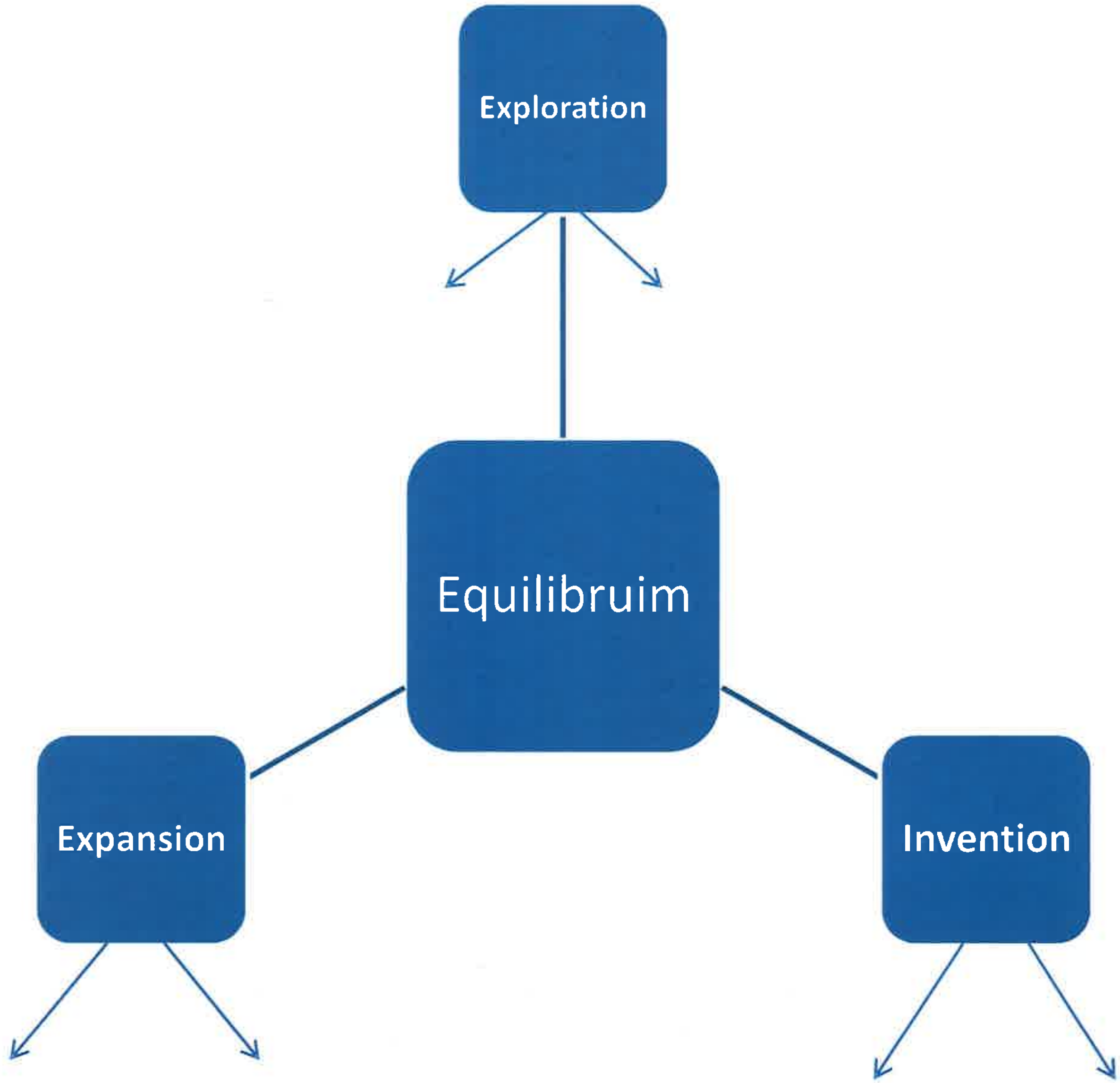


Learning Cycle – Kinetic Theory



Learning Cycle - Equilibrium

High School – Physical Science



Science and Engineering Practices

Checklist for Lesson Planning

For each of your lesson plans, use the checklist below to determine which, if any of the science and engineering practices has been included in your plan. You do not have to include every practice with each lesson plan, but some of the practices should be included within the overall unit plan of Structure and Properties of Matter (MS –PS1 and HS – PS1).

Science and Engineering Practices	Missing	Partial (Contains some of the practice but is not complete. For example you plan an investigation but do not have them identify the variables.)	Complete
#1 – Asking Questions and Defining Problems			
#2 – Developing and Using Models			
#3 – Planning and Carrying Out Investigations			
#4 –Analyzing and Interpreting Data			
#5 – Using Mathematics and Computational Thinking			
#6 – Constructing Explanations and Designing Solutions			
#7 – Engaging in Argument from Evidence			
#8 – Obtaining, Evaluating and Communicating Information			

Science and Engineering Practices

Practice #1 - Asking Questions and Defining Problems

Grades 6-8	*Grades 9-12*

Asking questions and defining problems in 6–8 builds on K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.
 	
• Ask questions
  o that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
  o to identify and/or clarify evidence and/or the premise(s) of an argument.
  o to determine relationships between independent and dependent variables and relationships in models.
  o to clarify and/or refine a model, an explanation, or an engineering problem.
  o that require sufficient and appropriate empirical evidence to answer.
  o that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles that challenge the premise(s) of an argument or the interpretation of a data set.
 	
• Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.
	Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.
	
	• Ask questions
	  o that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.
	  o that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
	  o to determine relationships, including quantitative relationships, between independent and dependent variables.
	  o to clarify and refine a model, an explanation, or an engineering problem.
	• Evaluate a question to determine if it is testable and relevant
	• Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
	• Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.
	• Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations

Notes:

Practice #2 – Developing and Using Models

Grades 6-8	Grades 9-12
Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Evaluate limitations of a model for a proposed object or tool. • Develop or modify a model— based on evidence – to match what happens if a variable or component of a system is changed. • Use and/or develop a model of simple systems with uncertain and less predictable factors. • Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena. • Develop and/or use a model to predict and/or describe phenomena. • Develop a model to describe unobservable mechanisms. • Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.	Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. • Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria. • Design a test of a model to ascertain its reliability • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. • Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. • Develop a complex model that allows for manipulation and testing of a proposed process or system. • Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Notes:

Practice #3 – Planning and Carrying Out Investigations

<table>
<tr><th>Grades 6-8</th><th>Grades 9-12</th></tr>
<tr><td>Planning and carrying out investigations in 6-8 builds on K-5 experiences and progresses to include investigations that use <u>multiple variables</u> and provide evidence to support explanations or solutions.

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.
Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
Evaluate the accuracy of various methods for collecting data.
Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
Collect data about the performance of a proposed object, tool, process or system under a range of conditions
</td>
<td>Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts.
Select appropriate tools to collect, record, analyze, and evaluate data.
Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.
Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.
</td></tr>
</table>

Notes:

Practice 4 – Analyzing and Interpreting Data

Grades 6-8	Grades 9-12
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships. • Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships. • Distinguish between causal and correlational relationships in data. • Analyze and interpret data to provide evidence for phenomena. • Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible. • Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials). • Analyze and interpret data to determine similarities and differences in findings. • Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.	Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. • Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. • Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. • Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. • Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. • Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. • Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.

Notes:

Practice #5 – Using Mathematics and Computational Thinking

Grades 6-8	Grades 9-12
Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments. • Use digital tools (e.g., computers) to analyze very large data sets for patterns and trends. • Use mathematical representations to describe and/or support scientific conclusions and design solutions. • Create algorithms (a series of ordered steps) to solve a problem. • Apply mathematical concepts and/or processes (e.g., ratio, rate, percent, basic operations, simple algebra) to scientific and engineering questions and problems. • Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.	Mathematical and computational thinking in 9- 12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. • Apply techniques of algebra and functions to represent and solve scientific and engineering problems. • Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. • Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m^3, acre-feet, etc.).

Notes:

Practice #6 – Constructing Explanations and Designing Solutions

Grades 6-8	Grades 9-12
Constructing explanations and designing solutions in 6–8 builds on K– 5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories. • Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena. • Construct an explanation using models or representations. • Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real- world phenomena, examples, or events. • Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion. • Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system. • Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints. • Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing	Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. • Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. • Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. • Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. • Design, evaluate, and or refine a solution to a real world problem, based on scientific knowledge, student generated sources of evidence, prioritized criteria, and tradeoff considerations.

Notes:

Practice #7 – Engaging in Argument from Evidence

Grades 6-8	Grades 9-12
Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). • Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts. • Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail. • Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. • Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints. • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. • Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. • Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions. • Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. • Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence. • Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).

Notes:

Practice #8 – Obtaining, Evaluating and Communicating Information

Grades 6-8	Grades 9-12
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 experiences and progresses to evaluating the merit and validity of ideas and methods. • Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s). • Integrate qualitative and/or quantitative scientific and/or technical information in written text with that contained in media and visual displays to clarify claims and findings. • Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence. • Evaluate data, hypotheses, and/or conclusions in scientific and technical texts in light of competing information or accounts. • Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs. • Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. • Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. • Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. • Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. • Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically).

Notes: