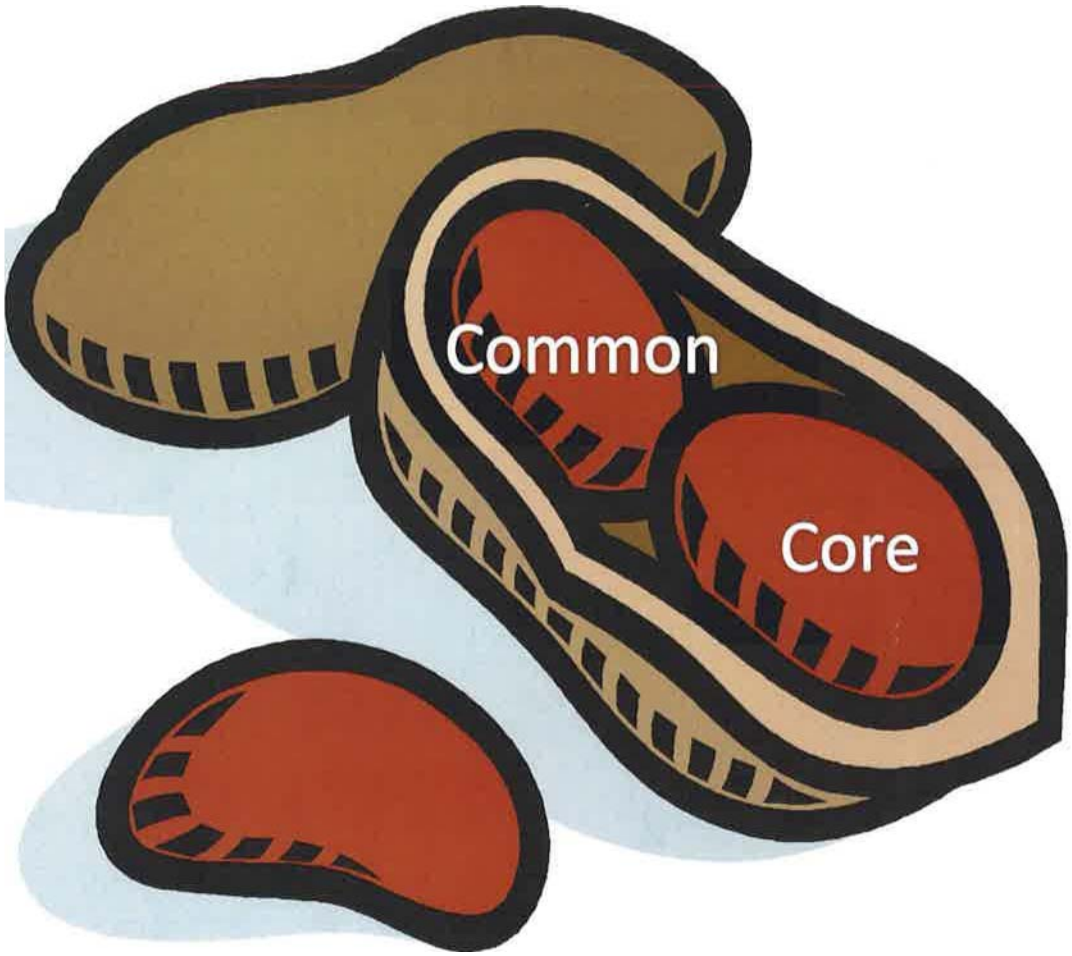

APEX PTI 2014

Dennis Sunal & Marilyn Stephens

Physical Science Progression

INCREASING **SOPHISTICATION OF STUDENT THINKING**

NEXT GENERATION SCIENCE STANDARDS
For States, By States

	K-2	3-5	6-8	9-12
PSI.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.
PSI.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	NIA	NIA	NIA	NIA
PS3.A Definitions of energy	NIA	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). Systems move toward stable states.
PS3.B Conservation of energy and energy transfer	[Content found in PS3.D]			

Performance Expectations - Physical Science - Middle School

Next Generation Science Standards

Forces and Interactions	
Disciplinary Core Idea	Crosscuttine Concepts

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)

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-t), (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)

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

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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-J)
• Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2)
• Jf 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)
ETSJ.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)
ETSJ.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. (secondarv 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>

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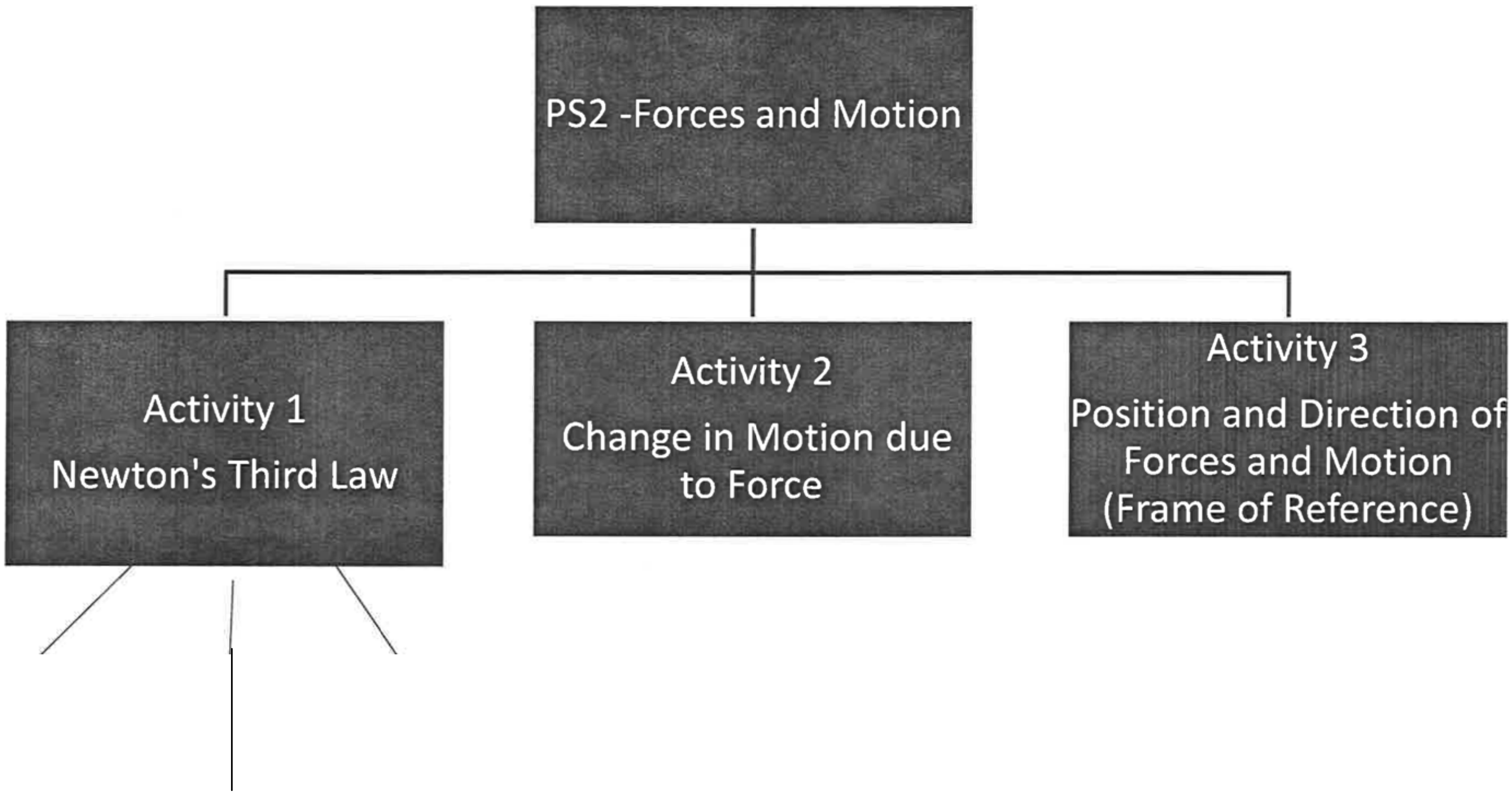
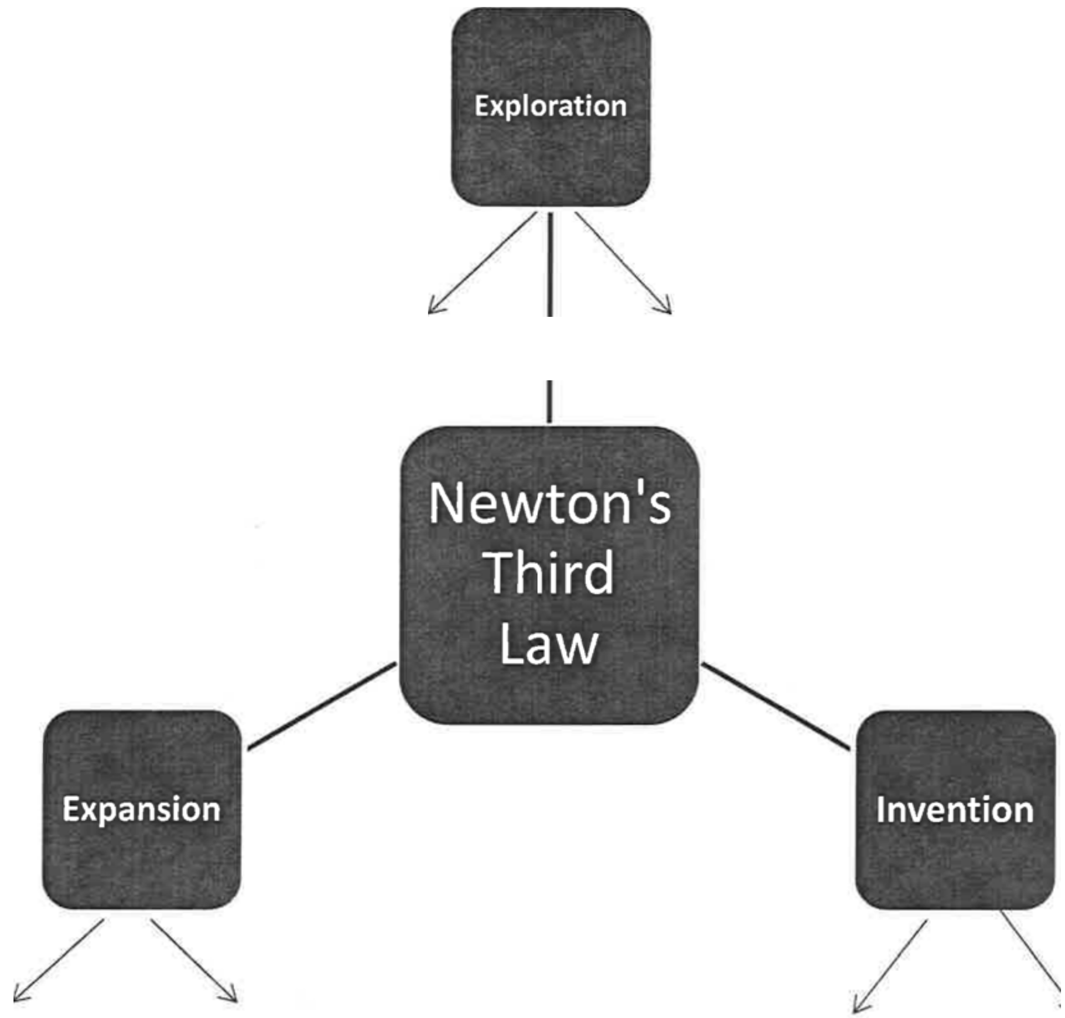
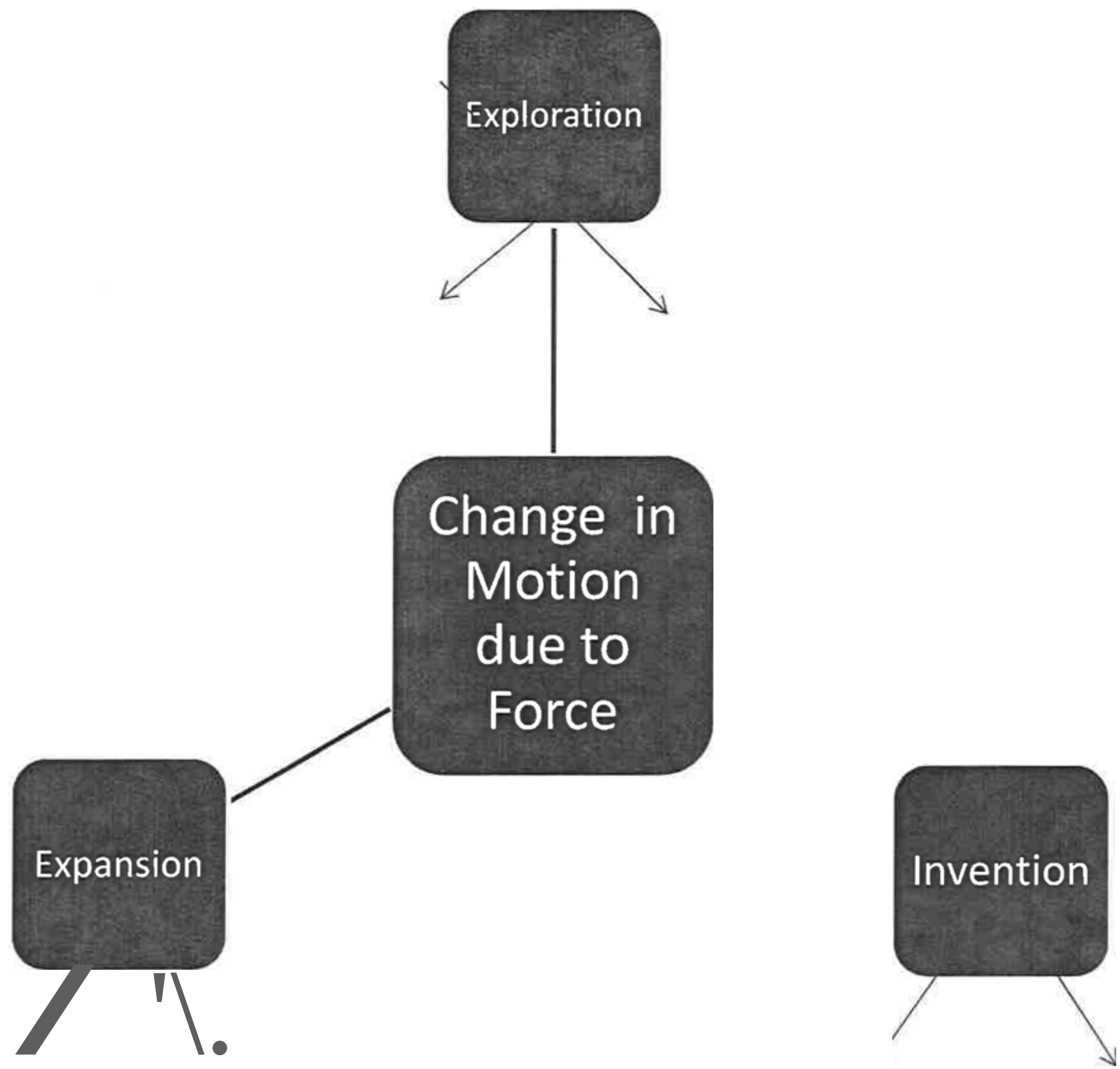
See following organization of lessons to be developed as a learning cycle for each sub concept. Learning Cycle lesson has 3 (or 5 parts) 1) Exploration (explore students prior knowledge) 2) Invention (explanation of the new concept through student activities and 3) Expansion (apply the new concept to other examples and in other settings to help the students to transfer the concept beyond the lesson setting.

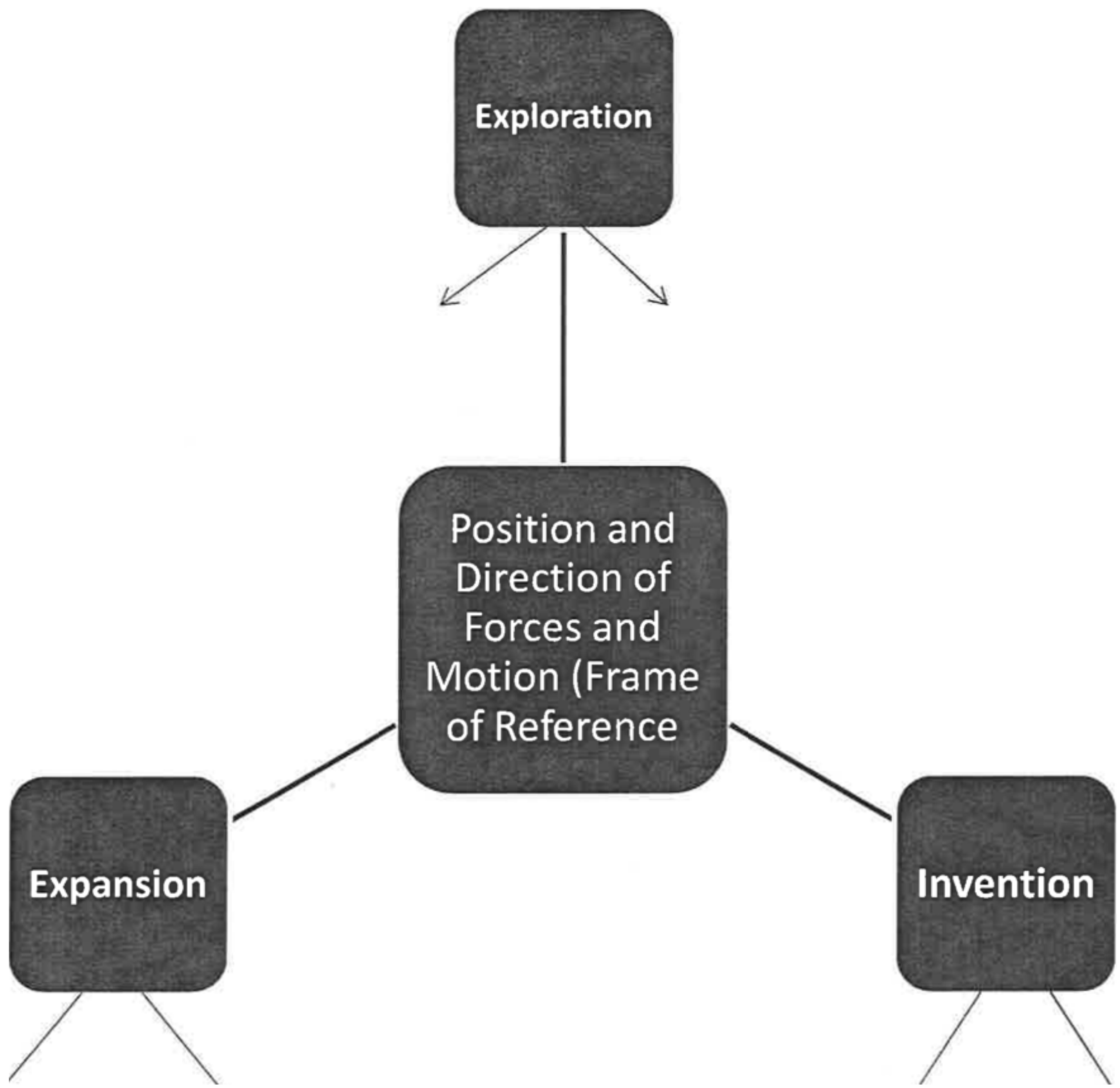

PS2 -Forces and Motion
Activity 1
Newton's Third Law
Activity 2
Change in Motion due to Force
Activity 3
Position and Direction of Forces and Motion (Frame of Reference)

– Newton’s Third Law



Learning Cycle - Change in Motion Due to Force




Exploration
Position and Direction of Forces and Motion (Frame of Reference
Expansion
Invention

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Next Generation Science Standards

Energy

Disciplinary Core Idea

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 spontneously 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)

ETSI.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)

ETSI.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)

Crosscutting Concepts

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

Energy

Disciplinary Core Idea	Crosscutting Concepts
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-l) • Uncontrolled systems always evolve toward more stable states – that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their	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)

Performance Expectations - Physical Science - High 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?

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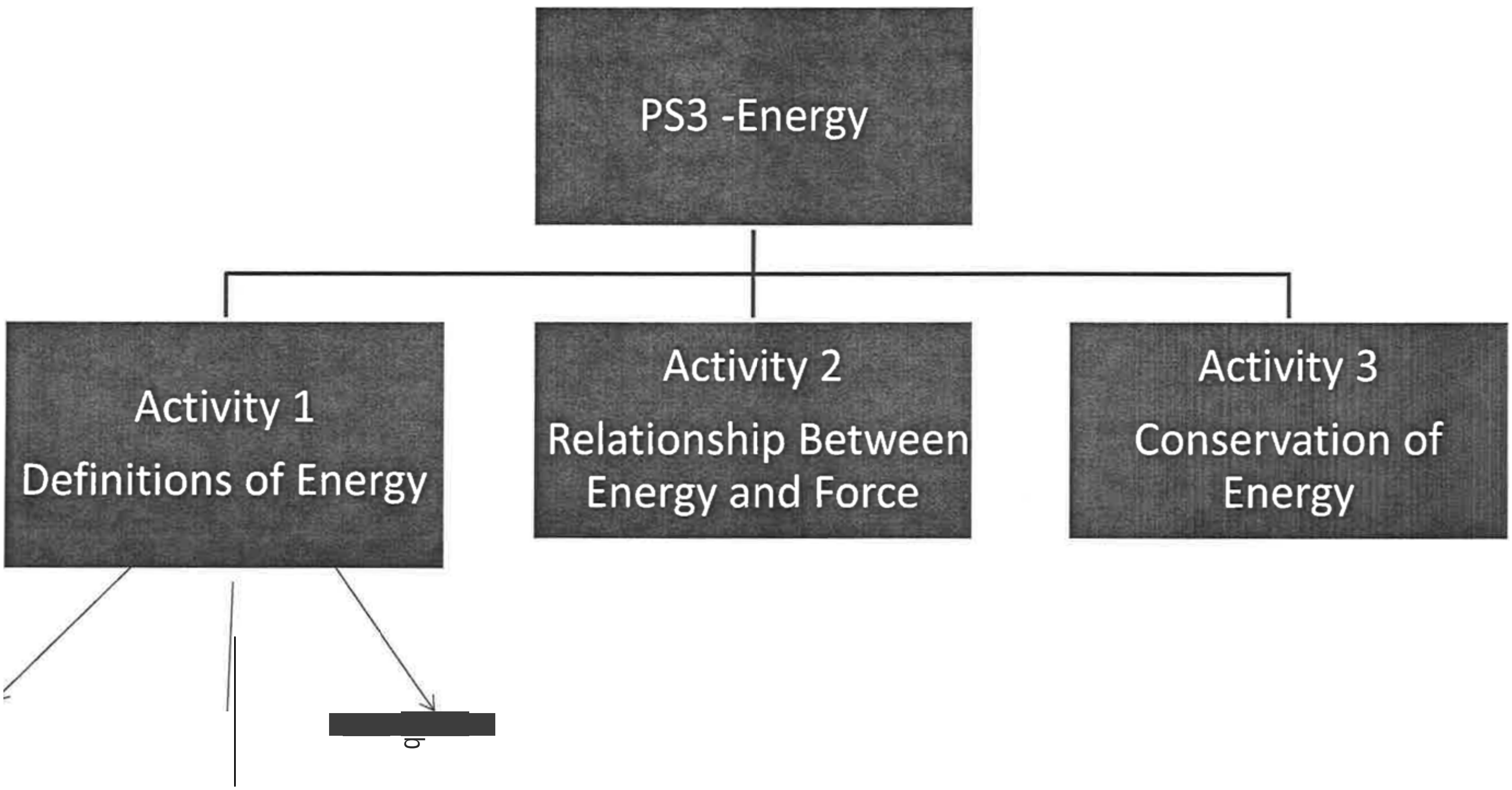
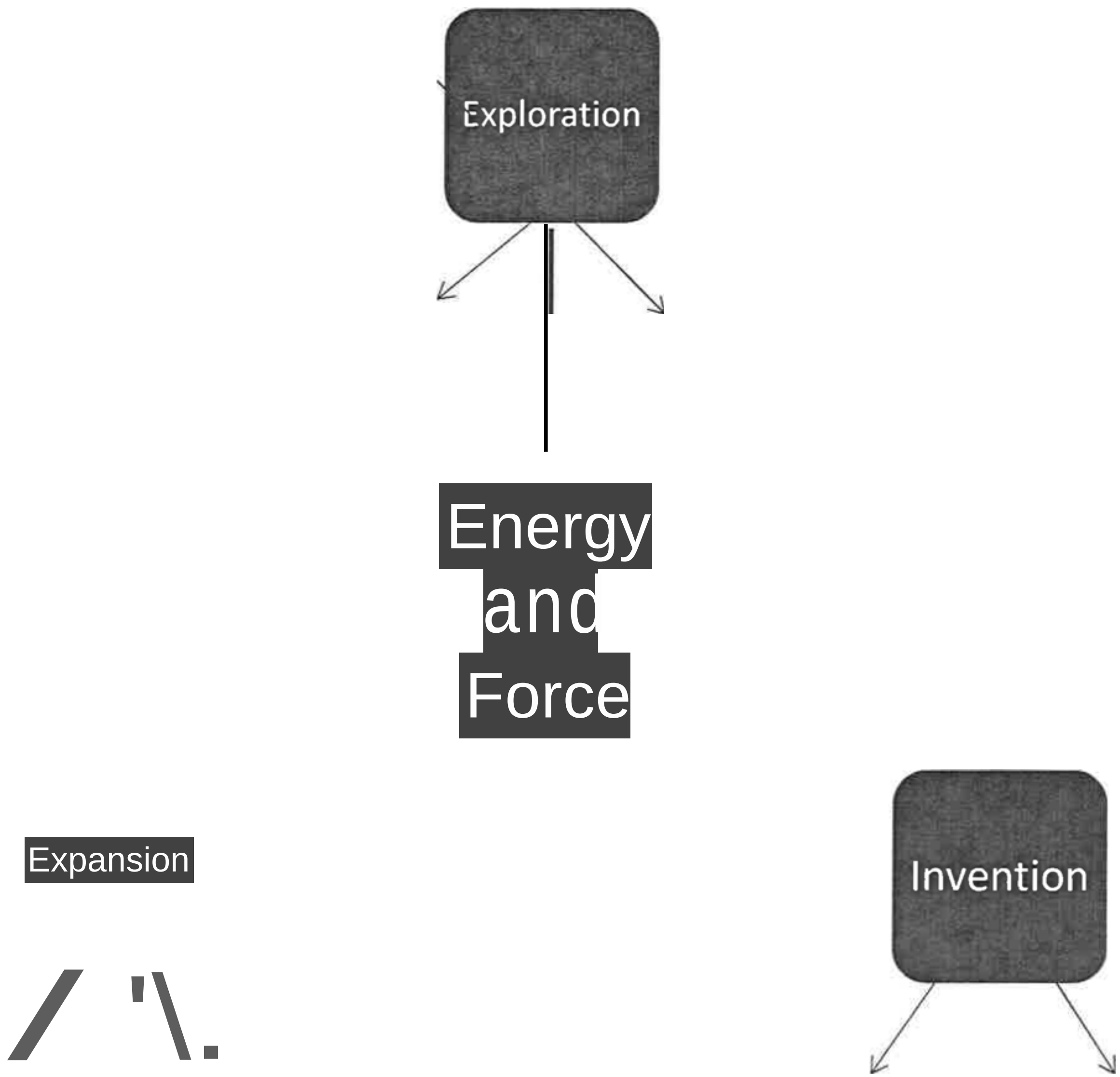
See following organization of lessons to be developed as a learning cycle for each sub concept. Learning Cycle lesson has 3 (or 5 parts) 1) Exploration (explore students prior knowledge) 2) Invention (explanation of the new concept through student activities and 3) Expansion (apply the new concept to other examples and in other settings to help the students to transfer the concept beyond the lesson setting.


PS3 -Energy
Activity 1
Definitions of Energy
Activity 2
Relationship Between Energy and Force
Activity 3
Conservation of Energy

Learning Cycle - Relationship Between Energy and Force



Learning Cycle - Conservation of Energy