Table 3-2. Activity and idea summary for unit 2, cycle 3: Combining Pushes and Pulls.

Activity	Activity Summary	Benchmark Ideas
A1, Elicitation: Can you lend me a hand?	Students consider who will win a tug-of-war: a strong alien on one side, or two weaker aliens on the other side. Groups then weigh individual objects and predict the combined weight of groups of objects. The teacher then leads a class discussion that examines the students' predictions.	Forces along a line, either in the same or opposite directions, can be added.
A2, Development: Lots of pulls!	Groups predict how multiple aliens (strengths) in an imagined tug-of-war will affect the motion of the system. Then groups simulate tugs-of-war with lego bricks attached to a pulley system to examine the effect of multiple forces. Afterwards, groups reflect on the effect that multiple forces have on an object's motion.	Forces along a line, either in the same or opposite directions, can be added. An unbalanced force acting on an object changes its speed. An unbalanced force is a net force that is not equal to zero.
A3, Development: Lots of pushes and pulls!	Students fill out force diagrams for multiple forces acting on an object (representing tugs-of-war). Afterwards, groups reflect on the effect that multiple forces have on an object's motion.	Forces along a line, either in the same or opposite directions, can be added. An unbalanced force acting on an object changes its speed.
A4, Consensus: Putting it all together	Groups record their final ideas on presentation boards, and then the teacher leads a class discussion as to which ideas best explain the cycle phenomena.	All cycle ideas.
A5, Power Drive: Going fishing	Students use pull arrows and various motion representations to represent the interactions between a fishing line/hook and a fish.	All cycle ideas.

Table 3-3. Activity and idea summary for unit 2, cycle 4: Resistive Interactions.

Activity	Activity Summary	Benchmark Ideas
A1, Elicitation: Will it slow down?	Students predict whether a pushed skateboard (on earth), bicycle (on earth), shopping cart (on earth), and wrench (in space) would keep moving at a constant speed or eventually slow down. The teacher then leads a class discussion that examines the students' predictions and reasoning.	When a resistive force acts alone on an object, that object steadily loses its speed. Friction is a resistive force.
A2, Development: What's a little friction?	Students rub together their hands, and then rub blocks with sandpaper to see that heat is generated. They then analyze the energy transfers of the sandpaper/block system. Students then push blocks on a rough surface and analyze the system in terms of energy transfers. Students imagine magnified views of the rough surface and sandpaper, and then analyze the block/rough surface system in terms of pull arrows. The teacher shows energy, force, and motion simulations of a pushed block, and then groups reflect on the effect of surface roughness on pulls and energy transfers.	When both a push/pull and a resistive force act on an object, the object's speed will either remain constant (if the push/pull equals the resistive force) or will steadily decrease (if the push/pull is less than the resistive force). The same can be said for the object's motion energy. Friction is a resistive force.
A3, Development: Slowing down	Students explore the effect of friction on motion. In teams, students slide blocks on their desks and explain why it slows down. In so doing, they fill in energy diagrams and use other representations to describe the block's motion. They then reflect on the effect of friction on an object's motion.	When a resistive force acts alone on an object, that object steadily loses its speed and motion energy. Friction is a resistive force.
A4, Development: No friction?	Students engage in a class discussion about which sports might be possible without friction, and then they watch a Magic School Bus cartoon that shows what frictionless baseball would be like. Groups then consider reasons why they would or would not want to live in a frictionless world.	An object will continue to move at constant speed unless acted on by an unbalanced force.
A5, Development: What's a little drag?	Students watch a drag racing video, and then set up experiments to test how far cars travel with and without attached sails. They then reflect on the effect of drag on an object's motion and energy.	(Same as ideas for A2) Drag is a resistive force.
A6, Consensus: Putting it all together	Groups record their final ideas on presentation boards, and then the teacher leads a class discussion as to which ideas best explain the cycle phenomena.	All cycle ideas.
A7, Power Drive: What happened?	Students read a mock newspaper account of an actual incident -- the burn up of NASA's Mars Climate Orbiter as it entered the Martian atmosphere. Students analyze this event in terms of forces and energy transfers.	All cycle ideas.

Table 3-4. Activity and idea summary for unit 2, cycle 5: Non-Contact Interactions -- Gravity.

Activity	Activity Summary	Benchmark Ideas
A1, Elicitation: What causes gravity?	Groups debate the possible causes of gravity, and then the teacher leads a class discussion on the same topic.	Every object exerts a gravitational force on every other object. The force depends on the mass of the objects.
A2, Development: Exploring what causes gravity	Groups experimentally test whether all objects are magnetic (to test the idea that gravity is caused by magnetism). Next, groups test whether a spun weight moves toward the pencil to which it is attached (to test the idea that gravity is caused by the earth's spin). Finally, students watch a video that shows than an object in an air-tight chamber does not get lighter then the air is evacuated (to test the idea that gravity is caused by the atmosphere). Groups then reflect on the cause of gravity.	Every object exerts a gravitational force on every other object. The force depends on how much mass the objects have.
A3, Development: More exploration of what causes gravity	Students watch two videos. The first video recreates the Cavendish experiment, the experiment that shows how boxes of sand are attracted to bottles of water -- thus helping to prove that all objects have a gravitational attraction for one another. After the video, the teacher guides students through an interaction analysis (using the interaction tool) of the water and sand. The second video shows hammers dropping simultaneously on the moon and on the earth. Students then put two pencils on their desk, note that they don't attract each other, and reflect on the cause of gravity.	Forces result from interactions between objects. Every object exerts a gravitational force on every other object. The force depends on how much mass the objects have. The force is hard to detect unless one of the objects has a lot of mass.
A4, Development: Gravity and motion	Groups crumple a piece of paper and then drop it a few times. Groups then use the interaction tool to analyze the interaction between the crumpled paper ball and the earth; they also represent the motion of the dropped ball using various motion representations. Next, groups let crumpled and flat pieces of paper drop to the ground, after which they analyze both phenomena in terms of forces. Individually, students then perform force analyses on falling bodies - some moving at constant speed, and some speeding up.	Forces result from interactions between objects. As long as an unbalanced force is applied, an object continues to change speed. An object will continue to move at constant speed unless acted on by an unbalanced force.
A5, Consensus: Putting it all together	Groups record their final ideas on presentation boards, and then the teacher leads a class discussion as to which ideas best explain the cycle phenomena.	All cycle ideas.
A6, Power Drive: Power Drive	The class begins by thinking about a super ball tossed into the air. The ball's motion (on the way up, on the way down) is simulated on the computer. Students then analyze the ball's upward/downward motion in terms of forces.	All cycle ideas.