Grade 6
Science
Unit 6: Work, Power, and Efficiency

Time Frame: Approximately four weeks

Unit Description

This unit introduces the concepts of *force*, *work*, *power*, and *efficiency* and how they are interrelated. The review of simple machines is an integral part of this unit. The relationships among work, machines, and the real world will be considered.

Student Understandings

Students will be able to identify forces. They will describe the relationship between kinetic and potential energy. Further, the idea of work and its relationship to power and efficiency will be introduced with regard to simple machines.

Guiding Questions

1. Can students identify forces such as push, pull, lift, twist, and press?
2. Can students explain the relationship between kinetic energy and potential energy?
3. Can students describe the relationship between work input and work output in a simple machine?
4. Can students explain the relationship between work, power, and efficiency??

Unit 6 Grade-Level Expectations (GLEs)

GLE #	GLE Text and Benchmarks
Science as Inquiry	
Note: The following Science as Inquiry GLEs are embedded in the suggested activities for this unit. Other activities incorporated by teachers may result in additional SI GLEs being addressed during instruction.	
1.	Generate testable questions about objects, organisms, and events that can be answered through scientific investigation (SI-M-A1)
2.	Identify problems, factors, and questions that must be considered in a scientific investigation (SI-M-A1)
3.	Use a variety of sources to answer questions (SI-M-A1)
4.	Design, predict outcomes, and conduct experiments to answer guiding questions (SI-M-A2)
5.	Identify independent variables, dependent variables, and variables that should be controlled in designing an experiment (SI-M-A2)

GLE #	GLE Text and Benchmarks
6.	Select and use appropriate equipment, technology, tools, and metric units of measurement to make observations (SI-M-A3)
7.	Record observations using methods that complement investigations (e.g., journals, tables, charts) (SI-M-A3)
8.	Use consistency and precision in data collection, analysis, and reporting (SI-M-A3)
9.	Use computers and/or calculators to analyze and interpret quantitative data (SI-M-A3)
10.	Identify the difference between description and explanation (SI-M-A4)
11.	Construct, use, and interpret appropriate graphical representations to collect, record, and report data (SI-M-A4)
12.	Use data and information gathered to develop an explanation of experimental results (SI-M-A4)
16.	Use evidence to make inferences and predict trends (SI-M-A5)
18.	Identify faulty reasoning and statements that misinterpret or are not supported by the evidence (SI-M-A6)
19.	Communicate ideas in a variety of ways (e.g., symbols, illustrations, graphs, charts, spreadsheets, concept maps, oral and written reports, equations) (SI-M-A7)
21.	Distinguish between *observations* and *inferences* (SI-M-A7)
22.	Use evidence and observations to explain and communicate the results of investigations (SI-M-A7)
23.	Use relevant safety procedures and equipment to conduct scientific investigations (SI-M-A8)
28.	Recognize that investigations generally begin with a review of the work of others (SI-M-B2)
29.	Compare and/or investigate the relationships among work, power, and efficiency (PS-M-C2)
31.	Recognize that there is an acceptable range of variation in collected data. (SI-M-B3)
32.	Explain the use of statistical methods to confirm the significance of data (e.g., mean, median, mode, range) (SI-M-B3)
36.	Explain why an experiment must be verified through multiple investigations and yield consistent results before the findings are accepted (SI-M-B5)
37.	Critique and analyze their own inquiries and the inquiries of others (SI-M-B5)
39.	Identify areas in which technology has changed human lives (e.g., transportation, communication, geographic information systems, DNA fingerprinting) (SI-M-B7)
Physical Science	
17.	Describe and demonstrate that friction is a force that acts whenever two surfaces or objects move past one another (PS-M-B2)
19.	Identify forces acting on all objects (PS-M-B3)
20.	Draw and label a diagram to represent forces acting on an object (PS-M-B4)

GLE #	GLE Text and Benchmarks
22.	Demonstrate that an object will remain at rest or move at a constant and in a straight line if it is not subjected to an unbalanced force (PS-M-B5) (PS-M-B3)
23.	Predict the direction of a force applied to an object and how it will change the speed and direction of the object (PS-M-B5)
27.	Explain the relationship between work input and work output by using simple machines (PS-M-C2)
29.	Compare and/or investigate the relationship among work, power, and efficiency (PS-M-C2)

Sample Activities

Activity 1: The Force May Be With You (SI GLEs: 6, 7, 10, 12, 19, 22, 28, 37; PS GLEs: 17, 19, 20)

Materials List: science learning logs, chart paper or sentence strips, Simple Machines Opinionaire BLM (1 for each pair of students)

Review the work of Isaac Newton in the study of forces and point out to students that investigations generally begin with a review of the work of others who have made significant contributions in that field.

Students should be aware of all safety issues that need to be considered while conducting investigations at home as well as at school.

Force can be defined as any push or pull on an object that causes that object to move in a particular direction. Students will search throughout the home to identify places where forces are used. Students should include a description of how the force is employed and an explanation of what the force is doing. Their observations and explanations should be recorded in their science *learning log* (view literacy strategy descriptions) and should include supporting evidence. An example of how this might look is *a push on the lawnmower handle causes the lawnmower to move forward and the lawn that it moves over gets cut.* Other examples to consider might include opening and closing a door, raising a window, opening a jar or bottle, making a bed, and certain parts of cleaning a room!

Students should select one example from the home search to illustrate the forces at work using a diagram. These illustrations can be used to categorize the work being done, keeping in mind that *work* is defined as *movement (as a result of a force), in the direction of the force.* Students can create a symbol to classify those illustrations that represent work and this symbol can be added to each illustration once it has been determined through the class discussion that it depicts work being done.

The teacher should lead a class sharing of the diagrams and a discussion of how the forces that were used were employed. The discussion could flow very neatly into a further discussion of how to identify *work* by noting the force applied and the responding movement.

Display and compare the student results so that all may critique the investigation (not the artwork!) and make recommendations for improvement. The teacher may also assist students in identifying the counter-forces at work (*gravity, air resistance, and friction*). Evidence of these forces can be seen as wear-down of the surface, drag or a reduction in speed, or the existence of heat.

Have students complete the Simple Machines *Opinionnaire* (view literacy strategy descriptions) BLM to establish a starting point for a discussion of simple machines. Students will work in pairs to read and discuss statements about simple machines. They will take a position with regard to each statement and defend their position with a written point of view. Once all pairs have completed the Simple Machines Opinionnaire BLM, allow time for each pair to share and debate their stances. This activity should heighten their interest in learning about simple machines. Revisit the *opinionnaire* at the close of this unit to see if students want to reevaluate their position.

Activity 2: Rolling Right Along! (SI GLEs: 1, 2, 4, 5, 6, 7, 12, 21, 22, 23, 32, 36; PS GLEs: 22, 23)

Materials List: inclined plane for each group (may use a ramp made with a board and books), a collection of sealable, cylindrical containers from which each group will select (can with snap on lid, tennis ball can, film canister with lid, plastic jar with lid, etc.), meter tapes or sticks, additional mass for students to put inside the container (clay, sand, etc.), carpet samples, fabric, large sandpaper sheets, rulers for speed bumps, other materials as requested by students as they design their investigation, science learning logs

Students should be able to explain what safety consideration must be observed. They will need to agree on the safety guidelines for the lab and particularly if several ramps are set up and used simultaneously.

In this activity, students will gain a quantitative understanding of the relationship between potential (stored) energy and kinetic (movement) energy and how a force, like friction, may affect the speed and direction of the rolling container. Students may work in small groups of two or three.

Using an inclined plane and an empty cylindrical container, students will observe the container's action as it rolls down the inclined plane and continues to roll until it stops. They will make observations based on the speed and direction of the container and create an investigation in which they change one variable so they can predict and control the forces which affect the speed and direction of the container. The initial observation should include measurements so as to provide a base of comparison and to provide a springboard from which they can formulate their plan. For the initial observation have each group set their ramp on four (4) books and have additional books available that can be used to change the height of the ramp.

The teacher should make certain the students understand that *only one* variable may be changed at a time. Each group should design an investigation that explores a different testable question. (e.g., How does adding more (or less) mass affect the speed of the container? How does changing the surface of the ramp affect the distance the container will roll? How does adding an obstacle to one side of the ramp affect the speed and direction the container rolls?) Students will need to create a chart in their science *learning log* (view literacy strategy descriptions) so that all data and measurements collected can be recorded in an organized manner.

Using the metric system, students are to measure the height of the inclined plane (distance from the floor, straight up to the top of the ramp/inclined plane) and the distance the container rolled (distance between the start point of the container at the top of the ramp to the position when the container comes to rest). The container should be released five times for each testing situation. This would be a good time to investigate the mean, median, and range of data collected. Solicit input from the students as to the logic of running multiple tests.

Students should identify independent variables, dependent variables, and variables that can be controlled in designing this experiment. Variables that can be employed in this investigation include changing the height of the inclined plane, adding mass to the container, changing the size of the container, changing the surface over which the container will travel (e.g., bare floor, carpet, sand paper on the ramp).

Through class discussion and/or science *learning log* entries, students should respond to the following:

1. Where does an observation end and an inference begin? (Observation→ The container rolled straight down the ramp and stopped when it hit the carpet on the floor. Inference→ Contact with the carpet caused the container to stop rolling.)
2. Describe the energy transformations that occur, beginning when the container is placed at the top of the inclined plane and released to when the can stops rolling on the floor. Students should be able to indicate potential energy and kinetic energy, as well as any forces that may be acting on the container.
3. Compare the amount of potential energy initially given the container with the amount of kinetic energy acquired at the bottom of the plane, as indicated by the horizontal distance the container rolls.
4. For each ramp height tested, graph the vertical height of the container when it is at the top of the inclined plane versus the horizontal distance rolled.
5. What variables seem to affect the distance the container rolls from the release point until stopping? Which variables affect the speed at which the container rolls?
6. Why is it important to run multiple trials?

Activity 3: Simply Machines (SI GLEs: 3, 19, 39; PS GLE: 27)

Materials List: 4 X 4 inch squares of colored paper (1 for every two students), scissors, markers, pencils, cellophane tape, examples of general simple machines: pulleys (windows and flag poles), screws (jar lids and spiral staircases) , inclined planes (ramps), wheels with axle (doorknobs and screwdriver) , and levers (scissors and see saws) , Internet access, resource books for support with research of simple machines, science learning logs, presentation resources may also be needed (*PowerPoint*® access, poster materials, paper for flyers, etc.)

PART 1
Review the different types of simple machines. With the students, take an inventory of the simple machines they come in contact with each day (screw, inclined plane, wedge, pulley, wheel with axle, and lever). Create a class list that includes how the students may see simple machines used in everyday life.

Revisit the inclined plane. Have the students cut a square of paper in half, diagonally. The resulting triangle represents a ramp or inclined plane. Trace the cut edge of the triangle with a bright marker color. Tape one of the sides that end in the 90-degree angle to a pencil and slowly wrap the rest of the triangle around the pencil. The colored edge wraps around the pencil in a winding path**.** Ask students if this reminds them of any previous machine they have studied**?** This example illustrates that winding mountain roads, jar lids and even screws are inclined planes in origin. What are the limitations of this model of an inclined plane? See http://www.edheads.org/activities/simple-machines/ for examples of assessments involving the identification of simple machines.

Have students explain the benefits of using simple machines. Introduce the terms *work input* and *work output* to explain efficiency. Students should be able to identify when they are "putting in" work (applying a force over a distance) and when the machine is "putting out" work. Have students identify the input work and output work for each of the samples of simple machines. Students should be able to identify how forces are transferred within the use of the machine to make work easier (changing the direction of force, changing the amount of force, or changing the distance over which the force is exerted)

PART 2
Students will work in small groups to investigate, create a visual display of information, on a *simple machine* of their choice, and make a presentation, based on an adaptation of the p*rofessor know-it-all* (view literacy strategy descriptions) strategy. A variety of resources should be identified by the group. They must research the following:

- its place in history and/or how long ago this machine was reported in use
- the components of the machine
- the forces that are employed with the use of the machine
- how it works—work input and work output (use calculations and graphs where appropriate)
- how the mechanical advantage of this simple machine would be calculated (output force divided by the input force)
- a discussion of the energy changes that occur with its use, if any

- the progression of the development of this machine, from earlier models through improvements
- present-day versions of the machine
- how the invention and subsequent improvement of this machine has changed human lives

Students may also create a model of their simple machine using building materials, or recycled materials, if time permits.

This activity leads nicely into an adaptation of a *professor know-it-all* strategy. Once groups have researched their simple machine and are knowledgeable in its attributes and uses, they can present their machine as a product of technology to be purchased and sold by a local chain store. Their sales pitch is to a group of supporters from whom they seek endorsements for their simple machine. The supporters (remaining students and teacher) then ask prepared questions of the presenters.

Through the presentation student supporters will question the usefulness of the product, the ease of which it is operated, how the product was developed and how it will change their lives. Each group will be given the opportunity to pitch their simple machine and may use a variety of tools to do so such as posters, Power Point® presentation, flyers, etc.

Activity 4: Work and the Inclined Plane (SI GLEs: 2, 4, 5, 6, 7, 9, 12, 16, 19, 22, 23; PS GLE: 29)

Materials List: calculators, spring scales and meter sticks / tapes (one of each per group), string suitable for tying and holding small loads, books and boards to create ramps, science learning logs

Begin with a review of safety concerns regarding lifting and pulling. It is beneficial for students to lead the review and construct safety guidelines. The teacher may also choose to limit the size of the load to a size that it can be easily accommodated by the available spring scales.

Student groups will compare the work done in lifting a mass to a vertical height with the work done in lifting the same mass to the same height using an inclined plane. This activity can be done by groups of two or three students. Work is defined as force acting through a distance (work = force X distance).

A spring scale will be used to measure the force required to lift an object, of the group's choice, to a specific height above a horizontal surface. Students will calculate the work output *(reading on spring scale times the specific height above the horizontal surface)*. They will then construct an inclined plane.

Have students predict whether the work output will be more or less using the `inclined plane. Using the spring scale, the students will now pull the object up the inclined plane until the object reaches the same height as before. Suggest students set the number of times each investigation should be done to provide reasonable data.

Students will calculate the work input *(reading on spring scale times the distance moved along the surface of the inclined plane)* and compare the input with the output. In addition, they will calculate the efficiency of the inclined plane (efficiency = work output ÷ work input x 100). Provide access to calculators for students who need assistance with the computations.

Have students change the angle of the inclined plane, run several tests again, and compare each group's findings to identify a trend in the force needed to move the object from start to finish. They should be able to identify a trend that indicates that the work input lessens as the inclined plane's height decreases. This simple machine makes work easier by increasing the distance over which the force must be applied and so lessens the amount of force needed.

Through class discussion and/or science *learning log* (view literacy strategy descriptions) entries, students should respond to the following:

- Identify the variables that are to be considered in this investigation.
- Track the transformations of the energy involved. Where does the energy change from potential to kinetic?
- Compare the force needed to move the object to the specific height using the inclined plane to the force needed to lift the object vertically.
- Identify the trend that is evident when the height of the inclined plane is lowered / raised.
- Identify examples of the use of inclined planes to lessen the effort needed and make work easier. (wheelchair ramps, inclined sections of curbs on the sidewalk, etc.)
- How might this information be useful to a student?

Activity 5: Classy Levers (SI GLEs: 7, 18, 19, 22, 29; PS GLE: 27)

Materials List: collection of familiar lever-based simple machines (scissors, hammer, pliers, tweezers, nail clippers, corkscrew, screwdriver, tongs, can openers, kid-sized broom, kid-sized shovel, nutcracker, staple remover, etc.), photocopy of each machine (place tools directly on the copier) for each group, small adhesive note pads for each group (used for labeling), science learning logs, resources for teacher support regarding simple machines and classes of levers

The teacher will guide an exploration of the various lever-based simple machines and help students identify where the load will be (L), the point at which effort is applied (E), and the point at which the simple machine pivots or the fulcrum (F). Students should be able to identify and label the point of input force and output force.

The teacher should demonstrate how changing the position of the effort with regards to the fulcrum affects the effort needed to deal with the load. Using scissors to cut cardboard with the cardboard placed near the fulcrum and then towards the tip of the scissors is a great demonstration of how moving the effort near and away from the fulcrum affects the amount of effort needed. Provide concrete examples such as this so that students can connect the concept of levers with real world experiences.

Once students are confident that they can identify these points on the simple machine, give each group a set of the photocopied machines and a small adhesive note pad. Have the student groups use adhesive notes to label the effort (E), load (L), and fulcrum (F).

Discuss the three classes of levers and how the class relates to the position of the fulcrum with relation to the effort and force.

Class 1 levers are those with the fulcrum between the load and the effort. (L / F / E)
Class 2 levers are those with the load between the fulcrum and the effort. (E / L / F)
Class 3 levers are those with the effort between the load and the fulcrum. (L / E / F)

Once students seem to grasp the concept of classes of levers, have the groups use the small adhesive notepads to label each photocopy of a simple machine with effort, load, and fulcrum and the correct class of the lever. Groups should also indicate where the input force and output force are located for each simple machine illustrated. Have student groups exchange sets of illustrations to check and critique. Students should illustrate the different classes of levers in their science *learning logs* (view literacy strategy descriptions).

The following website offers an illustrated guide to identifying classes of levers and may be helpful: http://www.enchantedlearning.com/physics/machines/Levers.shtml

Activity 6: Power (SI GLEs: 2, 5, 6, 7, 8, 11, 12, 22, 23, 31; PS GLE: 29)

Materials List: bathroom scale, access to stairs, yard sticks (measurement in feet), stopwatches (several per group), science learning logs

If the absence of stairs creates difficulty for completing this activity, use bleachers, playground equipment, or use a computation of work in lifting objects such as lifting cans of paint up onto the table, or moving books from a shelf to the floor. This will move you away from the foot-pounds/per second computations but will still be a valid measurement of "work" or force applied over a given distance (work = force X distance).

Have students plan for safety concerns once the activity parameters are defined (stairs vs. lifting). The teacher should plan for several groups using an area once safety concerns are defined.

Understanding that power is the rate of doing work, students will experimentally determine their own power in walking up a flight of stairs. Because the vertical height is needed to calculate the work done, challenge students to figure out how to calculate the height of the stairs being used (measuring the height of one step and multiplying by the number of steps in the flight can make a good estimate). Use the standard measurement of feet as opposed to meters for this activity.

Have all students create a data table in their science *learning log* (view literacy strategy descriptions) to record each trial. The table should include room for multiple tests, student weight, and height of the stairs, time, and power generated.

Since you will need the weight of a student for these computations, elicit volunteers instead of making each student stand on the scale. The student volunteer is weighed and then walks up the stairs while the other students time how long it takes to do so. Multiple data collections should be run to provide an average upon which the computations may be based. Solicit from students why it is important to use consistency and precision in their data collection.

From this data, the power the students generate can be calculated in foot-pounds/second. Students must be cautioned not to run up the stairs, although they may walk up briskly. An extension of this activity is to calculate the students' horsepower, knowing that 1 HP = 550 foot-pounds/second. Students should identify independent variables, dependent variables, and factors that should be controlled in designing this experiment.

Through class discussion and/or science *learning log* entries, students should respond to the following:

- Calculate the work done by each participating student in climbing the flight of stairs.
- Calculate the power generated by each participating student.
- Determine the horsepower of each student who participates.
- Research the origins of the term horsepower as a unit of power.
- Write a laboratory report describing the experiment and results.
- Propose a simple machine that would make lifting a load to the second floor easier (elevator/pulley). Comment on the efficiency of this machine to decrease the amount of effort needed to lift the load.

Sample Assessments

General Guidelines

Assessment will be based on teacher observation/checklist notes of student participation in unit activities, the extent of successful accomplishment of tasks, and the degree of accuracy of oral and written descriptions/responses. Science learning log entries provide reflective assessment of class discussions and laboratory experiences. Performance-based assessment should be used to evaluate inquiry and laboratory skills. All student-generated work, such as drawings, data collection charts, models, etc., may be incorporated into a portfolio assessment system.

- Students should be monitored throughout the work on all activities.
- All student-developed products should be evaluated as the unit continues.
- When possible, students should assist in developing any rubrics that will be used and have copies of the rubrics during task directions.

General Assessments

- The students will provide laboratory reports on experiments, such as potential-kinetic energy conversion and the inclined plane.

- The student will create a presentation, display, and model on a simple machine of their choosing.
- The student will maintain science learning log entries for all investigations.

Activity-Specific Assessments

- Activity 1: The student collection of forces used in the home and how they are used should reflect an understanding of forces and their use in the home.

  Activity 2: Students should be able to discriminate between kinetic and potential energy. They will correctly identify kinetic energy and potential energy when the containers roll down the ramp. They should recognize the forces that affect the speed and direction of the container as it rolls down the ramp.

- Activity 4: Students will measure and compare efficiency when using an inclined plane to lift a load.

Resources

- *Horsepower.* Available online at http://auto.howstuffworks.com/horsepower1.htm

- http://www.gmhsscience.com/problems/kineticpotential.htm

- *Kinetic and Potential Energy.* Available online at http://users.bigpond.net.au/mechtoys/mouse.html http://www.k12.wa.us/assessment/WASL/Science/ClassroomAssessments/ScenarioMousetrapCar.pdf

- *Machines and Work.* Available online at http://www.sasked.gov.sk.ca/docs/elemsci/gr5ugesc.html

- *Potential Energy.* Available online at http://www.glenbrook.k12.il.us/gbssci/phys/Class/energy/u5l1b.html http://dept.physics.upenn.edu/courses/gladney/phys150/lectures/lecture_oct_08_1999.html

- NSTA Science *Scope*, April 2003 issue, *Shaky Head Dogs*

- *Forces Worksheets.* Available online at http://science-class.net

- *Simple Machines Pretest & Posttest.* Available online at http://www.edheads.org/activities/simple-machines/