**Outline - Energy, Force, Work & Efficiency**

Desiree Newhook & Brittnaye Warriner

**Background Information**

Every tried lifting a heavy object across a room? Well then you have experienced work, you have expended energy and you have applied a force to lift the object from the floor to your comfortable height.

Ever wonder how or what you could use to reduce the amount of effort it took to move that object? Then you have also considered the concept of efficiency.

Energy, force, work and efficiency are intertwined concepts. Most students will have had experience developing basic knowledge around these concepts before they get to grade 8. It will be your responsibility to build on their pre existing schema.

*Background information useful for teachers:*

* the characteristics of a system and a mechanical system
* the purpose, inputs, and outputs of a mechanical system
* how heat is produced
* the relationship between work, force, and distance moved
* measure force using a spring scale
* calculate the work done to move objects
* calculate the mechanical advantage of a mechanical system
* a force is a push or a pull that acts on an object
* forces can be classified as either contact forces or action-at-a-distance forces
* mass is the amount of matter in an object
* weight is the force of gravity acting on an object
* for an object on Earth, the force of gravity, in newtons, is the product of the object’s mass, in kilograms, and the gravitational field 9.8 N/kg
* work is done when a force causes something to move and energy is transferred
* when a force causes an object to move a distance in the same direction as the force, then work = force x distance
* energy is the ability to do work
* kinetic energy is the energy due to an object’s motion
* potential energy is stored energy
* a machine is a mechanical system that reduces the force required to accomplish work
* machines make work easier by increasing the force, increasing the distance, or changing the direction of the force
* the force applied to the machine is called the input force, and the force applied by the machine is called the output force
* the amount by which a machine can multiply an input force is called mechanical advantage
* mechanical advantage can be calculated by using the equation MA = *F*out/*F*in

*Prior Knowledge for Forces Lesson:*

* System: a group of individual parts or procedure that work together to accomplish a desired task
* Component: all of the different parts of a system
* Mechanical System: composed of physical parts working together (bus, bicycle)
* Non-mechanical System: a set of procedures, methods, or rules that accomplish a task (bus route, class schedule)
* Natural System (solar system)
* Evolving System (healthcare system)

*Definitions*

**Energy:** The capacity to do work.

**Force:** A push, pull, or other factor that can make an object change speed, shape, or direction. If the total force is zero, the object is at rest or moving at a constant speed in a straight line.

**Efficiency:** The ratio of the energy delivered (or work done) by a machine to the energy needed (or work required) in operating the machine.

**Work:** The amount of effort expended in moving an object. It is calculated as the amount of force applied to the object times the distance through which the force acts. (Ontario curriculum)

*Formulas to be used:*

Work (W) = Force (F) x distance (d) (J or kg m/s2)

Force (F) = m (mass) x a (acceleration)

1 Newton (N) = kg \*m/s2

Gravitational acceleration is 9.81 m/s2

**Advance Preparations**

* Make sure you are comfortable with using the formulas and describing their relation to how things work.
* Prepare all materials for the laboratory exercise prior to student participation.
* Ensure technology connections are tested prior to commencement of the lesson.
* Ensure all safety equipment is available and in proper working condition.
* Ensure that all students have the appropriate prior knowledge to be successful in this unit.

**Special Materials**

Computer/Internet access, calculators, mass set or objects of known mass, two broom sticks and a rope for demonstration,

Final project students must have access to: paperclips, ring clips, sewing spools, fishing line, rope, rulers, cardboard, wood, chairs, doweling, marker, tape and glue

**Curriculum Emphasis:**

UNDERSTANDING STRUCTURES AND MECHANISMS - SYSTEMS IN ACTION

*Big Ideas:*

Systems are designed to accomplish tasks. (Overall expectations 1, 2, and 3)

All systems include an input and an output. (Overall expectations 2 and 3)

Systems are designed to optimize human and natural resources. (Overall expectations 1 and 3)

*Overall Expectations:*

By the end of grade 8 students will:

1. assess the personal, social, and/or environmental impacts of a system, and evaluate improvements to a system and/or alternative ways of meeting the same needs;

2. investigate a working system and the ways in which components of the system contribute to its desired function;

3. demonstrate an understanding of different types of systems and the factors that contribute to their safe and efficient operation.

*Specific Outcomes:*

1.2 assess the impact on individuals, society, and the environment of alternative ways of meeting needs that are currently met by existing systems, taking different points of view into consideration

2.1 follow established safety procedures for working with apparatus, tools, materials, and electrical systems

2.2 investigate the work done in a variety of everyday activities and record the findings quantitatively

2.3 use scientific inquiry/experimentation skills to investigate mechanical advantage in a variety of mechanisms and simple machines

2.4 use technological problem-solving skills to investigate a system that performs a function or meets a need

2.6 use appropriate science and technology vocabulary, including mechanical advantage, input, output, friction, gravity, forces, and efficiency, in oral and written communication

2.7 use a variety of forms to communicate with different audiences and for a variety of purposes

3.1 identify various types of systems

3.2 identify the purpose, inputs, and outputs of various systems

3.3 identify the various processes and components of a system that allow it to perform its function efficiently and safely

3.4 compare, using examples, the scientific definition with the everyday use of the terms work, force, energy, and efficiency

3.5 understand and use the formula work = force × distance (W = F × d) to establish the relationship between work, force, and distance moved parallel to the force in simple systems

3.6 calculate the mechanical advantage (MA = force needed without a simple machine divided by force needed with a simple machine) of various mechanical systems

3.7 explain ways in which mechanical system produce heat, and describe ways to make these systems more efficient

3.8 describe systems that have improved the productivity of various industries

3.9 identify social factors that influence the evolution of a system

**Lesson Sequence**

Lesson 1 - **Energy** - what is energy?

Teacher and students brainstorm ideas about energy, where it comes from, and where it is found in nature and in society. In groups students further brainstorm about the types of energy and provide examples in the graffiti activity. This sheet can be used as an assessment to see where the students currently know about energy.

The teacher can then show a SMART Exchange presentation on types of energy to reinforce the ideas around light, heat, kinetic and potential energy. ([http://express.smarttech.com/?url=http://exchangedownloads.smarttech.com/public/content/83/833aafd3-ed87-49a3-99f5-ff112b183ead/forms\_of\_energy.notebook#](http://express.smarttech.com/?url=http://exchangedownloads.smarttech.com/public/content/83/833aafd3-ed87-49a3-99f5-ff112b183ead/forms_of_energy.notebook))

To end the lesson the students and teacher will develop a definition of energy (Energy: The capacity to do work) and post in on an anchor chart in the room.

Lesson 2 - **Forces** - Introduction of Forces

Students should have basic knowledge of the types of forces acting on an object from grade 3. This lesson will provide students with a quick review of the varying types of forces that could move an object and re-introduce them to the curriculum definition of force (Force: A push, pull or other factor (twist) that can make an object change speed, shape or direction. If the total force is zero, the object is at rest or moving at a constant speed in a straight line.) Students will complete the provided worksheets for assessment and to identify any student misconceptions.

Extra: This website is a great review of forces acting on objects (<http://www.pbs.org/wgbh/buildingbig/lab/forces.html>)

Lesson 3 - **Gravity and Measuring Force**

Students will participate in a pair & share to discuss their ideas about the influence of gravity in their daily lives. Following, direct instruction will occur with respect to the concepts of mass and weight and the relationship between these items. Students will then view the BBC video, "Force: Mass and Weight" and respond using the related worksheet, which will be assessed for accuracy. Students will then learn about the contributions of Newton to the study of force and gravity and gain knowledge of the two ways to measure force: spring scale and force calculation. The teacher will conduct the guided activity at: <http://www.deltaeducation.com/downloads/samples_dsm/ForceMotionLink2.pdf> and students will participate in the related inquiry activity. Students will then learn the formula for the force of gravity and complete the Gravitational Force Gizmo.

Lesson 4 - **Introduction to work and calculating work**

Students will discuss the meaning of the term "work" in their daily lives and also consider the term with respect to the scientific community. The students will get active by pairing up to participate or role play activities involving work, students will also make note of activities that require no work. The definition of energy will be recalled, Energy: The capacity to do work. The definition of, Work: a force acting over a distance to move an object, will be introduced and this term will be added to the anchor chart or word wall for student use. Students will learn of the formula for calculating work and practice using this formula. Students will complete a quicklab and use computer technology to inform their responses.

Extra: (Homework for lesson 4) - More work word problem examples – This will provide the students a chance to work with the formula on their own time.

Lesson 5 – **Simple Machines**

What do machines do for society? for us? Let the students brainstorm again, ideas and discuss in groups of 4 their ideas around this.

Have a class discussion on their thoughts.

Video: <http://www.youtube.com/watch?v=jAPxALm9fZA&feature=related> (Mr. Anderson explains simple machines)

Demonstration: People Pulley System (Science Is, please see attached sheet in Appendix A). When you use machines to move a load you decrease the amount of effort needed to displace the object.

Introduce other simple machines (lever, ramp, pulley systems) in a center-based activity. Students will rotate through the activities and answer questions about the simple machines and what they could be used for in everyday use.

Lesson 6/7 (Lab) - **Efficiency and Mechanical Advantage (MA)**

Introduce the concept of efficiency by recapping lesson 5. Ask students how they know that the simple machines made moving the objects more efficient.

Talk about input and output in relation to yesterday's lesson and introduce Gizmo for the Pulley Lab

<http://www.explorelearning.com/index.cfm?method=cResource.dspDetail&ResourceID=572>

Extra: <http://www.cpo.com/home/Portals/2/Media/post_sale_content/PHY2/Ancillaries/SkillSheets/Unit_4/10.1_MechAdvSimpMach.pdf>) This is a great worksheet to practice using the MA formula with levers and ramps.

Lesson 8/9/10 - **Applications and culminating task**

Design to specification activity - Have students work in groups to design a simple machine to solve the problem of moving a load. The analysis should include calculations for work, force, and MA and applications of this simple machine could help out in a real world situation.

Assignment: Design a simple machine that can lift a 20 kg object 1 meter.

Materials students can use: paperclips, ring clips, sewing spools, fishing line, rope, rulers, cardboard, wood, chairs, doweling, marker, tape and glue.

Each student must hand in his or her own analysis and discussion. The Analysis and discussion must include:

* Calculations of Force, Work and MA for your machine
* A detailed diagram of their simple machine
* A detailed example of how your machine could help solve a real world problem
* A list of any references you used to build you machine

Lesson 11 - **Unit Review and test**

Review- consider main concepts and areas of common misconceptions

Test - <http://www.edquest.ca/pdf/sf84ut.pdf>

**Accommodations/Modification for Differentiate Instruction**

Depending on IEP’s and students needs some accommodations/modifications could include:

* The use of assisted technology
* Increased time given to complete assignments
* Decreased expectations or workloads
* Oral instruction
* Repeated instruction

**Safety Considerations**

* Online safety – students will be using computers to complete a portion of this concept sequence. A reminder of internet safety should be done before you complete the lab online.
* Repetitive task injury – working on a computer can often result in repetitive task strain, and students should be reminded to take breaks and stretch out to prevent sore and stiff muscles.
* Injuries from experimentation – students could hurt themselves in a few ways when working with the simple machine systems in the center based activity and demos. A reminder of safety procedures around injuries and injury prevention (tie back hair, make sure all body parts are clear of working machine parts) should be provided.
* Tidy work places – during the final activity, students may have materials spread out over a large space. A reminder to keep a tidy workspace and put away all unneeded items may be necessary.

**Students Difficulties/Misconceptions**

*Difficulty:* If students struggle with math anxiety the calculation portion of this concept could be an area of difficulty. Often students will plug in the numbers without understanding the basic concepts that apply to the principle.

*Solution:* By using multiple intelligence teaching strategies, students who struggle with logical/mathematical learning will find another avenue to develop a concrete understanding of the concepts of force, work and efficiency or mechanical advantage.

*Difficulty:* Students may struggle with the memorization of formulas or definitions.

*Solution:* produce anchor charts to post around the room with definitions and formulas for work, force, energy, and efficiency/mechanical advantage.

**Teaching Strategies**

Teaching strategies used throughout this concept presentation include:

* Inquiry based learning – the final assignment is a design to specifications assessment to test knowledge gained throughout the course
* Group work – for discussions on ideas
* Whole group discussion
* Teacher led demonstrations and guided activities
* Technology based interaction - Computer lab work, SMART Exchange activity
* Center based learning
* Independent study and reflection

**Evaluation**

The following forms of assessment are used for evaluation throughout the concept lessons:

* Graffiti Pre assessment for energy
* Brainstorm sheets
* Center observation sheets
* Calculation sheets (Force, Work and MA)
* Gizmo lab sheets
* Culminating task – Discussion and analysis write up, presentation evaluation, effectiveness and efficiency of simple machine built.
* Unit test
* Observation, participation, effort, and cooperation will also be considered

**Applications and Societal Issues**

Examples of simple machines that use energy, force, work and mechanical advantage:

Pulley: Elevators, theater curtains, flag raising, construction pulleys

Inclined planes: Wheelchair ramp, stairs, slide

Lever: Hammer, your forearm, scissors, nail clippers, fishing pole, wheelbarrow, bottle opener

**Annotated References**

**Books**

Bosak, S. 2000. Science Is: A source book of fascinating facts, projects, and activities. (2nd ed.) Toronto (ON): Scholastic.

*This book contains more than 450 projects, experiments, games, puzzles and stories in all areas of science. Although the activities are aimed more for elementary level students, older students can still find the concepts fascinating!*

Physical Science Grade 8 Text: Pearson Education, Inc. (2005): Physical Science- Science Explorer,

Pearson Prentice Hall: Needham, Massachusetts.

*This resource is the text used in many schools to integrate the science curriculum.*

**Websites**

DeWaters, J. & Powers, S.(2008)Energy Systems. Teach Engineering. Retrieved on July 12, 2012 from <http://www.teachengineering.org/view_activity.php?url=collection/cla_/activities/cla_activity3_energy_systems/cla_activity3_energy_systems.xml>

*Great website for information on definitions of work, force, energy and power, and how to apply the equations in a practical teaching setting. Lesson sequences form this sight are helpful in building a unit plan.*

Intel skool. (n.d.) SMART Exchange. Retrieved on July 12, 2012 from <http://exchange.smarttech.com>

*SMART Exchange is another great website that contains interactive presentations to help students bring concepts to life.*

PBS online. (2001) PBS Building Big: Forces lab. Retrieved on July 12, 2012 from [www.pbs.org/wgbh/buildingbig/lab/forces.html](http://www.pbs.org/wgbh/buildingbig/lab/forces.html)

*This lab is a wonderful interactive review of the types of forces that act on objects.*

(n.d.) Explore Learning: Gizmos. Retrieved on July 12, 2012 from <http://www.explorelearning.com/index.cfm?method=cResource.dspDetail&ResourceID=572>

*This website contains online labs called Gizmos and is another wonderful resource for online lab planning.*

(n.d.) Mass and Weight Worksheet. Retrieved on July 14, 2012 from

<http://www.djusd.k12.ca.us/patwin/pwong/documents/5Mass_WeightWksht.pdf>

*This website provides an excellent worksheet to assess students’ learning in the area of mass and weight.*

(n.d.) Measuring Force. Retrieved on July, 14 from

<http://www.delta-education.com/downloads/samples_dsm/ForceMotionLink2.pdf>

*This website provides for teacher guided activities and independent student activities in science.*

(n.d.) Newton’s Three Laws of Motion. Retrieved on July 14, 2012 from

<http://csep10.phys.utk.edu/astr161/lect/history/newton3laws.html>

*This website provides students with a brief and simplified version of Newton’s Three Laws of Motion.*

(n.d.) Web. Retrieved on July 14, 2012 from

<http://www.thinkport.org/d5d58008-1003-444d-8a99-877abc4f20a5.asset?>

*The website includes a spider-form graphic organizer.*

(n.d.) What is Force? Retrieved on July 14, 2012 from

<http://misssimpson.com/q26a-chapters/forces.pdf>

*The document retrieved from this website offers explanations for forces and its related concepts in student-friendly language as well as associated classroom activities.*

Appendix A

Pulley People Demo:

