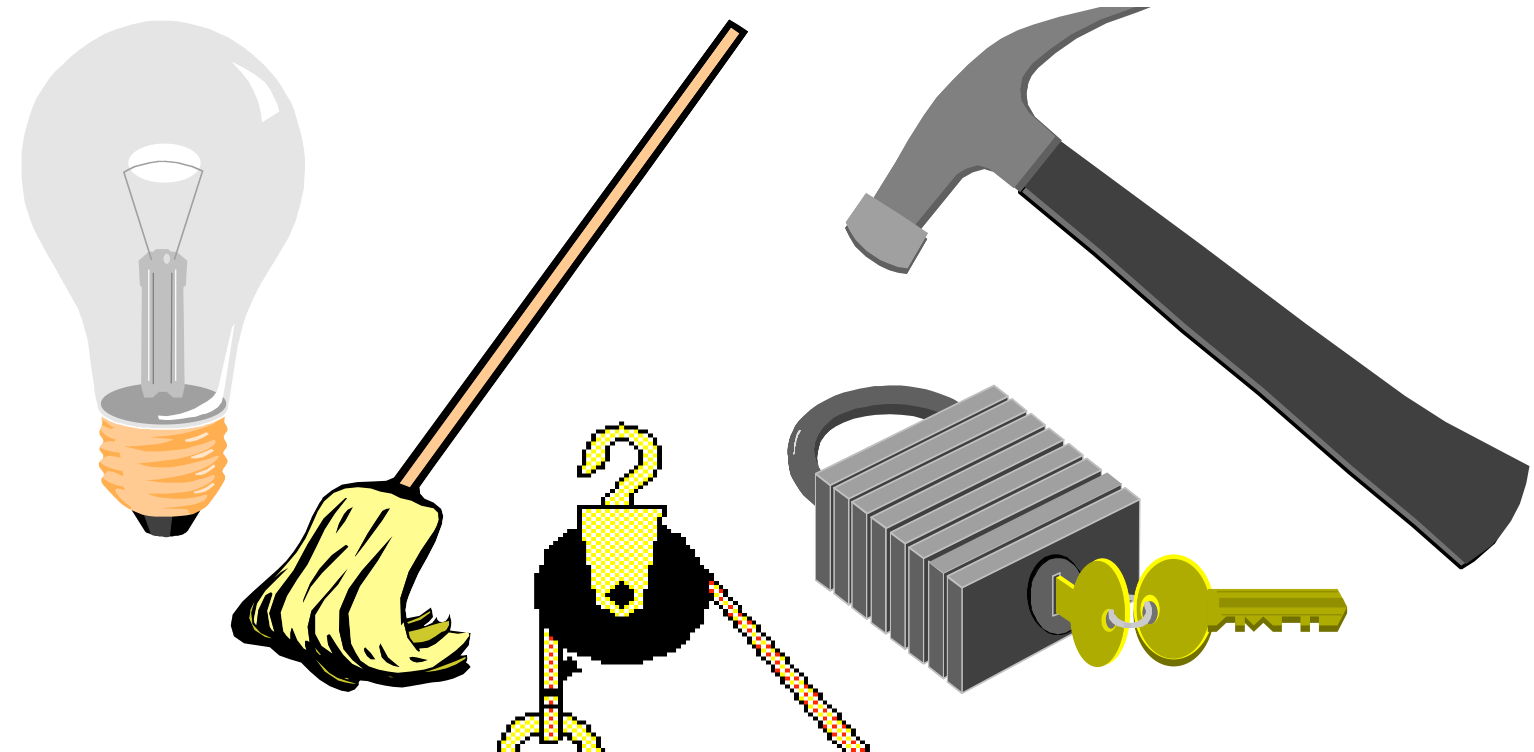
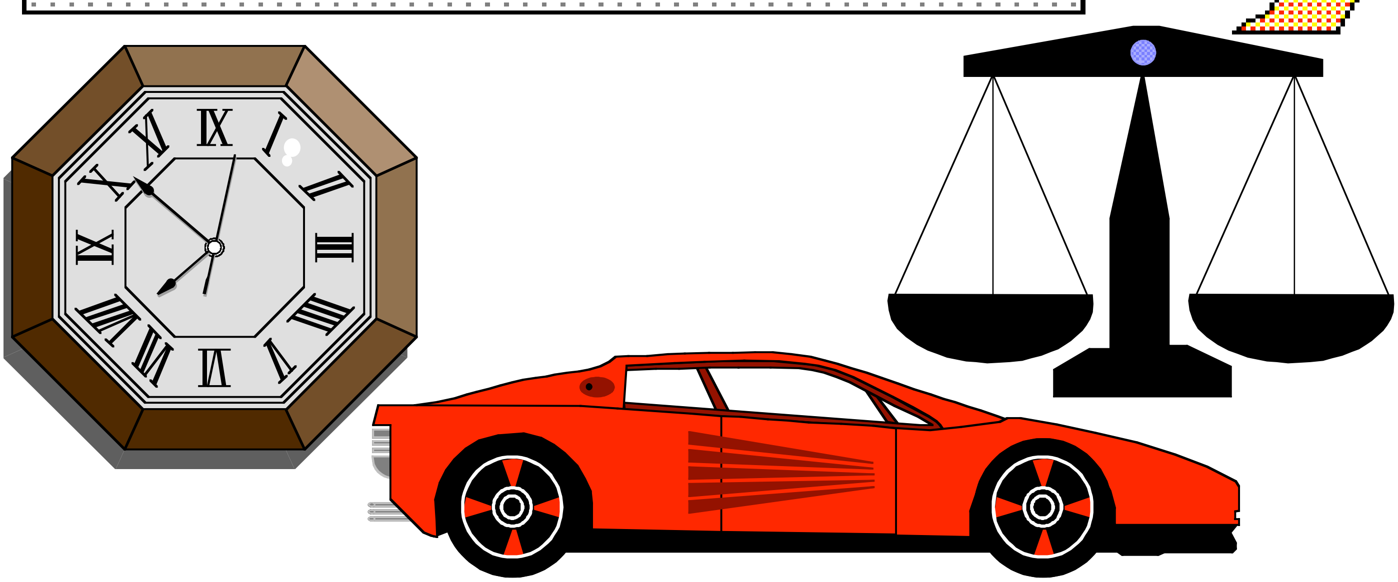


Teacher's Guide Addendum to Simple Machines



This document is a compilation of many hours of toil, discussion, confusion, re-discussion, learning, experience and patience between four elementary school educators and one engineer-turned-science program developer.

Developed for use as an Addendum to the Simple Machines module, giving a more well-rounded education on Simple Machines to students and teacher than that provided by the LEGO Dacta™ kit.

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GENERAL

OVERVIEW

The format for this Addendum is based on the FOSS (Full Option Science System)Teacher's Guide manual, and includes a resource list and handouts that may be copied for this Simple Machines module.

A simple machine is a device that makes work easier. Two other concepts introduced in this module are: (1) a simple machine changes direction of a force, and (2) a simple machine increases forces. To better understand the concept of simple machines, this module is broken down into four main parts.

In Part One, **What's Behind Simple Machines**, students explore the physics principles behind simple machines. They observe, describe, and record their discoveries made in the playground and in the classroom with simple experiments underlining Newton's Laws of motion.

In Part Two, **Discovering Simple Machines**, students are given scraps of paper and pieces of plastic clay to change. They explore the ways they can change the item both with and without using tools, and discuss the force and work involved in making the changes. Student groups are then given a discovery challenge to solve using their knowledge from Part One and the exploration of Part Two. Their resulting presentations will lead the follow-up discussion into formally introducing the six simple machine types.

In Part Three, **What Are Simple Machines?**, students discover the inclined plane, wedge, screw, lever, wheel and axle, and pulley in further detail with both classroom demonstrations and group activities. They start to use the LEGO Dacta™ kit pieces and activity cards building models of simple machines.

In Part Four, **Beyond Simple Machines**, students explore the inner workings of compound machines using working models, diagrams, and illustrations. They are given a design challenge to build a device to solve a problem posed by a literary article. Using the card activities from the LEGO Dacta™ kit, the students explore different types of gears and how they work separately and together.

There are two final assessment activities in this module, located at the end of Part Four. One is an identification and drawing exercise where each student group is given a compound machine to examine and then draw and label its basic elements and connections, answering certain key questions about the parts. Another is a machine design challenge. Here, students are given a choice of problems to solve and are to design (and build if materials are available) a machine to solve the problem they have chosen.

PURPOSE

Children have a natural curiosity and excitement about their surroundings and the world. They need opportunities to explore and be engaged in activities to develop an understanding of science. People are always inventing new ways to solve problems and get work done. New tools and new ways to get work done affect all aspects of life.

In this module, students will explore and discover basic forces of motion using everyday materials. They will develop an understanding of the six types of simple machines first hand, and how these tools help them do work in their everyday lives. The activities in the Simple Machines module will encourage students to observe, reason, and to think critically and creatively. They will develop a science vocabulary as they solve problems and communicate their ideas.

SCIENCE BACKGROUND

Since the main purpose of the existence of Simple Machines is to help us do work easier, requiring less force and effort on our part, it is necessary to provide this same understanding of the basic science principles behind them in this module. One cannot discover the differences in the force required to move an object using the different machines without learning first what force is and how it is affected by friction and inertia. These principles are experienced by the students in Part One by means of hands-on experiments with playground equipment and classroom materials. The activities done in the classroom are primarily taken from some of the experiments in the *A World in Motion* kit developed by the Society of Automotive Engineers. This kit is available to teachers who have completed the Newton's Gig course given by the Society of Women Engineers during the Summer Institute. There are more experiments in this kit that could be done as further extensions to this module that are not included in this addendum. It is important that students understand the reasons why things act the way they do in the world around them before they jump in and learn the uses of the machines. By understanding *why* the machine acts the way it does, they can then understand *how* the machine works.

Speaking of work, this is an important concept for students to understand as well. The following equations may illustrate how work is related to the machines and why we use machines to help us do work, rather than rely on our own power and strength.

WORK = FORCE X DISTANCE ; measured in foot-pounds

Simple machines help us do the same amount of work with less force, but if the force decreases, the distance increases.

EFFICIENCY = WORK OUTPUT/WORK INPUT

The efficiency of a machine is the ratio of useful work it does to the total work input.

POWER = AMOUNT OF WORK DONE/TIME TO DO IT; measured in horsepower

Power is the rate of doing work.

If you push against a wall that won't move, are you doing work? If you turn pages in a book, are you doing work? Look at the first of the above equations and you can answer these questions fairly easily. When you push against a wall, you may be using a lot of force, but the wall isn't moving, so no distance is traveled; thus, no work is done. When you turn the pages of a book, your finger is applying force to each page, moving it a distance to turn it over; thus, work is being done. So using these two examples, reading a book is more work than pushing a wall!

In Part Two, the principles of work, force, friction, and inertia are discussed further while students learn why tools were created. They will discover uses of tools and why they make our lives easier. At the end of the last session, they will start to learn the names of the six basic simple machines that they have discovered for themselves by designing a tool to solve a particular problem.

In Part Three, the science behind each of the six simple machines is detailed further in the Science Background section for each lesson. Each machine is defined, as well as the reasons why it works and how it works so you can easily explain this to the students.

Part Four is actually an extension of simple machines, since it involves compound machines that are made up of the basic simple machines, and gears, which are another form of wheel and axle used in a different way than the basic machine. Both compound machines and gears are discussed in detail in the Science Background section to the lessons.

Information for each science background has been gleaned from experience, knowledge, and from more material sources such as Macauley's *The New Way Things Work, The How and Why Wonder Book of Machines,* the Teacher's Guide for *A*

World in Motion, and various web sites on simple machines and work. A list of Simple Machine resources is included in this Addendum.

SCIENCE PROGRAM COMPONENTS FOR CHILDREN

Science is natural for young children. For most, the world is full of interesting things to explore and discover. Young minds are active and expansive, and eager to embrace science.

The most important components of a science program for children of all ages are firsthand experience with objects and organisms, and intellectual challenges that exercise the mind and help students construct and organize knowledge about the working of the world. Richness of understanding comes from depth of experiences. The activities in this module guide students through a number of simple experiences, any one of which taken alone may appear trivial. The materials used in a good program should be mundane and familiar to students, but the way they interact with the materials and the precise way they describe them makes the endeavor science. Through accumulation of these experiences young minds are able to construct a deeper understanding of the natural world around them.

Using Free Exploration

One of the keys to successful science experiences for students is to provide them with opportunities for free exploration. Materials are provided, and students are invited to "see what you can do with them" or "find out how they go together." This is a time for you to listen to students, ask questions, and note actions and comments that come from them. Free exploration does not require direction per se, but it does require you to be actively engaged with students. An occasional nudge may move students into productive interactions that they might otherwise miss (e.g. "Have you tried …?")

Classroom Discussions and Assessment

Discussions in which students share their ideas and observations and answer questions posed by you are a central part of the science program. However, don't try to conduct discussions while students are working with materials. The allure of materials will always defeat the attempt to engage students' minds in discussion. Ask students to push the materials to the center of the table during the discussion, or hold the discussion after the materials have been collected. Gathering students "at the rug" away from the hands-on science activities is another method to focus their attention. If it is necessary for students to demonstrate a discovery, have one set of materials ready for them to use for demonstration during discussion.

One productive technique for capturing student ideas and comments for discussion is to carry a clipboard or notepad while you observe the groups during free exploration. Snippets of informal conversation can be written down and transcribed onto the board for a discussion later that day or the next. These comments and observations can also be used as springboards for engaging students in written reports and drawings that become part of the experience. Such exercises can be used as assessments of student achievement and progress.

Styles of Learning and Development

Some children plan their models; some jump right into action and begin building without planning. This kind of learning style preference will reveal itself through a child's building process. During free exploration and the various science activities, you can observe how the student's motor skills develop over time and their powers of concentration on a particular task, i.e., whether they are easily frustrated or will take the time to complete the activity. You can also observe how well students work together in a group and how they express themselves both within the group and within the entire class. Whether or not the student uses mathematical language in his/her observations, such as faster, slower, more, less, etc. may also be observed and noted in this module. Students should be able to: distinguish between man-made things and natural things, build a stable structure, learn about balance within structures, test out a hypothesis, and evaluate and solve a problem. During this module, the student will become a better problem solver learning through trial and error, and develop unique and inventive solutions to everyday problems. In solving the problems, the student may also demonstrate innovative uses of the materials on hand.

Language Development

Science is a rich content area for developing language concepts and vocabulary. Observing properties is one key to science, but equally important is communicating those observations. To do so students need to develop a sound vocabulary that will serve them in science and life in general.

Science vocabulary may be introduced to children formally and informally. Students may describe a piece of plastic tubing as bendy, rubbery, and squishy. This is the time to introduce *flexible* as the precise word for materials that are these qualities they have described. Students should pronounce the new word and see it written. The informal method of introducing a new word is by using the context of the discussion to provide the meaning of the word. For example, when asked how a student made the box top move across the surface of the table, the student might respond that she pushed and pulled it. The precise word *force* can be introduced informally. "Sally said she pushed and pulled the box top to make it move on the table. Who else observed the force used to move the box? What other objects move with a force like you moved the box?"

Students will be recording their observations and designs in individual journals. By having variety in drawing tasks, students will maintain a higher level of interest. If pictures are produced with pencil one day, assign crayons, colored pencils, markers, or paint for subsequent pictorial recording.

ORGANIZING TIME

There is no rigorous time requirement or schedule for teaching this unit. The activities are sequential and should be taught in order, and the time between sessions should be relatively short, but beyond that there is no "right" way to conduct the module.

The activities should not be rushed. The chart below is an estimation of how many sessions it will take to complete the module. The right-hand column indicates whether the activity will be conducted with the whole class simultaneously or in a center. You may find that it takes even more sessions to complete an activity in a way that is satisfactory to you and the students. Going slowly and dealing thoroughly with ideas is a good strategy. If you find that you do not have enough time to complete Part Four activities, as long as a good understanding of the first three parts has been accomplished, then you have achieved the main concept Simple Machines and should not be regretful that you did not complete the whole module.

In addition to the main lesson plans, each activity has suggested additional activities for home and/or school. The chart below does not include time for these extensions, but we hope you will find time for them and integrate them into your curriculum.

SUGGESTED TEACHING SEQUENCE

PART	ACTIVITIES	NO. OF SESSIONS	ORGANIZATION
ONE	L1: Playground	1	Whole class
Behind Simple	L2: Force	1	Half/half (swap)
Machines	L3: Friction	1	Half/half (swap)
	L4: Inertia	1	Half/half (swap)
TWO	L5: Introduction	1	Whole class
Discovering	Problem Solvers	2	Whole class
Simple Machines	L5: Types	1	Whole class
THREE	L6: Inclined Plane, Wedge, Screw	3	center
What are	L7: Lever	2	Whole class
Simple Machines?	L8: Wheel & Axle	2	Whole class
	L9: Pulley	2	Whole class
FOUR	L10: Compound machines	3-5	Whole class
Beyond Simple Machines	L11: Gears	4-6 (as time allows)	Whole class

ORGANIZING STUDENTS AND SPACE

Working Alone Together
Students in first and second grades are usually most comfortable working as individuals with materials. The abilities to share, take turns, and learn by contributing to a group goal are developing but not reliable as learning strategies all the time. To effectively manage the students and materials, we offer some suggestions.

Groups
We suggest organizing the class into groups of two to three students. When dividing them into groups of two or three, you can relate this group experience in the classroom to that of real-life engineers working together as a team to solve a problem. As each engineer has a title and is responsible for certain tasks peculiar to their specialty, so will each student in the group. But it should be stated that each student in the group shall also be thinking of a solution to the problem activity, and it is the team effort of pulling together all the ideas of the group that a consolidation of ideas or compromise may solve the problem.

A description of the individual "student engineer" task descriptions follow. There are two sheets following this Section that may be copied and given to groups when working in centers.

Groups of two:

Project Engineer

- You check the assignment
- You ask the teacher questions
- You conduct team discussions
- You work with the Manufacturing Test Engineer in designing the models
- You approve models after construction
- You are in charge of safety

- You record the data
- You check the data sheet
- You explain the team report

Manufacturing Test Engineer
- You make the construction materials list
- You collect the materials and equipment
- You report broken equipment
- You work with the Project Engineer in designing the models
- You construct the models
- You conduct the model test activities
- You are in charge of workstation cleanup
- You return materials and equipment

Groups of three:

Project Engineer
- You check the assignment
- You ask the teacher questions
- You conduct team discussions
- You work with the Facilities and Test Engineers in designing the models
- You approve models after construction
- You are in charge of safety
- You explain the team report

Facilities Engineer
- You work with the Project and Test Engineers in designing the models
- You make the construction materials list
- You collect the materials and equipment
- You report broken equipment
- You are in charge of workstation cleanup
- You return materials and equipment

Test Engineer
- You work with the Project and Facilities Engineers in designing the models
- You are in charge of getting the models built
- You conduct the model test activities
- You record the data
- You check the data sheet

Whole Class Activities

Often all of the groups will be doing the same thing. When using the LEGO Dacta™ kit, each group will have their own kit and will be building the same model. Students may think of additional pieces to add to their model to make it answer questions they may have about balance and motion, so they may try it to see what they discover. Students are encouraged to do their own exploration of their questions they may have. Often students see others doing something interesting and try it themselves, generating new ideas in the process. It is not uncommon to see an idea sweep across the room with everyone doing the same thing for a few moments.

Center Activities
Sometimes one or more groups will be doing hands-on activities while the other groups are engaged in other activities. This is like a traditional learning center methodology where students rotate through the center. This strategy is used when there are multiple activities that need to done and materials and time are limited to allow for every group to be doing the same activity at the same time. Lessons 2 through 4 and Lesson 6 involve students working at centers.

Organizing Space
Periodically during this module students need to be drawn in and focused for discussion or for a demonstration. A rug area or a place where students can easily and logically congregate is best, but if no such area is available, you can devise a mechanism that indicates to the students that it is time to focus their attention.

During much of the time spent doing this module, students will be spread out in the classroom in groups working at large tables or at desks pulled together to approximate a large table. Sometimes students should be in their seats, concentrating on set tasks, while at other times they need freedom to move about and interact with other students.

ORGANIZING MATERIALS

Part One and Two Materials
The materials listed for activities in the first half of the module are not included with the LEGO Dacta™ kit. However, most of these materials are easily accessible in either the school, home, or local store. It may be beneficial for a school to provide the boards necessary for the activities so all the teachers in that school who use this module may have access to them and not have to store them in their rooms when not in use.

LEGO Dacta™ Kit
Each container of LEGO™ pieces has enough pieces and activity cards for one group to use.

Consumable Materials
A number of items in the list of materials needed for Part One and Two activities are consumable. Some of these items will be used up during the activities and others will be worn out. These items should be replaced upon completion of the module.

Materials Distribution
You may use a centralized distribution system for whole-class activities. You place the materials needed for an activity on a table called the materials station. One student from the group is the Facilities Engineer. He or she gets the materials needed by the group. Students like the job, and the use of the Facilities Engineers really help with the movement of materials.

Materials Inventory
Included with the module are two lists to help you organize and maintain the student equipment. One is the *Simple Machines Inventory Sheet*. This is the material needed for the Part One and Two activities that is not provided with the LEGO Dacta™ kit. Items are listed as consumable or permanent equipment, and kit quantities are given.

The second list is found in the back of the LEGO Dacta™ Teacher's Guide. This is an illustrated list of all the pieces and quantities of each found in the kit. These sheets may be copied and used for students to do their own inventory of their kits upon receipt and after use.

GETTING READY

Read This Section First
There is a Getting Ready section for each lesson to help you prepare. It provides detailed information on the scheduling of the activities and helps you prepare and organize the student equipment used in the activity.

Consider the Schedule
The suggested teaching schedule in this overview will help you decide when to get the materials necessary for each activity and any extra help required. It is not necessary to complete the whole module, but as a minimum students should complete activities up to Part Four to learn the fundamentals of simple machines.

Consider Safety
Young children must be allowed to demonstrate that they can act responsibly with materials, but they must be given guidelines for safe and appropriate use of materials. Work with students to develop those guidelines so they participate in the making of behavior rules and understand the rationale for the rules. Emphasize that materials do not go in mouths, ears, noses, or eyes. Encourage responsible actions toward other students.

Plan How to Get Students' Attention
The activities in this module can be exciting, particularly when building models using the LEGOs™. Much of the time students will be engaged in free exploration. The level of activity that students enjoy during science may be different than what is acceptable at other times.

Explain to students that they will need to be given a level of freedom in order to do the activities, but that they must also be able to quickly give you their attention when you call for it. Impress on them the need for establishing signals that everyone agrees mean stop the activity and listen.

Send a Letter Home to Parents
The fourth page of the LEGO Dacta™ Teacher's Guide is a sample letter to parents describing the Simple Machines kit and how parents can participate in their child's science activities.

Prepare for Cruising the Groups
Most of the time students will be doing activities and making models, and you will be cruising group to group, offering assistance and acknowledging questions and discoveries. This is your opportunity to interact with students and to monitor your progress. Take a clipboard or note pad with you and write down student questions and comments.

Duplication Masters
There are 66 duplication masters included in this Addendum to the Simple Machines kit, including 10 data sheets for each of the recording activities. Some of the masters are for your use only, such as the center activity cards. Other sheets are for student use. Select the sheets that are appropriate for your students and make copies for each student as indicated in each lesson. The suggested sheets are listed in the Getting Ready section for each lesson.

Arrange for Helpers
It is suggested that you arrange for extra help on the days you conduct the centers. A second or third set of hands and eyes helps to keep the centers moving in a productive direction. Parents, aides, student teachers, or upper-grade students can fill this role. Plan to teach these centers when help is available.

Center Instruction Cards

Each activity part that involves a small number of students at a center has a Center Instruction Card written for a parent or other adult helper working with students. The card summarizes the information provided to the teacher in the Addendum. You may make your own cards from the sheets following the activities in the lesson as indicated on the teacher's page of the activities in the Addendum. Take time to orient your adult volunteers and aides to the overall purposes of the activities and encourage them to facilitate but not to direct the student learning at the center.

Simple Machines Module Planning Chart

The next four pages contain a planning chart that is a summarization of key items in each part of this Addendum to the Simple Machines module. The key items include: Key Ideas, Vocabulary, Thinking Process, Extensions, Assessment. You can use this chart to plan your curriculum, and add to it as time progresses with your experience with this module.

Simple Machines Resource Lists

Following the Planning Chart are two lists of resources you may use as reference and extensions to this module. One lists fiction and non-fiction books and manuals, and the second lists internet web sites where additional information and/or activities may be found. Some of these resources have been used in the writing of this Addendum and activities for the Simple Machines module.

Simple Machines Glossary

A Simple Machines glossary is included at the end of this Section for your use in the classroom.

SIMPLE MACHINES MODULE PLANNING CHART

	KEY IDEAS	VOCABULARY	THINKING PROCESS	EXTENSIONS	ASSESSMENT
PART ONE	Force is needed to do work. Friction is resistance to work being done. Structures need to be sturdy and safe. Triangular shapes are the most stable. Gravity, inertia, and friction are forces.	Work Force Gravity Motion Effort Friction Speed Resistance Slope Structure Stable Truss Distance	Observe force's effects on an object. Compare different surfaces and the effects of friction. Explore a variety of materials and processes related to force, gravity, motion, and friction. Record observations and data. Predict outcomes of discovery activities.	Provide for ongoing investigations by varying materials. Create an ongoing glossary of Simple Machine terms. Vary the shapes of the aluminum foil to explore points of friction on an inclined plane. Use Quick Writes. Relate concepts to school and home life, e.g. sports.	Bring in pictures or make collages of things that move and tell how it moves and what affects the motion.

	KEY IDEAS	VOCABULARY	THINKING PROCESS	EXTENSIONS	ASSESSMENT
PART TWO	Tools help people do work. Forces are needed to do work. There are six types of simple machines.	Tools Change Load Simple machines Inclined plane Wedge Screw Lever Wheel and axle Pulley	Use creative thinking to solve problems. Discover how the use of energy can change things around you. Discover new uses for familiar tools. Explore and solve problems to discover the six types of simple machines.	Tour the schoolbus or other areas of the school to find simple machines. Extend the Problem Solvers section to have students create their own problems to solve using simple machines. Make a collage of simple machines.	Identify a variety of simple machines in the classroom, school, or home. Make a web of the six simple machine types.

	KEY IDEAS	VOCABULARY	THINKING PROCESS	EXTENSIONS	ASSESSMENT
PART THREE	An Inclined Plane is a slanted surface that work is done on. A Wedge is an Inclined Plane that pushes two objects apart. A Screw is an Inclined Plane wrapped around a cylinder. A lever is a bar with a fulcrum or pivot point. A Wheel and Axle must rotate together to do work. A Pulley is a grooved wheel with a rope or chain on it. There are two kinds of pulleys: fixed and movable.	Mechanical advantage Horizontal Vertical Cylinder Shaft Pitch Thread Clockwise Counter- clockwise Fulcrum Pivot point Balance Axle Rotate Revolve Hub Rod Fixed pulley Movable pulley Drive belt Groove	Identify and sort the six types of simple machines. Compare how the simple machines are alike and different. Construct a model of each simple machine. Communicate using technical language of simple machines. Diagram and label simple machine construction.	Make an ABC book of Simple Machines. Have a screw sorting center with nuts, bolts, screws, jars, etc.. Sort pictures of Simple Machines. Create a song, poem, or story about simple machines. Relate concepts to school and home life, e.g. sports.	Use a graphic organizer to assess individual student's knowledge of Simple Machines. Use Quick Writes and Writing Prompts.

	KEY IDEAS	VOCABULARY	THINKING PROCESS	EXTENSIONS	ASSESSMENT
PART FOUR	Compound Machines are made up of Simple Machines. Gears are toothed wheels. Gears are used to change direction and speed. Triangular shapes are the most stable. Gravity, inertia, and friction are forces.	Compound machine Gear Input Output Driver Follower Spur gear Mesh Teeth Crown gear Bevel Idler gear Worm gear Gearing up/down Gear train Gear ratio	Identify simple machines within a compound machine. Explore connective-ness of simple machines using pictures, schematics, and objects. Design a compound machine to solve a problem. Sort and identify different kinds of gears. Observe how gears change the speed and direction of the machine.	Bring a bicycle in to class. Hold an Exploratorium with parents to design a compound machine to solve a problem. Use Problem Solving cards in kit.	Use *How Does it Work?* assessment activity in Addendum. Use *Machine Design Challenges* assessment activity in Addendum.

SIMPLE MACHINES RESOURCE LIST – printed material

NF = Non-fiction   F = Fiction

NF	*The New Way Things Work*, David Macaulay, Houghton Mifflin Company, Boston, 1998.
NF	*The Way Things Work*, David Macaulay, Houghton Mifflin Company, Boston, 1988.
NF	*The How and Why Wonder Book of Machines*, Dr. Jerome J. Notkin and Sidney Gulkin, Wonder Books, New York, 1960.
NF	*A World in Motion Teacher's Guide*, Society of Automotive Engineers, 1990.[1]
NF	*Seesaws, Nutcrackers, Brooms, Simple Machines that are Really Levers*, Rae Bains, Troll Association, 1985.
NF	*Buildings, Bridges, and Tunnels*, Jackie Gaff, Random House, 1991.
NF	*Wheels at Work*, Bernie Zubrowski, Morrow Junior Books, 1986.
NF	*How is a Bicycle Made?*, Henry Horenstein, Simon & Schuster, 1993.
NF	*Load Lifters*, Hope I. Marston, Dodd Mead Co., 1988.
NF	*The Truck Book*, Harry McNaught, Random House, 1983.
NF	*Bike Factory*, Harold Roth, Random House, 1985.
NF	*Wheels*, Julie Fitzpatrick, Silver Burdett, 1986.
NF	*Telephones, Televisions, Toilets*, Melvin and Gilda Berger, Ideals, 1993.
NF	*How Things Work, Lifting by Levers*, Andrew Dunn, Thomson Learning, 1996.
NF	*How Things Work, Simple Slopes*, Andrew Dunn, Thomson Learning, 1996.
NF	*How Things Work, Wheels at Work*, Andrew Dunn, Thomson Learning, 1996.
NF	*Science Activities, Forces*, Graham Peacock, Thomson Learning, 1994.
NF	*Marbles, Roller Skates, Doorknobs, Simple Machines that are Really Wheels*, C. Lampton, Troll Association.
NF	*Snap, Button, Zip*, V. Cobb
NF	*Make it Work! Machines*, Baker and Haslam
NF	*One Way Down, A Book about Gravity*, V. Fischer
NF	*Ramps*, B. Kohn
NF	*Wheels*, L. Miller
NF	*Monster Movers*, A. Ancona
NF	*Hoists, Cranes, and Derricks*, H. Zim
NF	*Levers*, L. Miller
NF	*Simple Machines*, A. Horvatic
NF	*The Lever and the Pulley*, H. Hellman
NF	*Simple Machines and How they Work*, E. Sharp
NF	*Power Machines*, K. Robbins
F	*Katy and the Big Snow*, Virginia L. Burton, Houghton Mifflin, 1971.
F	*Mike Mulligan and the Steam Shovel*, Virginia L. Burton, Houghton Mifflin, 1967.
F	*Haystack*, Bonnie and Arthur Geisert, Houghton Mifflin, 1995.
F	*After the Flood*, Arthur Geisert, Houghton Mifflin, 1994.
F	*The Ark*, Arthur Geisert, Houghton Mifflin, 1988.
F	*Pigs from A to Z*, Arthur Geisert, Houghton Mifflin, 1986.
F	*Doctor DeSoto*, William Steig, Scholastic, 1982.
F	*Galimoto*, K. Williams
F	*Bones Bones Bones*, B. Barton

[1] Available only upon completion of teacher course (Newton's Gig) given by Society of Women Engineers in Summer Institute of educational collaborative

SIMPLE MACHINES RESOURCE LIST – web-sites

Work	www.teachtsp.com/classroom/scicourt/work.html www.uen.org/utahlink/lp_res/TRB013.html www.ed.uri.edu/SMART96/ELEMSC/SMARTmachines/work.html
Force	www.ed.uri.edu/SMART96/ELEMSC/SMARTmachines/Force.html
Distance	www.ed.uri.edu/SMART96/ELEMSC/SMARTmachines.dist.html
Science principles	www.henry.k12.ga.us/cur/simp-mach/instruction.htm
Simple Machines (general)	www.ed.uri.edu/SMART96/ELEMSC/SMARTmachines/machine.html nyelabs.kcts.org/teach/eg_print/eg10.html teachers.net/lessons/posts/215.html www.sasked.gov.sk.ca/docs/elemsci/fr3uhesc.html www.trms.k12.fulton.ga.net/%7Rjtucker/lessons/sc/machines.html www.uark.edu/depts/aeedhp/agscience/simpmach.htm www.mos.org/sln/Leonardo/InventorsToolbox.html www.crpc.rice.edu/CRPC/GT/dawsonm/CAST/CAST95.html www.swe.org/SWE/Student Services/CareerGuidance /GirlScoutModules/machines.html
Inclined Plane	www.coe.ug.edu/archive/science/science_lessons/scienceles1/plane.htm www.ed.uri.edu/SMART96/ELEMSC/SMARTmachines/plane.html
Wedge	www.ed.uri.edu/SMART96/ELEMSC/SMARTmachines/wedge.html www.coe.uh.edu/archive/science/science_lessons/scienceles1/wedge.htm
Screw	www.ed.uri.edu/SMART96/ELEMSC/SMARTmachines/screw.html www.coe.uh.edu/archive/science/science_lessons/scienceles1/screw.htm
Lever	www.hamlin.pvt.k12.ca.us/science/scifair/art.html risc.usi.edu/~msampson/levers.html beakman.com/lever/lever1.html beakman.com/lever/lever2.html beakman.com/lever/lever3.html beakman.com/lever/lever4.html www.ed.uri.edu/SMART96/ELEMSC/SMARTmachines/lever.html www.uen.org/cgi-bin/websq1/lessons /14.hts?id=114&core=3&course_num=3030&std=4 www.coe.uh.edu/archive/science/science_lessons/scienceles1/lever.htm www.lerc.nasa.gov/Other_Groups/K-12/Summer_Training /KaeAvenueES/lever.html
Wheel and Axle	www.ed.uri.edu/SMART96/ELEMSC/SMARTmachines/wheel.html www.coe.uh.edu/archive/science/science_lessons/scienceles1/lever.htm
Gears	wildcats.lafsd.k12.ca.us/stanley/projects/simp3.html www.howstuffworks.com/gears.htm
Compound Machines	www.howstuffworks.com/inside-clock.htm www.howstuffworks.com/bicycle.htm

Simple Machine Glossary

GRAVITY
The pull on all objects towards the center of the earth.

FORCE
A push or a pull.

WORK
Work is done when a force moves something with weight through a distance.

ENERGY
In science, energy is defined as the ability or capacity to do work.

EFFORT
The use of energy to do work.

RESISTANCE
Relating to work, resistance is a weight or **LOAD**.

FRICTION
A rubbing of one object against another. It is also a force that resists motion.

MOTION
Movement; a moving from one place to another.

SPEED
Rate of movement; velocity.

INERTIA
The tendency for an object to stay at rest or a moving object to continue to move in a fixed direction unless affected by an outside force.

STRUCTURE
Something built or constructed.

STABLE
Firm; fixed; not likely to give way or fall down.

TRUSS
A triangular framework for supporting a structure such as a roof, bridge, etc.

SLOPE
Any inclined line, surface, etc.; slant.

DISTANCE
An interval between two points in space.

TOOLS
Any hand implement used for work.

CHANGE
To make different.

SIMPLE MACHINE
A basic device or tool to make work easier. There are six types: inclined plane, wedge, screw, lever, wheel and axle, pulley.

INCLINED PLANE
A flat surface with one end higher than the other.

WEDGE
One or two inclined planes that push two objects apart.

SCREW
An inclined plane wrapped around a cylinder or shaft.

LEVER
A bar that rests on a pivot point or fulcrum.

WHEEL AND AXLE
Rotates around a fixed point.

PULLEY
Based on the wheel and axle, has a groove in the wheel and a rope or chain over it.

MECHANICAL ADVANTAGE
The gain in force or speed that a machine gives to move a resistance.

HORIZONTAL
Parallel to the plane of the horizon; flat and even, level.

VERTICAL
Upright, straight up or down.

CYLINDER
A solid figure described by a line with end points in common with two equal, parallel, circular bases and moving parallel to a perpendicular axis.

SHAFT
A long, slender part or object, as a pillar or bar.

PITCH
The distance between two grooves on a screw, equal to one turn of the screw

THREAD
The groove on a screw.

CLOCKWISE
Moving in the direction of the hands of a clock.

COUNTER- CLOCKWISE
Moving in the opposite direction of the hands of a clock.

PIVOT POINT
The point on which something turns.

FULCRUM
The support on which a lever turns in raising something.

BALANCE
A state of equal weights.

AXLE
A rod on which a wheel turns.

ROD
A rod is a straight stick or bar.

HUB
The hub is the center part of a wheel.

ROTATE
To turn around an axis.

REVOLVE
To move in a circle or orbit.

GROOVE
In terms of pulleys, a groove is a channel or rut in the wheel.

FIXED PULLEY
A fixed pulley is attached to a fixed point by means of a hook.

MOVABLE PULLEY
A movable pulley is fastened to the load being lifted.

DRIVE BELT
In terms of pulleys, a belt drive is an endless band for transferring motion.

COMPOUND MACHINE
A compound machine is comprised of a number of simple machines connected together to make work easier.

GEAR
Gears are toothed wheels that change direction and speed.

TEETH
With regards to gears, teeth are the notches in the gear wheel.

MESH
When one gear wheel is interlocked with another, they are meshed together.

GEAR RATIO
The number of times one gear goes around once compared to another gear. For example, if a small gear went around twice every time a larger gear went around once, the ratio would be 2:1 (two to one).

GEAR TRAIN
A combination of gears connected together to do work.

GEARING UP
When a large gear turns a smaller gear, causing an increase in speed.

GEARING DOWN
When a small gear turns a large gear, causing a decrease in speed and an increase in force.

DRIVER
When one gear is turning another next to it, the one applying the force to the other is said to be the driver.

FOLLOWER
The gear being driven or turned by another gear is called the follower.

SPUR GEAR
A spur gear is a basic flat toothed wheel that controls the speed or applied force and can reverse direction

IDLER GEAR
A gear placed between two gears.

BEVEL
An angled part or surface.

CROWN GEAR
A crown gear has an angled toothed wheel that changes the direction of rotation, also changing the speed and force if necessary.

TORQUE
The force that acts to produce rotation.

WORM GEAR
A worm gear is a shaft with a screw thread that meshes with a toothed wheel to change the direction, speed, and force.

INPUT
In terms of machines, input is the power that goes into a machine.

OUTPUT
In terms of machines, output is the amount of work done or produced over a given period.

Group Job Assignments

Project Engineer

- You check the assignment
- You ask the teacher questions
- You conduct team discussions
- You work with the Manufacturing Test Engineer in designing the models
- You approve models after construction
- You are in charge of safety
- You record the data
- You check the data sheet
- You explain the team report

Manufacturing Test Engineer

- You make the construction materials list
- You collect the materials and equipment
- You report broken equipment
- You work with the Project Engineer in designing the models
- You construct the models
- You conduct the model test activities
- You are in charge of workstation cleanup
- You return materials and equipment

Group Job Assignments

Project Engineer

- You check the assignment
- You ask the teacher questions
- You conduct team discussions
- You work with the Facilities and Test Engineers in designing the models
- You approve models after construction
- You are in charge of safety
- You explain the team report

Facilities Engineer

- You work with the Project and Test Engineers in designing the models
- You make the construction materials list
- You collect the materials and equipment
- You report broken equipment
- You are in charge of workstation cleanup
- You return materials and equipment

Test Engineer

- You work with the Project and Facilities Engineers in designing the models
- You are in charge of getting the models built
- You conduct the model test activities
- You record the data
- You check the data sheet

SIMPLE MACHINES MATERIAL INVENTORY

** = CONSUMABLE ITEM*

For Demonstrations:

- Board
- Small ball or marble
- Metric ruler
- Toy car (best if has a sunroof or some way to hold a tennis ball on top)
- Carpet
- Sandpaper
- Sheet metal (optional)
- Tennis ball
- Block of wood (shorter than the height of the car)
- Examples of Simple Machines from home/school and pictures/posters of simple machines
- Small rock
- Doorstop
- Piano stool or swivel chair
- Scissors
- Cardboard*
- 4 pencils
- Heavy hardcover book
- 2 broomsticks
- Clothesline

For Activities (quantities given are per activity center):

- Board about 1m long
- 7 hardcover books of similar thickness
- Stack of books or box
- Masking tape (2 rolls) *
- Tennis ball
- Watch with second hand
- Small box or lid
- 2 paper clamps (small & medium)
- 2 rubber bands*
- Straws (enough for every student as they are thrown away after use)*
- 3 boards (2 regular and 1 particle board)
- 5 cm long pipe cleaner
- Aluminum foil*
- Paper clip*
- Notebook paper*
- Paper towels*
- Wax paper*
- Shoebox
- 2 marbles
- Clear plastic cylinder (may be made from a cut tennis ball tube container or liter bottle)
- Piece of scrap paper per student*
- Piece of plastic clay per student*
- Toy car

SIMPLE MACHINES MATERIAL INVENTORY (cont'd)

** = CONSUMABLE ITEM*

<u>For Activities (quantities given are per activity center):</u> *(cont'd)*

- Tissue paper*
- 2 Metric rulers
- Rock with string around it and loop on one end to put rubber band through
- Block of wood*
- Hammer
- Pointed nail*
- Blunt nail or bolt
- Wooden wedge
- 2 foot stack of books
- Coin or other small flat object
- Bar of soap*
- 4 screws of same length but different pitches
- Marked screwdriver (put dot or tape on one side)
- Screw containers with lids
- Hand lotion*
- Plastic wrap*
- Piece of flat rubber
- Pencil (one per student)*
- Paper triangles with slope marked (1 per student)*
- Scotch tape*
- Whole class shared supplies:
    - Scissors
    - Paper punch
    - Pencils or pens*
    - Paint*
    - Crayons and/or markers*
    - Scotch tape and/or glue*
    - Paper to write and/or draw on*
    - Construction paper*
    - Magazines*
    - Cardboard*

PART ONE: WHAT'S BEHIND SIMPLE MACHINES

OVERVIEW

This part of the Simple Machines module explains the basic principles behind the function of a Simple Machine in the form of hands-on experiments. The three main principles of force (Lesson 2), friction (Lesson 3), and inertia (Lesson 4) are explored and discussed as an understanding of what makes a machine work the way it does. Students explore and discover how these principles operate in Lesson 1, using playground equipment.

LESSON 1: WORK & FORCES

PURPOSE

In this lesson, students will discover:

- Force is needed to help them do work over a distance
- Friction is resistance that slows down their ability to move or do work
- Playground equipment (structures) need to be sturdy and stable to be safe
- Triangular shapes are the most stable structural shape
- Gravity is a force that always pulls them toward the earth

OVERVIEW

As an introduction to this module, take your class out on the playground for the observation and exploration of familiar equipment. Guide students to focus on how they use equipment to help them move and do work for them.

SCIENCE BACKGROUND

This activity introduces the basic concepts of simple machines in a student-friendly environment such as a playground.

Gravity is discovered as a ***force*** pulling objects to the center of the earth. It is readily observed when a student slides down a slide or drops from the monkeybars. A different type of force is observed on the pulling of a student on the edge of a turning merry-go-round.

Force, defined as a push or a pull, can easily be seen on a swing or merry-go-round. Both can only be moved by either a push or a pull. The same is true for a seesaw. Pushing off the ground with your feet causes the seesaw to move, unless one student is naturally heavier than the other. In this case, the force of gravity will pull the heavier student down causing the opposing student to be lifted. ***Work*** is involved in getting the heavier student back off the ground by pushing against gravity. Any time a force moves something with weight through a distance is an example of work being done.

Energy is also involved in doing work. Using energy to do work such as a child pushing off the ground to make a swing or seesaw move is an ***effort*** on his or her part.

Children wearing different types of clothing will discover variances in the force of ***friction*** as they slide down the slide. When surfaces move against one another, friction resists motion. Different surfaces create different amounts of friction. Children wearing nylon will slide down faster than those wearing heavy denim. The smoother material rubbing against the smooth surface of the slide has less friction since they are of similar surfaces than that of the rougher material which will resist motion and be a slower slide for that child.

Inertia is observed when an object such as a small rock or coin is placed on a merry-go-round or a swing and the equipment is set gently in motion and then stopped abruptly. According to Newton's first Law of motion, objects stay at rest and moving objects continue moving in a straight line until acted upon by an outside force. When set in motion, the object resting on the equipment is moving at the same rate as the equipment. When the equipment is stopped, inertia allows the object to continue its movement and it will "fly off" the equipment in a straight line.

Another observation that can be made at the playground is how stable the equipment needs to be to be able to handle different weights and forces acting on it. The triangle (or its three-dimensional version, the pyramid) is the basis for a stable structure, as can be easily seen on a swing set. If a house is under construction nearby, there will be roof ***truss***es that are triangular in shape. Many bridges and high tension power lines also use trusses, as do Ferris wheels and roller coasters.

MATERIALS

The only material needed in this lesson is a playground with various pieces of equipment to illustrate the above-mentioned scientific points. If a seesaw is not available in the playground, you might use a plank and log to illustrate some of the effects.

GETTING READY

1. Schedule the Activity

This lesson takes one session to complete and is a whole-class activity.

2. Decide Which Playground to Visit

Watching the GEMS-Net video on simple machine activities at a playground could be helpful in determining the playground to visit and some of the things to do once you get there with the class. This video is meant for teacher preparation and not for the class to watch.

3. Prepare the Students for the Field Trip

Students should be told in advance that they are going outdoors so they may bring jackets if weather is colder, and proper clothes and shoe attire for safety reasons. Safety rules and guidelines should be gone over in class together so they understand what it is they can and cannot do once they are outside with you. Any adult volunteers or aides should also be present at this session so they may also be knowledgeable of all the rules and guidelines you present to the students.

LESSON 1: Work & Forces

Activity: Playground Field Trip

Go to the playground and have the students freely explore and observe the following scientific principles on the various pieces of equipment:

- Monkeybars, slide, swings, merry-go-round, seesaw => force of gravity (pull)
- Slide, shoe soles => resistance/friction *(use towel and/or wax paper to slide down slide and see the difference with & without; compare soles of shoes on different surfaces, including roller skates)*
- Swings, seesaw, merry-go-round => work = force x distance *(compare work/effort involved to go certain distance & force used)*
- Swings, slide, seesaw => stable structure (triangular truss)

LESSON 2: FORCE

PURPOSE
In this lesson, students will experience and observe:
- Force is a push or a pull that produces a motion on a flat surface
- The force of gravity on an object using measurement of time
- That they often provide the force to produce movement

OVERVIEW
Students will discover that force is a push or a pull. They will also discover that gravity is a force that pulls.

SCIENCE BACKGROUND
A ***force*** is a push or a pull on an object to make it move. There are several different types of forces, but all employ either a push or a pull on objects within their domain. Whenever something moves, it moves due to a force either pushing or pulling on it. Gravity is a force that pulls all objects to the center of the earth. Air and water are forces that push objects. Magnets move objects by either pushing or pulling. When you move a part of your body, you are using a force coming from your muscles to throw a ball, run, or jump.

There are various ways to measure force. One way used by scientists is a spring scale. When you pull on the scale, the spring is stretched and indicates the amount of force pulling on it in ***Newtons***, named for Sir Isaac Newton, who originated the Laws of Motion. A spring scale can also measure weight. When the weight is place on the scale, it pulls the scale with a certain amount of force due to gravity. A heavy object will pull with more force than a light one, so will stretch the spring more.

Force is stated in Newton's second Law of Motion as $F = ma$ (Force = mass x acceleration). In simpler terms, the more force you apply to an object, the more it moves.

MATERIALS
For Demonstration:
- Board
- Small ball or marble
- Metric ruler

For Activity 1 (Is the Force with You?):
- Board about 1m long
- Six hardcover books of similar thickness
- Masking tape
- Tennis ball
- Watch with second hand

For Activity 2 (Box Push & Pull):
- Small box or lid
- Paper clamp
- Rubber band
- Straws (enough for every student as they are thrown away after use)
- Masking tape

GETTING READY

1. Schedule the Activity

This lesson takes one session to complete. The class is split in half so that half will be doing Activity 1 while the other half does Activity 2, and then they will swap so each student gets a chance to do both activities.

2. Setting Up the Demonstration

Set aside space that allows for a large group observation for the demonstration. Have available a chart to record students' observations and measurements.

3. Setting Up the Activities

Set up each activity to allow for at least two groups to conduct the activity at the same time. Have the necessary materials for multiple sets of the same activity. Each group should have a recording sheet for each activity.

4. Suggested Student Documentation

Students should be adding any data sheets recorded to their journals, as well as any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *Work, Work, Work!, Doing Work*, and *The Push-and-Pull Song* found in the documentation masters in this Addendum.

LESSON 2: Force

CLASSROOM DEMONSTRATION

Make a marble or ball move on an inclined plane (board). Compare the distance the ball moves to the height of the inclined plane. Vary the height and measure the height and distance of each trial.

CLASSROOM ACTIVITIES

Activity 1: Is the Force with You?

1. Make a ramp by stacking 2 books and prop one end of the board on top.
2. Put a piece of tape on the ramp near the top. Place a second one on the table about 1-2 meters away from the end of the board.
3. Roll the tennis ball down the ramp starting at the tape mark on the board. Have a teammate start timing when the ball is released and stop when the ball reaches the finish line tape mark.
4. Perform 3 trials and record times on data sheet.
5. Add 2 more books to the stack under the top of the ramp. Perform 3 trials.
6. Add 2 more books to the stack and perform 3 more trials.

Does the height of the ramp affect the time of the ball?

Activity 2: Box Push or Pull

1. Put a piece of masking tape at either end of a long table.
2. One way to make something move is to push it. Use the straw to push the box from one tape to the other. On your data sheet, write "pushing with straw" under the How Movement Was Caused column for Trip 1.
3. Using any of the materials (or none of them), move the box back to the starting tape without pushing. Record what you did to make it move for Trip 2.
4. Keep moving the box from one end of the table to the other, alternating between pushing and pulling. Record what you did for each trip. Keep going until you cannot think of any new ways to make the box move. You may add trip numbers to your data sheet.

NOTE: The following page may be copied and cut for the instructions at the activity centers.

Activity 1: Is the Force with You?

1. Make a ramp by stacking 2 books and prop one end of the board on top.

2. Put a piece of tape on the ramp near the top. Place a second one on the table about 1-2 meters away from the end of the board.

3. Roll the tennis ball down the ramp starting at the tape mark on the board. Have a teammate start timing when the ball is released and stop when the ball reaches the finish line tape mark.

4. Perform 3 trials and record times on data sheet.

5. Add 2 more books to the stack under the top of the ramp. Perform 3 trials.

6. Add 2 more books to the stack and perform 3 more trials.

Does the height of the ramp affect the time of the ball?

Activity 2: Box Push or Pull

1. Put a piece of masking tape at either end of a long table.

2. One way to make something move is to push it. Use the straw to push the box from one tape to the other. On your data sheet, write "pushing with straw" under the How Movement Was Caused column for Trip 1.

3. Using any of the materials (or none of them), move the box back to the starting tape without pushing. Record what you did to make it move for Trip 2.

4. Keep moving the box from one end of the table to the other, alternating between pushing and pulling. Record what you did for each trip. Keep going until you cannot think of any new ways to make the box move. You may add trip numbers to your data sheet.

Activity 2: Box Push and Pull Datasheet

Trips	How Movement was Caused
1	
2	
3	
4	
5	
6	
7	
8	
9	

Activity 1: Is the Force with You?
Datasheet

Height of Ramp	Trial	Time	Average Time (T1+T2+T3) / # of trials	Speed Distance / Time = (m/s)
2 Books	1			
	2			
	3			
4 Books	1			
	2			
	3			
6 Books	1			
	2			
	3			

Observations:

LESSON 3: FRICTION

PURPOSE
In this lesson, students will experience and observe:
- The more surface area of an object that touches the inclined plane, the slower the movement.
- The fewer points of friction the object has, the faster that object will move down the inclined plane.
- By changing the shape of the object, you can decrease or increase the friction
- Flat surfaces with different textures will change the amount of friction

OVERVIEW
Students will discover that friction slows down the movement of objects. As friction increases, movement decreases.

SCIENCE BACKGROUND
When surfaces move against one another, the force of ***friction*** resists motion. All moving objects, including fluids such as air and water, have friction between them and any surface they touch. Forces between the molecules in the surfaces pull the surfaces together. The closer the molecules get to each other, the stronger the force of friction. Different surfaces create different amounts of friction. If there is not a lot of friction between an object and the surface over which the object moves, then the object moves easily. In general, as friction increases, ease of movement decreases.

You can never get the same amount of work from a mechanical device as you put into it. Friction will reduce some of the energy that is transferred through the machine, so there is some degree of inefficiency due to the amount of friction between the moving surfaces. One way friction can be reduced is by lubricating the surface between moving objects. Another is to reduce the area where the object touches the surface, e.g. putting wheels or ball bearings between the object and the surface. However, some machines use friction to work, such as brakes in a vehicle, parachutes, tires, and grinding machines.

MATERIALS
For Demonstration:
- Toy car
- Board or linoleum tile
- Carpet
- Sandpaper
- Sheet metal (optional)

For Activity 1 (Which One Moves First?):
- 2 boards (regular and particle board)
- 5 cm long pipe cleaner
- aluminum foil
- paper clip

For Activity 2 (Slip or Grip?):
- Hardcover book
- Paper clamp
- Rubber band
- Notebook paper
- Paper towels
- Wax paper

GETTING READY

1. Schedule the Activity

This lesson takes one session to complete. The class is split in half so that half will be doing Activity 1 while the other half does Activity 2, and then they will swap so each student gets a chance to do both activities.

2. Setting Up the Demonstration

Set aside space that allows for a large group observation for the demonstration. Have available a chart to record students' observations and measurements.

3. Setting Up the Activities

Set up each activity to allow for at least two groups to conduct the activity at the same time. Have the necessary materials for multiple sets of the same activity. Each group should have a recording sheet for each activity.

4. Suggested Student Documentation

Students should be adding any data sheets recorded to their journals, as well as any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *Friction and Work*, found in the documentation masters in this Addendum.

LESSON 3: Friction

CLASSROOM DEMONSTRATION

Roll a toy car on different surfaces like carpet, wood, linoleum, sandpaper, sheet metal. Note what happens to the car's movement as it rolls on these surfaces. Try rolling it from one surface to another and see what happens. Does a rougher surface slow the car down?

CLASSROOM ACTIVITIES

Activity 1: Which One Moves First?

1. Make a marble-sized ball out of a piece of aluminum foil. Line up the paper clip, foil ball, and pipe cleaner side by side on one end of the board.
2. Predict which object will move first if the board is lifted up. Slowly lift the board. Which object moved first? Repeat 2 more times. Did the same object move first each time? Were you correct in your prediction?
3. Repeat Step 2. This time note the order in which the objects slide off the board. What do their surfaces feel like? What does the board's surface feel like?
4. If time allows, try the same experiment using aluminum foil covering the board. Did the objects slide off the board the same order as before?
5. Try the same experiment using a particle board as the surface. Did the objects slide off the board in the same order?

Activity 2: Slip or Grip?

1. Tie one end of the rubber band to the handle of the paper clamp.
2. Put the book on the notebook paper. Attach the clamp to the book's cover. Predict what will happen if you pull the rubber band. Will the book slide off the paper or will they move together across the table? Try it.
3. Measure and record in millimeters (mm) how far the rubber band stretches before the book moves. This is a measurement of the force it took to move the book.
4. Repeat Steps 2 and 3 first with the book on the paper towel and then on the wax paper. Did the force needed to move the book change?
5. Stack the sheets and put the book on top. Predict what will happen when you pull the rubber band. Try it. Change the order of the layers. Predict and try it for all variations.

NOTE: The following page may be copied and cut for the instructions at the activity centers.

Activity 1: Which One Moves First?

1. Make a marble-sized ball out of a piece of aluminum foil. Line up the paper clip, foil ball, and pipe cleaner side by side on one end of the board.

2. Predict which object will move first if the board is lifted up. Slowly lift the board. Which object moved first? Repeat 2 more times. Did the same object move first each time? Were you correct in your prediction?

3. Repeat Step 2. This time note the order in which the objects slide off the board. What do their surfaces feel like? What does the board's surface feel like?

4. If time allows, try the same experiment using aluminum foil covering the board. Did the objects slide off the board the same order as before?

5. Try the same experiment using a particle board as the surface. Did the objects slide off the board in the same order?

Activity 2: Slip or Grip?

1. Tie one end of the rubber band to the handle of the paper clamp.

2. Put the book on the notebook paper. Attach the clamp to the book's cover. Predict what will happen if you pull the rubber band. Will the book slide off the paper or will they move together across the table? Try it.

3. Measure and record in millimeters (mm) how far the rubber band stretches before the book moves. This is a measurement of the force it took to move the book.

4. Repeat Steps 2 and 3 first with the book on the paper towel and then on the wax paper. Did the force needed to move the book change?

5. Stack the sheets and put the book on top. Predict what will happen when you pull the rubber band. Try it. Change the order of the layers. Predict and try it for all variations.

Which One Moves First?
Datasheet

Predictions: Which object will move first?

Trial 1
Trial 2
Trial 3

Actual: Which object moved first?

Trial 1
Trial 2
Trial 3

Comments:

Which object has the least friction between it and the board?

Activity 2: Slip or Grip?
Datasheet

SURFACE	DISTANCE RUBBER BAND STRETCHES	COMMENTS
Notebook paper		
Paper towel		
Wax paper		
Notebook/towel/wax		
Notebook/wax/towel		
Towel/wax/notebook		
Towel/notebook/wax		
Wax/notebook/towel		
Wax/towel/notebook		

LESSON 4: INERTIA

PURPOSE
In this lesson, students will experience and observe that:

- Things that are still tend to stay still
- Things that are moving tend to keep moving
- Moving objects keep moving until a force stops them

OVERVIEW
Students will discover that inertia is a force that affects the movement of an object.

SCIENCE BACKGROUND
Inertia, as described in Newton's first Law of Motion, is the tendency of objects at rest to stay at rest and moving objects to continue to move in a straight line until acted upon by an outside force. Inertia is the resistance of objects to any change in speed, even if there is no speed. The amount of inertia an object has depends on its mass. The greater the mass, the more inertia the object has. For example, if you are pushing a car to try to start it by popping the clutch, it takes a lot of effort to get it moving. However, once it is moving, it will continue for some distance without further pushing. Another example students can relate to is traveling in a car and the car stops short. Hopefully, they have their seatbelts on, as they find that their bodies want to continue moving at the same rate of speed as the car was going before it stopped. They have just experienced the effects of inertia.

Different forces use inertia in another way. When an object moves in a circle, it is also always changing direction. Its inertia resists the change of direction and will make the object move straight on if it is free to leave the circle. If the object is trying to move away from the center of the circle under an outward-acting force, this is called ***centrifugal force***. This force is used in machines to throw something outward, such as a spin drier which throws the water outward from the clothes, and a centrifuge which separates liquids.

Centripetal force is an outside force that pulls on an object and causes it to move in a circle. The amount of centripetal force depends on the object's speed and the amount of friction between the object and the surface on which it is moving. This force is used in the design of cars and roller coasters that must move quickly but safely in a circle. An example is going around a curve on a bicycle or in a car. The bottom part of your body is pulled in by centripetal force, but the top half is not, which is why you feel as if you're being pulled outward.

MATERIALS
For Demonstration:

- Toy car (best if has a sunroof or some way to hold a ball on top)
- Tennis ball
- Block of wood (shorter than the height of the car)

For Activity 1 (Marble in the Box):

- shoebox
- marble

For Activity 2 (Marble in the Cylinder):

- clear plastic cylinder (may be made from a cut tennis ball tube container or liter bottle)
- marble

GETTING READY

1. Schedule the Activity

This lesson takes one session to complete. The class is split in half so that half will be doing Activity 1 while the other half does Activity 2, and then they will swap so each student gets a chance to do both activities.

2. Setting Up the Demonstration

Set aside space that allows for a large group observation for the demonstration. Have available a chart to record students' observations and measurements.

3. Setting Up the Activities

Set up each activity to allow for at least two groups to conduct the activity at the same time. Have the necessary materials for multiple sets of the same activity. Each group should have a recording sheet for each activity.

4. Suggested Student Documentation

Students should be adding any data sheets recorded to their journals, as well as any observations they may have about the particular activity they are doing.

LESSON 4: Inertia

CLASSROOM DEMONSTRATION

Place the ball on top of the toy car and roll it on a smooth surface. Note that the car and ball are moving at the same speed. Now place a barrier (block of wood) in front of the car and roll it again toward the block of wood. Note what happens to the ball when the car is stopped by the block of wood. The ball should continue on the same path and speed as the car was before it was stopped by the force of the wood block.

CLASSROOM ACTIVITIES

Activity 1: Marble in the Box

1. Place the marble against the inside front wall of the box. Predict how the marble will move if you slide the box forward. Try it. Did the marble move? In which direction? Record your observations and predictions.
2. Place the marble against the inside back wall of the box. Predict how the marble will move if you slide the box backward. Try it. In which direction did the marble move? Record your results.
3. Place the marble in the center of the box. Predict how the marble will move if you slide the box to the right. Slide the box sharply to the right. Did you predict correctly? Record your results.
4. Try placing the marble in a different position in the box. Predict which way the marble will move when you slide the box in different directions. Try each one and record your findings.

Activity 2: Marble in the Cylinder

1. Hold the tube at a slight angle tilted up from the table so that one edge is touching the table. Roll the marble in a straight path toward the tube. Just as the marble rolls inside, tip the tube upright to catch the marble. How did the marble roll inside the tube? Repeat this step two more times. Did the results change?
2. Stand the tube on the table. Center the marble in the tube. Slide the tube back and forth with small movements and watch the marble. How did the marble roll at first? After 5 seconds? After 10 seconds?
3. Slide the tube back and forth a few seconds. The lift the tube. What happens to the marble? Draw a diagram of the marble's path inside and outside the tube. Repeat this step two more times. Did the results change?

NOTE: The following page may be copied and cut for the instructions at the activity centers.

Activity 1: Marble in the Box

1. Place the marble against the inside front wall of the box. Predict how the marble will move if you slide the box forward. Try it. Did the marble move? In which direction? Record your observations and predictions.

2. Place the marble against the inside back wall of the box. Predict how the marble will move if you slide the box backward. Try it. In which direction did the marble move? Record your results.

3. Place the marble in the center of the box. Predict how the marble will move if you slide the box to the right. Slide the box sharply to the right. Did you guess correctly? Record your results.

4. Try placing the marble in a different position in the box. Predict which way the marble will move when you slide the box in different directions. Try each one and record your findings.

Activity 2: Marble in the Cylinder

1. Hold the tube at a slight angle tilted up from the table so that one edge is touching the table. Roll the marble in a straight path toward the tube. Just as the marble rolls inside, tip the tube upright to catch the marble. How did the marble roll inside the tube? Repeat this step two more times. Did the results change?

2. Stand the tube on the table. Center the marble in the tube. Slide the tube back and forth with small movements and watch the marble. How did the marble roll at first? After 5 seconds? After 10 seconds?

3. Slide the tube back and forth a few seconds. The lift the tube. What happens to the marble? Draw a diagram of the marble's path inside and outside the tube. Repeat this step two more times. Did the results change?

Activity 1: Marble in the Box
Datasheet

Trial		Prediction	Actual
Forward:	1		
	2		
	3		
Backward:	1		
	2		
	3		
Right:	1		
	2		
	3		

Observations:

Activity 2: Marble in the Cylinder
Datasheet

Tilting tube: how does the marble roll inside?

Trial 1
Trial 2
Trial 3

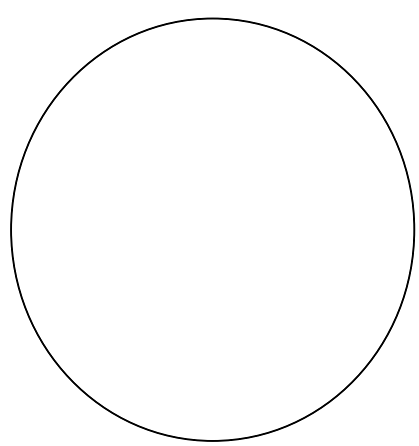
Center slide back and forth

How does it roll at first?
After 5 seconds?
After 10 seconds?

Slide back & forth and lift: How does the marble travel?

Trial 1
Trial 2
Trial 3

Drawing of marble's path inside and outside tube:



PART TWO: DISCOVERING SIMPLE MACHINES

OVERVIEW

This part of the module is a discovery and exploration of tools and how they came to be Simple Machines. The names of the six machines are not discussed until the last portion of Lesson 5 after the students present their own solutions to making a tool to perform a particular task. Details of what the six Simple Machines are will be covered in Part Three of the Simple Machines module.

LESSON 5: INTRODUCTION TO SIMPLE MACHINES

PURPOSE

Students will discover:

- That tools help them do work and tools make their work easier
- That forces are needed to do work
- That they need to work cooperatively to solve problems
- That there are six types of simple machines
- A means (skit, diagram, song, etc.) to present the solution to their problem

OVERVIEW

Students will discover that tools help them do work. Students will use exploration and observation while problem solving to discover the six types of simple machines. These activities may provide an informal assessment of a student's background and prior knowledge of simple machines.

SCIENCE BACKGROUND

The word "machine" comes from a Greek word, mechos, *meaning "expedient" or something that makes easy. The Romans used the Latin word* machina*, a word which meant "trick" or "device." The Hebrew word for "machine" is* mechonah*, and as used in the Old Testament and in other Hebrew writings, was variously interpreted as "foundation," "base," "plan."*[1] A machine is a tool that makes work easier by applying a force. It can also change the direction of the applied force or increases the speed with which work is done. Tools were devised by early man to make his work easier. Some help us overcome large loads or resistance with little effort by magnifying the force used to move the resistance, giving us a ***mechanical advantage of force***. Others allow us to move the resistance faster than the applied force is being used, giving us a ***mechanical advantage of speed***.

Primitive tools were developed to alleviate the need for brute strength of human or animal to move a resistance or load. As humans adapted their environment to make life easier, they discovered tools that made the necessary work for survival easier. They started to see how tools such as wheels simplified their work, and that an axle added to wheels worked even better. As mankind progressed, other simple machines and tools came to be discovered and soon they were combined to make work even easier. Simple machines help us do the same amount of work but with less force. There is a tradeoff of using a simple machine, however: the distance traveled must increase if the force is reduced. This is explored in further detail in Part Three of this module.

[1] P. 4, *The How and Why Wonder Book of Machines*

MATERIALS

For Activity 1 (Scrap Paper Changes):

- Piece of scrap paper per student
- Tools to change paper such as
    - Scissors
    - Paper punch
    - Pencil
    - Paint
    - Crayons
    - Markers
    - Scotch tape
    - Glue

For Activity 2 (Plastic Clay Changes):

- Piece of plastic clay per student

For Problem Solvers:

Possible presentation means using

- Pen or pencil
- Paper to write and/or draw on
- Construction paper
- Magazines
- Scissors
- Glue
- Cardboard

For Types of Simple Machines:

- Examples from home/school and pictures/posters of simple machines

GETTING READY

1. Schedule the Activity

This lesson takes four sessions to complete. This is a whole-class activity, with the exception of the Problem Solvers portion where the class is split into six groups, each solving a unique problem their own way.

2. Discuss the Means used for Presentation of Problem Solvers Solutions

Brainstorm the various choices the student groups could use to present their solution to the particular problem posed. For example, they can create and perform a skit, write a story, draw and/or build a model (depending on materials supplied by the teacher), make a diorama, make a collage using magazine pictures, or any others you may add. They should be encouraged to be creative in both their thinking and solution, as well as in their presentation to the class.

3. Gather Examples of Simple Machines

When you are discussing the solutions to the Problem Solvers situations, you will be formally introducing the six simple machines. Pictures, posters, and/or examples should be in the classroom and used to supplement the students' presentations on each machine.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *Tools Word Search, What is a Machine?, How can you use simple machines?, Machines & Work, Machines in Action, How are Machines Used?, Can You Make a Simple Machine Ride?, Amazing Simple Machines Sorting & Cards, Match-up, Machines Can Be Simple, Know Your Simple Machines, What Simple Machine Will You Need?, Machines Help us Play*, found in the documentation masters in this addendum. Some of these you can use as assessment materials.

LESSON 5: Introduction to Simple Machines

Activity 1: Scrap Paper Changes

1. Give each student a piece of scrap paper. How can they change the paper without using any tools? What force(s) is/are used?
2. How can they change the paper using tools? What force(s) is/are used?
3. Compare the difference in how the paper was changed with and without tools and the forces used with each.

Activity 2: Plastic Clay Changes

Give each student a piece of plastic clay. How can they change the clay without using any tools? What force(s) is/are used to change the clay? What changes can be made? Shape? Discuss the energy transfer being made to make the clay change shape *(heat from hand softens clay and makes it more pliable).*

PROBLEM SOLVERS FOR DISCOVERING SIMPLE MACHINES: *How can you make your work easier?*

Divide students into six groups. Each group will try to solve one of the problems below, finding some easier way to do work.

NOTE: Do *NOT* discuss the six types of simple machines before doing this activity.

1. Your group is in the desert and you have decided that you want to build a shelter. You go hunting for some kind of material that could be used for a desert shelter. You find the perfect rocks, but in order to carry them back to the place where there is enough shade, it would take all of you to carry each one back. Decide on a tool that will make your work easier using natural materials.

2. You are traveling in the rain forest with a caravan of elephants carrying your equipment. The path is very narrow, with very tall trees on either side. You come to a place in the path where there is a very large rock. It is obvious that you cannot go around the rock or over it and it will have to somehow be removed. Determine how you can remove the rock using natural materials.

3. You decide you want to build a log cabin at the top of a mountain. The logs are at the bottom of the mountain by the stream. You try lifting the logs and you realize they are just too heavy to carry up the mountain. Devise a natural and simple way that the logs could be moved to the cabin site at the top of the mountain.

4. As you are traveling up an icy cliff in the polar region, one of the members of your group falls down a 20' cliff. Thank goodness he/she is not hurt! But now, as you struggle to pull up the rope, you will find your friend is too heavy for you to lift. Devise a way to pull him/her up the cliff. You have the following equipment in your pack: three metal rings, heavy gloves, and an extra rope.

5. As you are wandering around the hills in the grasslands, you find a small cave. As you enter, you notice something sparkling. It looks like gold! You need to develop some kind of tool that will help you carefully get the nugget out of the wall of the cave using only human power.

6. You are boating in a small pond. The seat you are sitting on keeps coming apart where you have it nailed together. The holes have become too big to secure the nails. You decide to see what materials scattered on the bottom of the boat might be useful in fixing the seat. Aha! You find rope, slow drying glue, nails, hammer, screwdriver, and screws. What do you use to fix the seat so that you can immediately use it? Explain your answer.

Types of Simple Machines: Discuss the solutions to the informal assessment exercise above using the blackboard. If every simple machine is not covered, then use posters and examples to introduce the six types of simple machines. Go over them in order (Inclined Plane, Wedge, Screw, Lever, Wheel and Axle, Pulley) so students can see the relationship to each other. For example, Inclined Plane, Wedge, and Screw could be considered “cousins”, as they are all based on the Inclined Plane. A Lever might be considered a “distant cousin”, since it is a little more advanced than an Inclined Plane, but some levers use a plane and wedge to do work as a lever (e.g., a crowbar). A Wheel and Axle is actually a rotating lever. A Pulley is a grooved wheel with a rope, so it is a “cousin” of the wheel and axle. Use examples found in the classroom, school, playground, home, reading books, and any other sources that are available to you.

NOTE: The following pages may be copied and cut for the instructions of the six student groups of Problem Solvers.

Your group is in the desert and you have decided that you want to build a shelter. You go hunting for some kind of material that could be used for a desert shelter. You find the perfect rocks, but in order to carry them back to the place where there is enough shade, it would take all of you to carry each one back. Decide on a tool that will make your work easier using natural materials.

You are traveling in the rain forest with a caravan of elephants carrying your equipment. The path is very narrow, with very tall trees on either side. You come to a place in the path where there is a very large rock. It is obvious that you cannot go around the rock or over it and it will have to somehow be removed. Determine how you can remove the rock using natural materials.

You decide you want to build a log cabin at the top of a mountain. The logs are at the bottom of the mountain by the stream. You try lifting the logs and you realize they are just too heavy to carry up the mountain. Devise a natural and simple way that the logs could be moved to the cabin site at the top of the mountain.

As you are traveling up an icy cliff in the polar region, one of the members of your group falls down a 20' cliff. Thank goodness he/she is not hurt! But now, as you struggle to pull up the rope, you will find your friend is too heavy for you to lift. Devise a way to pull him/her up the cliff. You have the following equipment in your pack: three metal rings, heavy gloves, and an extra rope.

As you are wandering around the hills in the grasslands, you find a small cave. As you enter, you notice something sparkling. It looks like gold! You need to develop some kind of tool that will help you carefully get the nugget out of the wall of the cave using only human power.

You are boating in a small pond. The seat you are sitting on keeps coming apart where you have it nailed together. The holes have become too big to secure the nails. You decide to see what materials scattered on the bottom of the boat might be useful in fixing the seat. Aha! You find rope, slow drying glue, nails, hammer, screwdriver, and screws. What do you use to fix the seat so that you can immediately use it? Explain your answer.

PART THREE: WHAT ARE SIMPLE MACHINES?

OVERVIEW

This part of the module goes into detail exactly what defines the six Simple Machines, with hands-on activities and building models of each in order: Inclined Plane (Lesson 6A), Wedge (Lesson 6B), Screw (Lesson 6C), Lever (Lesson 7), Wheel and Axle (Lesson 8), and Pulley (Lesson 9). A summary of the six machines is shown in the table below for your information.

SIMPLE MACHINE	DESCRIPTION	HOW IT HELPS US WORK	EXAMPLES
Inclined Plane	A slanting surface connecting a lower level to a higher level	Things move up or down it	Slide, stairs, ramp, slope, escalator, hill
Wedge	One or two inclined planes ending in a sharp edge	Cuts or pushes two objects apart	Knife, pin, nail, chisel, axe, fork, snowplow, front of boat (bow)
Screw	An inclined plane wrapped around a cylinder or pole	Holds things together or lifts	Screw, jar lid, vise, bolt, drill, corkscrew
Lever	A stiff bar that rests on a support called a fulcrum	Lifts or moves loads	Shovel, nutcracker, seesaw, crowbar, elbow, tweezers, bottle opener
Wheel and Axle	A wheel with a rod called an axle through its center, both parts move together	Lifts or moves loads	Car, wagon, doorknob, roller skates, pencil sharpener, bicycle
Pulley	A grooved wheel and axle with a rope or chain/cable around it	Moves things up, down, or across	Curtain rod, tow truck, mini-blind, flag pole, crane, clothesline

LESSON 6: INCLINED PLANE, WEDGE, SCREW

This lesson has three parts, and each is broken out separately for ease of understanding. Since the Wedge and Screw are based on the Inclined Plane, they are presented here as part of the same lesson.

LESSON 6A: INCLINED PLANE

PURPOSE

Students will experience and discover:

- That an inclined plane is a slanted surface on which work is done
- That an inclined plane uses gravity as a force
- That an inclined plane increases the distance for the work to be done but requires less force to do it
- As the height of the inclined plane increases, the force needed to do the work changes

OVERVIEW

Students will discover that an inclined plane is a device that makes work easier.

SCIENCE BACKGROUND

An ***inclined plane*** is a flat surface with one end higher than the other. It is used to help raise an object that is too heavy to be lifted straight up. This is accomplished by exerting a smaller force through a greater distance. It doesn't matter whether the inclined plane is long or short as the amount of work is the same, but it is easier to move the load over the longer distance. The less the angle of the inclined plane, the longer the distance and the less effort is required to move the load.

To find the ***mechanical advantage*** in using the inclined plane, divide the length of the plane by the height (A = L/H). An example of this rule is as follows: You have a board 10 feet long to make your inclined plane and you want to lift a 50 pound weight 5 feet above the ground. Since the height above the ground is half the length of the board, you would only need half the weight of the force to move the weight, i.e. 25 pounds of force to lift the 50 pound weight. The mechanical advantage in using the inclined plane is 10/5 or 2. As far as friction goes, the smoother the board and the object to be moved, the less the resistance. If the object to be moved has wheels, the resistance is even less. That is why a dolly is used to move furniture or heavy items on a loading ramp.

Some examples of inclined planes are: loading ramps, handicap ramps, stairs (straight), a mountain road, ski ramp, roof tops, dish drain, sink/tub drain, dump truck.

MATERIALS

For Demonstration:
- Board
- Stack of books or box
- Small rock

For Activity 1 (Inclined Plane & Friction):
- Board
- Toy car
- Tissue paper
- 7 hardcover books of similar thickness
- Metric ruler
- Masking tape

For Activity 2 (Inclined Plane & Work):
- Board
- Stack of books or box
- Rubber band
- Metric ruler
- Rock with string around it and loop on one end to put rubber band through

GETTING READY

1. Schedule the Activity

This lesson takes one session to complete. The class is split in half so that half will be doing Activity 1 while the other half does Activity 2, and then they will swap so each student gets a chance to do both activities.

2. Setting Up the Demonstration

Set aside space that allows for a large group observation for the demonstration. Have available a chart to record students' observations and measurements.

3. Setting Up the Activities

Set up each activity to allow for at least two groups to conduct the activity at the same time. Have the necessary materials for multiple sets of the same activity. Each group should have a recording sheet for each activity.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *What is an Inclined Plane?* and *Cheetah Race,* found in the documentation masters in this Addendum.

LESSON 6A: Inclined Plane

CLASSROOM DEMONSTRATION:

Use a board, stack of books or box, rock and two students to demonstrate why using an inclined plane is easier to lift an object up to another level. Students use one pinky finger each to attempt to lift rock to top of stack of books/box without using the board (just have the board lying on the table; don't set it up in position). Have them and/or the class determine how to move the rock using the two pinkies up to the top of the books/box. They should come up with the inclined plane as a solution. Have the students demonstrate how much easier it is to move the rock with two pinkies up the board/ramp to the top of the books/box.

CLASSROOM ACTIVITIES:

Activity 1: Inclined Plane & Friction

1. Cut 3 strips of tissue paper, each 3 cm by 10 cm. Tape one strip to the front of the toy car. Try lifting the car straight up using the tissue paper strip. Does the tissue break?
2. Make a ramp 3 cm high by setting the board on a book. Tape a tissue strip to the side of the car.
3. Set the car sideways at the bottom of the ramp. Pull carefully on the tissue strip. Record your results on the data sheet in the Sideways Section.
4. Raise the ramp 2 cm and record the ramp height. Repeat Step 3. Record your data. Keep raising the ramp 2 cm and repeat Step 3 until the strip breaks, recording for each trial.
5. Make a ramp 3 cm high. Attach a new tissue strip to the front of the car. Put the car at the bottom of the ramp with the wheels facing up the ramp. Try pulling the car up the ramp with the tissue. Record the results on the data sheet in the Front Section. Repeat Step 4. Record how high the ramp is when the tissue breaks. Is the break height the same as that in the Sideways?

Activity 2: Inclined Plane & Work

1. Loop and tie the rubber band through the loop in the string on the rock and put it beside the stack of books or box.
2. Lift the rock straight up by the rubber band to the top of the stack. Measure the length of the rubber band as it is stretched to put it on the top of the stack of books/box.
3. Put the board against the books/box, making an inclined plane. Put the rock on the board at its base. Measure the length of rubber band stretch when the rock first starts to move up the ramp. Is it the same as before when you lifted the rock straight up?

NOTE: The following page may be copied and cut for the instructions at the activity centers.

Activity 1: Inclined Plane & Friction

1. Cut 3 strips of tissue paper, each 3 cm by 10 cm. Tape one strip to the front of the toy car. Try lifting the car straight up using the tissue paper strip. Does the tissue break?

2. Make a ramp 3 cm high by setting the board on a book. Tape a tissue strip to the side of the car.

3. Set the car sideways at the bottom of the ramp. Pull carefully on the tissue strip. Record your results on the data sheet in the Sideways Section.

4. Raise the ramp 2 cm and record the ramp height. Repeat Step 3. Record your data. Keep raising the ramp 2 cm and repeat Step 3 until the strip breaks, recording for each trial.

5. Make a ramp 3 cm high. Attach a new tissue strip to the front of the car. Put the car at the bottom of the ramp with the wheels facing up the ramp. Try pulling the car up the ramp with the tissue. Record the results on the data sheet in the Front Section. Repeat Step 4. Record how high the ramp is when the tissue breaks. Is the break height the same as that in the Sideways?

Activity 2: Inclined Plane & Work

1. Loop and tie the rubber band through the loop in the string on the rock and put it beside the stack of books or box.

2. Lift the rock straight up by the rubber band to the top of the stack. Measure the length of the rubber band as it is stretched to put it on the top of the stack of books/box.

3. Put the board against the books/box, making an inclined plane. Put the rock on the board at its base. Measure the length of rubber band stretch when the rock first starts to move up the ramp. Is it the same as before when you lifted the rock straight up?

Activity 1: Inclined Plane & Friction
Datasheet

CAR FACING	RAMP HEIGHT (cm)	TISSUE PAPER BROKE	TISSUE PAPER DID NOT BREAK
Sideways			
Front			

Activity 2: Inclined Plane & Work
Datasheet

RUBBER BAND LENGTH

RAMP HEIGHT (cm)	UNSTRETCHED (mm)	STRETCHED LIFTING UP (mm)	STRETCHED ON PLANE (mm)

LESSON 6B: WEDGE

PURPOSE
Students will discover that:
- A wedge acts as a moving inclined plane
- A wedge is the cutting edge of a tool
- Piercing tools have wedges
- A wedge is used to overcome large resistance (doors, logs, etc.)

OVERVIEW
Students will discover that the wedge is one inclined plane or two inclined planes put together. A wedge is a simple machine that increases force and does work.

SCIENCE BACKGROUND
The ***wedge*** is used to overcome large resistance and may be one or two inclined planes put together. A wedge is a movable inclined plane that does work, usually pushing two objects apart. It is used to cut and pierce. Instead of the resistance being moved up an inclined plane, the inclined plane moves the resistance. As the plane moves a greater distance than the object, it raises the object with a greater force. An example of this is a doorstop. As it is jammed under the door, the wedge lifts the door slightly and exerts a strong force on it. The door forces the wedge hard against the floor, and the friction between the floor and the wedge makes the wedge grip the floor so the door stays open.

Some examples of wedges include: knife, axe, fork, nail, doorstop, needle, carpenter's plane, key, scissors, can opener, electric shaver, razor blade, electric trimmer, plow, zipper, chisel, shovel, blades of bulldozer, handsaw, teeth.

MATERIALS
For Demonstration:
- Doorstop
- Door

For Activity 1 (Wedge & Non-wedge):
- Block of wood
- Hammer
- Pointed nail
- Blunt nail or bolt

For Activity 2 (Wedge & Work):
- Wooden wedge
- 2 foot stack of books
- Coin or other small flat object

GETTING READY

1. Schedule the Activity

This lesson takes one session to complete. The class is split in half so that half will be doing Activity 1 while the other half does Activity 2, and then they will swap so each student gets a chance to do both activities.

2. Setting Up the Demonstration

Set aside space that allows for a large group observation for the demonstration. Have available a chart to record students' observations and measurements.

3. Setting Up the Activities

Set up each activity to allow for at least two groups to conduct the activity at the same time. Have the necessary materials for multiple sets of the same activity. Each group should have a recording sheet for each activity.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *What is a Wedge?,* found in the documentation masters in this Addendum.

LESSON 6B: Wedge

CLASSROOM DEMONSTRATION

Use a doorstop and door to demonstrate the force(s) used to hold the door open. Use students instead of a doorstop first to hold the door open and have them tell the class how much force they are using to hold the door. Then use the doorstop. Discuss where the force is working on the door to keep it open.

CLASSROOM ACTIVITIES

Activity 1: Wedge & Non-wedge:

1. Try to hammer the blunt nail or bolt into the block of wood just enough to make it hold.
2. Now try to hammer the pointed nail into the block of wood. Which one took less effort to hammer into the wood?

Activity 2: Wedge & Work

1. Place the coin or small object on the floor and stack the books on top of it.
2. Try to get the object out using the wedge.

NOTE: The following page may be copied and cut for the instructions at the activity centers.

Activity 1: Wedge & Non-wedge:

1. Try to hammer the blunt nail or bolt into the block of wood just enough to make it hold.

2. Now try to hammer the pointed nail into the block of wood. Which one took less effort to hammer into the wood?

Activity 2: Wedge & Work

1. Place the coin or small object on the floor and stack the books on top of it.

2. Try to get the object out using the wedge.

LESSON 6C: SCREW

PURPOSE

Students will experience and observe that:

- The threads of a screw are the slope of the inclined plane
- The pitch is the distance between the threads
- The number of threads determine whether a screw can be moved more easily
- The more threads, the more turns, the easier it is to do the work or turn the screw
- The screw requires a force to do work

OVERVIEW

Students will discover that a screw is an inclined plane wrapped around a cylinder. The screw is a simple machine that increases force and does work.

SCIENCE BACKGROUND

A ***screw*** is an inclined plane wrapped around a cylinder or shaft. They are generally used to hold things together, but larger screws can be used for lifting. The ***pitch*** of a screw is the distance between two grooves. This is equal to one turn of the screw. The groove on a screw is called the ***thread***.

As in an inclined plane, when distance decreases, force increases. A nut moving along a bolt moves with a greater force than the effort used to turn it. The nut and bolt hold objects together because they grip the object with great force. Friction stops the nut from working loose. With a screw, as the screw turns, it works its way into the material. There is less effort to turn the screw, but with each turn, the force is magnified and acts on the material to drive the screw into it. Friction holds the screw in the material and is strong because the spiral thread is long and the force between the thread and material is strong. A wedge produces a strong force at right angles to its motion, and a screw does the same, but perpendicular to its rotation.

Depending on how many threads a screw has, a screw can be moved more or less easily. The more threads, the more turns, but the easier it is to turn because it takes less effort for each turn. A good analogy to remember this is like walking up a flight of stairs. If you have more stairs to climb (more threads) that are small, it requires less effort to climb than a flight of less stairs (less thread) that are large and high. But which type of screw would hold better in material? One that has many small threads or one that has several large ones? If it takes more effort to unscrew the one with the several large threads, that will take more effort to work itself loose, so that type of screw will hold better.

Some examples of screws include: screw, bolt, housejack, piano stool, swivel chair, screw jack, corkscrew, vise, micrometer, wood clamp, faucet, drill, auger, meat grinder, pencil sharper, light bulb, propeller, screwtop bottle.

MATERIALS

For Demonstration:

- Piano stool or swivel chair
- Metric ruler

For Activity 1 (What's the Pitch?):

- Bar of soap
- 4 screws of same length but different pitches
- Marked screwdriver (put dot or tape on one side)
- Metric ruler

For Activity 2 (Screw & Friction):

- Screw containers with lids
- Hand lotion
- Wax paper
- Plastic wrap
- Piece of flat rubber

For Activity 3 (Make a Screw):

- Pencil (one per student)
- Paper triangles with slope marked (1 per student)
- Scotch tape

GETTING READY

1. Schedule the Activity

This lesson takes one session to complete. The class is split in half so that half will be doing Activities 1 & 2 while the other half does Activity 3, and then they will swap so each student gets a chance to do all activities.

2. Setting Up the Demonstration

Set aside space that allows for a large group observation for the demonstration. Have available a chart to record students' observations and measurements.

3. Setting Up the Activities

Set up each activity to allow for at least two groups to conduct the activity at the same time. Have the necessary materials for multiple sets of the same activity. Each group should have a recording sheet for each activity.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *How is a Screw Useful?* and *Round and Round,* found in the documentation masters in this Addendum.

LESSON 6C: Screw

CLASSROOM DEMONSTRATION

Students can measure distance up or down the chair/stool travels per revolution.

CLASSROOM ACTIVITIES

Activity 1: Screw & Work

1. Look at each screw and guess how many turns of the screwdriver it will take to screw into the bar of soap 1/3 of the length of the screw.
2. Using the screwdriver, screw each in, counting the turns of the screwdriver.
3. Record the number of turns taken for each screw next to your prediction on the data sheet.
4. Unscrew each screw and compare the soap residue left on each screw.

Activity 2: Screw & Friction

1. Rub a little hand lotion on your hands.
2. Try to unscrew the lid of a container. Is it hard or easy to do with the hand lotion?
3. Now try to unscrew the lid of a container using a piece of wax paper. Is it easier of harder?
4. Try to unscrew the lid of a container using a piece of plastic wrap. Is it easier or harder?
5. Now try to open the lid of a container with the piece of rubber. Is it easier or harder?

Activity 3: Make a Screw

1. Take a paper triangle and a pencil. Lay the triangle on the table so that one straight side is facing to your left and the other straight side is toward the bottom of the triangle (the straight sides should look like 3:00 on the hands of a clock). The slope (marked side) should look like an inclined plane going down from left to right.
2. Place the pencil such that the left straight side of the triangle is under it.
3. Attach the straight side under the pencil to the pencil using tape.
4. Starting at the pencil, roll up the triangle around the pencil so the marking is clearly shown wrapped around the pencil like a spiral staircase/screw.

NOTE: The following pages may be copied and cut for the instructions at the activity centers.

Activity 1: Screw & Work

1. Look at each screw and guess how many turns of the screwdriver it will take to screw into the bar of soap 1/3 of the length of the screw.

2. Using the screwdriver, screw each in, counting the turns of the screwdriver.

3. Record the number of turns taken for each screw next to your prediction on the data sheet.

4. Unscrew each screw and compare the soap residue left on each screw.

Activity 2: Screw & Friction

1. Rub a little hand lotion on your hands.

2. Try to unscrew the lid of a container. Is it hard or easy to do with the hand lotion?

3. Now try to unscrew the lid of a container using a piece of wax paper. Is it easier of harder?

4. Try to unscrew the lid of a container using a piece of plastic wrap. Is it easier or harder?

5. Now try to open the lid of a container with the piece of rubber. Is it easier or harder?

Activity 3: Make a Screw

1. Take a paper triangle and a pencil. Lay the triangle on the table so that one straight side is facing to your left and the other straight side is toward the bottom of the triangle (the straight sides should look like 3:00 on the hands of a clock). The slope (marked side) should look like an inclined plane going down from left to right.

2. Place the pencil such that the left straight side of the triangle is under it. Attach the straight side under the pencil to the pencil using tape.

3. Starting at the pencil, roll up the triangle around the pencil so the marking is clearly shown wrapped around the pencil like a spiral staircase/screw.

Activity 1: Screw & Work
Datasheet

NO. OF TURNS

COMMENTS

SCREW NO.	PREDICTION	ACTUAL
1		
2		
3		
4		

Which screw had more soap left on it?

Which screw had the least?

Activity 2: Screw & Friction
Datasheet

ITEM USED	HARD TO UNSCREW	EASY TO UNSCREW
HAND ALONE		
WAX PAPER		
PLASTIC WRAP		
RUBBER		

Which was easiest to use to unscrew the lid?

Which was the hardest?

What do you think would happen if you used a paper towel to unscrew the lid?

Would it be better than the wax paper?

Would it be better than the rubber?

Where do you think it would fall in the hard/easy results of the four items you tested above?

LESSON 7: LEVER

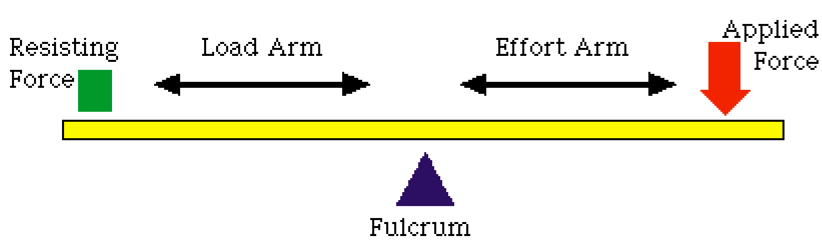
PURPOSE
Students will discover that:
- A lever requires an effort to move a load
- Changing the position of the fulcrum changes the amount of force needed to move the load
- There are three classes of levers
- When an effort is applied to a lever force, speed, or distance can be gained

OVERVIEW
Students will discover that a lever is a bar with a fulcrum (pivot point) that helps make work easier.

SCIENCE BACKGROUND
A ***lever*** is a bar that rests on a ***pivot point*** or ***fulcrum***. If you apply a force or ***effort*** on one part of the lever, the lever pivots on the fulcrum to do the work required. Whether it is to raise a weight or overcome a resistance, both of these examples are called the ***load*** or ***resistance***. The lever need not always be straight like a board, but can be curved like a claw hammer or crowbar.

Archimedes discovered the Law of the Lever: Two loads balance when the weight of one load multiplied by its distance from the fulcrum, is the same as the weight of the other load multiplied by its distance to the fulcrum. The distance from the effort to the fulcrum is called the ***effort arm***, and the distance from the load or resistance to the fulcrum is called the ***resistance arm*** or ***load arm***. The Law can then be stated as follows: Effort x effort arm = Load x load arm. Similar to the inclined plane, you gain in force but add distance. Less effort can move the same load as long as the force of the effort is applied farther from the fulcrum. The effort has to move a greater distance to move the load. The distances moved by the effort and load depend on how far they are from the fulcrum.

Illustration from *www.hamlin.pvt.k12.ca.us/science/scifair/art.html*



There are three classes of levers, depending on the relative position of the fulcrum, load, and effort. The first-class lever has the fulcrum between the effort and load. If the force exerted and the load lifted are just enough to keep the lever in balance, then the force-magnifying capacity, or ***mechanical advantage***, of the lever is equal to the ratio of the force exerted to the load lifted. In simpler terms, if the lever is equally balanced, both of the forces applied are equal in strength and are in ***equilibrium***. If the fulcrum is in the center, such as a seesaw, the effort and load are at the same distance and are equal. However, if the fulcrum is placed such that the effort is twice as far from it as the load, only half the force is required to lift the load. If the effort was three times as far from the fulcrum than the load, then only a third would be needed to lift the load. The lever magnifies the force requires to lift the load, which can be calculated using the Law of Levers. This can be shown easily with a pair of scissors and cardboard. Try to cut a piece of cardboard with the points of the scissors. Now try to cut it close to the fulcrum of the scissors. You will find this way much easier to cut the cardboard. Some examples of Class 1 levers include: crowbar, seesaw, scissors, claw hammer, balance, hand cart, pliers.

The second-class lever has the load between the fulcrum and the effort. The load cannot move as far as the effort, but the force with which it moves is greater than the effort. The closer the load is to the fulcrum, the more the force is increased, and the easier it is to raise the load. The force is always magnified, but the distance moved is decreased. This can be illustrated with a rowboat and oars. The handles of the oars is the effort, the oarlocks attached to the boat is the load (since you are moving the boat and you), and the paddle portion of the oars in the water is the fulcrum. When you row, you move the handle of the oar farther than the portion of the oar in the oarlock moves. There is more force at the load (oarlock). You move the effort through a greater distance to get a greater force to move the boat along. Some examples of Class 2 levers are: wheelbarrow, bottle opener, nutcrackers, rowboat and oars.

The third-class lever has the effort between the load and the fulcrum. As the load is farther from the fulcrum, it moves with less force than the effort, but it moves a greater distance. In this case, the distance is always magnified, but the force is reduced. A good example of this is a fishing pole. The end of the pole nearest you is the fulcrum. The part you are holding is the effort, and the fish is the load on the other end of the pole. When you pull a fish out of the water, the distance it moves is greater than the distance you move the pole where your hands are. You trade force for more distance and speed. Some examples of Class 3 levers are: fishing pole, broom, baseball bat, golf club, sugar tongs, our arms and legs, hammer driving a nail, tweezers.

Class 1 – changes direction of force (increases force if fulcrum is near load; increases speed & distance if fulcrum is near effort)
Class 2 – increases force
Class 3 – increases speed & distance, thus decreasing force

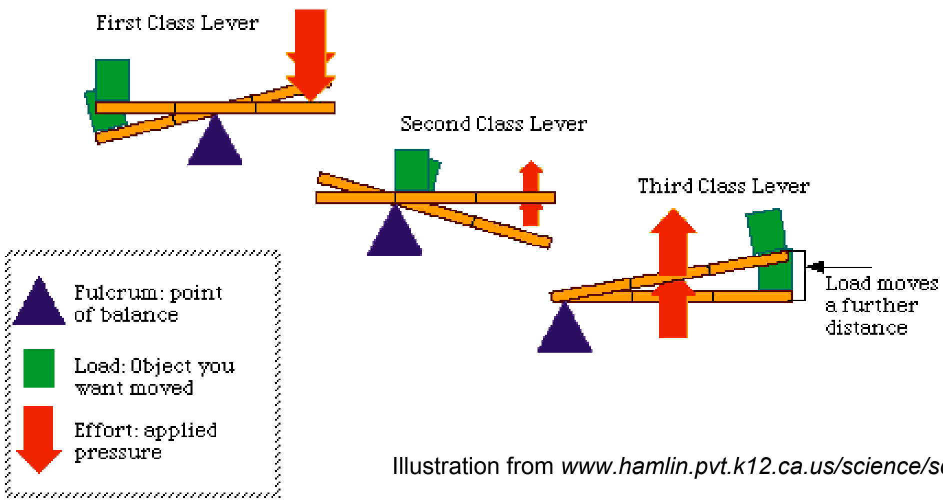


Illustration from *www.hamlin.pvt.k12.ca.us/science/scifair/art.html*

Examples of machines using multiple levers are: steam shovel (boom is Class 3, bucket and bucket-arm are Class 1), nail clippers (handle is Class 2, blades are compound Class 3), bathroom scale (crank is Class 1, system of Class 3 beneath platform), platform scales (Class 1 & 3), piano, typewriter, bicycle brake, cherry picker.

MATERIALS

For Demonstration:

- Scissors
- Cardboard

For Activities:

- LEGO Dacta™ kit

GETTING READY

1. Schedule the Activity

This lesson takes two sessions to complete. The class is divided into groups such that each group has a LEGO Dacta™ kit.

2. Setting Up the Demonstration

Set aside space that allows for a large group observation for the demonstration. Have available a chart to record students' observations and measurements.

3. Setting Up the Activities

Set up a space to hold all the kits where one student from each group can get and return them when completed. There should be sufficient space such that each group has room to build their models and write in their Journals.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *What is a Lever?* and *Levers,* found in the documentation masters in this Addendum.

LESSON 7: Lever

CLASSROOM DEMONSTRATION

Try to cut a piece of cardboard with the points of the scissors. Now try to cut it close to the fulcrum of the scissors. Which way is easier to cut the cardboard?

CLASSROOM ACTIVITIES

Activity 1: LEGO Dacta^{TM} Unit 1 - Yellow Card Activity: Frame “Up & Down”

Activity 2: LEGO Dacta^{TM} Unit 1A – “Seesaw”

Activity 3: LEGO Dacta^{TM} Unit 1B – “Stamper”

LESSON 8: WHEEL AND AXLE

PURPOSE
Students will discover that:
- Wheels and axles make movement possible
- A wheel cannot move by itself; it needs an axle to hold it in place while turning
- Heavy loads can be moved with less effort when rollers or wheels are used to reduce friction

OVERVIEW
Students will discover that a wheel and axle makes backward and forward movement possible.

SCIENCE BACKGROUND
The ***wheel*** alone is not a simple machine. However, when used in combination with an ***axle***, it becomes a simple machine and is used to transfer force. It rotates around a fixed point, acting like a ***rotating lever***. The center of the ***wheel and axle*** is the fulcrum of the rotating lever. The wheel is the outer part, and the axle is the inner part near the center of the lever. As it rotates, the wheel moves a greater distance than the axle but turns with less force. Effort applied to the wheel causes the axle to turn with greater force than at the wheel. As with the inclined plane and lever, you gain in force what you lose in distance moved.

One of the early applications of a wheel and axle is the windlass, a machine used to draw water up from a well. It consists of a large wheel (with a groove and rope) attached to an axle. The rope and bucket is attached to the axle. If, for example, the circumference of the large wheel is four times the size of the axle, when you pull the rope around the wheel one complete turn, you will be winding one-fourth of the rope on the axle and will be lifting the bucket with one-fourth of the effort. The law of the lever pertains here as well. For a numerical example of the windlass, let's assume the large wheel is four feet in circumference and a filled bucket is forty pounds. For one complete turn of the wheel, the bucket moves one foot up the well. Using the Law of the Lever, load x load arm = effort x effort arm, or 40 x 1 = 4 x effort or 10. Therefore, the effort required to raise the bucket is 10 pounds. Since the bucket is 40 pounds, the ***mechanical advantage*** is 40/10 = 4.

The same principle of the windlass influenced the early bicycle. There was a large front wheel and a small rear wheel. When the front wheel turned once with every pedal, the rear wheel turned many times in proportion to the wheel ratio. For example, if the front wheel was four times as large as the rear, the rear turned four times for each turn of the front. The modern bicycle works on the same principle, but has two wheels of the same size with additional wheels in the rear. The rear wheel axle has a smaller notched wheel (gear) which turns with the rear wheel. There is a chain that goes over this notched wheel to another notched wheel with attached pedals in the center of the two bicycle wheels. When the notched wheel and chain is turned once with the pedals, the small rear notched wheel to which the chain is attached turns many times, turning the large rear wheel with it.

Some examples of wheel and axles are: screwdriver, key opening a tin can, steering wheel, wrench, faucet, hand drill, waterwheel, turbine, windmill, pencil sharpener, meat grinder, doorknob, eggbeater.

MATERIALS

For Demonstration:

- Heavy hardcover book
- 4 pencils

For Activities:

- LEGO Dacta™ kit

GETTING READY

1. Schedule the Activity

This lesson takes two sessions to complete. The class is divided into groups such that each group has a LEGO Dacta™ kit.

2. Setting Up the Demonstration

Set aside space that allows for a large group observation for the demonstration. Have available a chart to record students' observations and measurements.

3. Setting Up the Activities

Set up a space to hold all the kits where one student from each group can get and return them when completed. There should be sufficient space such that each group has room to build their models and write in their Journals.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *Water Wheel Fun* and *Machines with Wheels,* found in the documentation masters in this Addendum.

LESSON 8: Wheel and Axle

CLASSROOM DEMONSTRATION

Using students, move a heavy book on the table surface with one finger.
Now put pencils under it and move it again with only one finger. Is it easier? The wheel and axle of the pencil reduces friction between the book and the table surface.

CLASSROOM ACTIVITIES

Activity 1: LEGO Dacta™ Unit 2 - Yellow Card Activity: "Push and Pull"

Activity 2: LEGO Dacta™ Unit 2 – Blue Card Activity: "Car and Launcher"

Activity 3: LEGO Dacta™ Unit 2 – Blue Card Activity: "Cab and Trailer"

LESSON 9: PULLEY

PURPOSE
Students will discover that:

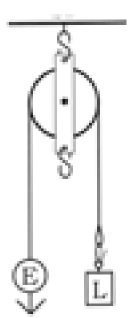
- There are two types of pulleys: fixed and movable
- Pulleys can change the direction of the load being moved
- The more pulleys, the less effort needed to do the work
- A movable pulley can be used with a fixed pulley to lift a load with less effort than with a fixed pulley alone

OVERVIEW
Students will discover that a pulley is a simple machine with a wheel that is grooved over which a rope or chain passes. A pulley is a device that makes work easier.

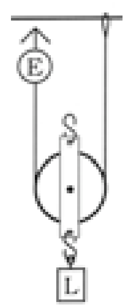
SCIENCE BACKGROUND
A ***pulley*** is based on the wheel and axle, its name derived from the Greek word *polos*, meaning "axle". The pulley has a groove in the wheel and a rope or chain over it, and is used to lift heavy weights or to change the direction of a force. There are two types of pulleys: ***fixed*** and ***movable***. A fixed pulley is attached to a fixed point by means of a hook. A movable pulley is fastened to the load being lifted.

The simplest kind of pulley is a single fixed pulley. In this instance, the pulley is attached to a support and the rope is run over the wheel to the load. A pull downward on the rope lifts the load as high as the support. The puller's body weight works downward to help lift the load. There is no mechanical advantage in this case since only the wheel turns and doesn't magnify the force; just the direction of the force is changed. Examples are a flagpole, elevator, and sailboat mast. In an ideal pulley, the effort of pulling the rope is equal to the weight of the load. In reality, the effort is always slightly more than the load since it must overcome the force of friction in the wheel, as well as raise the load.

The movable pulley allows you to lift a load with half the force, since the weight is supported with two sections of rope. In this case, if you had to lift a forty-pound weight, you would only have to exert 20 pounds of force. The mechanical



Single fixed pulley



Single movable pulley

advantage would be 40/20, or 2. The Law of the Lever also applies to pulleys since a pulley contains a wheel and axle. Taking our numerical example, for every foot the weight is raised, you have to pull twice as much rope, so this translates numerically as: 40 x 1 = 20 x 2.

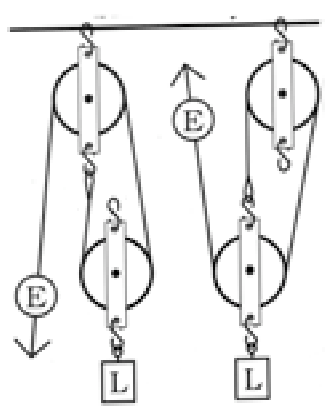
As well as changing a pulling force's direction, pulleys can also be used to magnify it like levers. Connecting pulleys together making a compound pulley system allows you to raise loads many times your weight. The amount by which a compound pulley magnifies the effort to raise the load depends on how many pulleys it has. Ideally, the magnification is equal to the number of sections of rope that raise the lower set of pulleys attached to the load. In reality, the effort has to overcome friction in all the pulley wheels and raise the lower set of pulleys as well as the load, so the magnification is slightly reduced. As with the inclined plane, there is a tradeoff of amount of rope being pulled to the amount of pulleys in the system. The more pulleys you have, the easier it is to lift the load but the more rope you have to pull to lift it. For example, in a double pulley system, one pulley is attached to the load (movable) and the other is attached to a fixed support (fixed). The rope runs over the upper pulley, down and around the lower pulley and back up to the upper pulley where it is fixed. As the rope is pulled, the lower pulley moves closer to the upper one, thus raising the load as it moves. The load moves only half the distance of the rope pulled, but the force is double the effort pulling the rope. In a four pulley system, there are two fixed pulleys (one below the other), and two movable (one above the other) attached to the load. The rope runs over the upper pulley, down and around the lowest one, up and around the lower fixed pulley, down and around the higher movable pulley back up to the lower fixed pulley where it is attached. Since the load is now supported by four sections of rope, each section is carrying one-fourth of the weight. Taking the same numerical weight example as before, each section is supporting 40/4 or 10 pounds. Therefore, the mechanical advantage of the four pulley system is 40/10 = 4.

Some examples of pulleys are: flagpole, sailboat mast, chain hoist, clothesline, crane, block and tackle, elevator, escalator.

MATERIALS

For Demonstration:

Compound Pulley Systems



Double pulley system:
Single fixed, single movable

- 2 broomsticks
- clothesline

For Activities:

- LEGO Dacta™ kit

GETTING READY

1. Schedule the Activity

This lesson takes two sessions to complete. The class is divided into groups such that each group has a LEGO Dacta™ kit.

2. Setting Up the Demonstration

Set aside space that allows for a large group observation for the demonstration. Have available a chart to record students' observations and measurements.

3. Setting Up the Activities

Set up a space to hold all the kits where one student from each group can get and return them when completed. There should be sufficient space such that each group has room to build their models and write in their Journals.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing.

LESSON 9: Pulley

CLASSROOM DEMONSTRATION

Tie one end of the clothesline to the center of one of the broomsticks. Have 3-4 students hold each broomstick parallel to each other, about three feet apart. Wrap the clothesline back and forth from one broomstick to the other, a couple of wraps on each, and hand another student the remaining line to pull. Before pulling, remind the students holding the broomsticks that this is NOT a tug of war, and if they feel the stick start to move, then they should move with it, trying to keep the line taut. Ask the student pulling how difficult it was to pull the broomsticks together.

Now set it up again, but this time double the number of wraps around the sticks and try pulling again. Ask the student pulling if it was easier or harder this time. This should be easier.

The number of wraps are equivalent to adding pulleys to a system. This is a compound pulley system of fixed and movable pulleys.

CLASSROOM ACTIVITIES

Activity 1: LEGO Dacta™ Unit 3 - Yellow Card Activity: "Up and Down, Round and Round"

Activity 2: LEGO Dacta™ Unit 3 – Blue Card Activity: "Crane"

Activity 3: LEGO Dacta™ Unit 3 – Blue Card Activity: "Fan"

PART FOUR: BEYOND SIMPLE MACHINES

OVERVIEW
This part of the module extends the Simple Machines, going beyond the six basic machines to discuss Compound Machines (Lesson 10) and Gears (Lesson 11). There is also an Assessment Section that may be used upon completion of the Simple Machines module.

LESSON 10: COMPOUND MACHINES

PURPOSE
Students will:
- Identify the many compound machines they use in their daily lives
- Discover the connectiveness of Simple Machines in the compound machines
- Solve problems by designing and building compound machines

OVERVIEW
Students will discover that compound machines are made up of two or more simple machines.

SCIENCE BACKGROUND
A ***compound machine*** is comprised of a number of simple machines connected together to make work easier. It either changes the direction of the force or increases the speed at which work is done. They may be interconnected in complex linkages, or easy to see as in a pair of scissors or tree pruner. They may convert one form of movement into another, either in a straight line or circular. The mechanical parts move to change the force applied into one that is necessary to do the work.

MATERIALS
For Classroom Activity:
- Examples of compound machines from home or school may include:
  - Scissors (wedge & lever)
  - Tree pruner (wedge, lever, & pulley)
  - Can opener (wedge, lever, wheel & axle)
  - Nail clipper (wedge & lever)
  - Fishing rod (lever & wheel and axle)
  - Hand cart/wheel barrow (lever & wheel and axle)
  - Bathroom scale (lever, wheel and axle)
  - Copy machine
  - School bus
  - Car
  - Bicycle
  - Faucet (screw & wheel and axle)
  - Illustrations from machine manuals
  - Drawings of DaVinci & Macauley

For Assessment Activity:
- LEGO Dacta™ kit

GETTING READY

1. Schedule the Activity

This lesson takes three to five sessions to complete. This is a whole class activity.

2. Gather Examples of Compound Machines

When you are discussing compound machines, you will be identifying which of the six simple machines are found within each compound machine. Pictures, posters, and/or examples should be in the classroom and used to supplement any students' presentations on a compound machine.

3. Setting Up the Classroom

Set aside space that allows for a large group observation for the demonstration of each compound machine. Have available a chart to record students' observations. Student groups could also take a machine to their own space and record their observations in their Journal.

3. Setting Up the Assessment Activity

Set up a space to hold all the kits where one student from each group can get and return them when completed. There should be sufficient space such that each group has room to build their models and write in their Journals.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *Tools Word Search, What Simple Machine Will You Need?, Simple Machine Quiz, Compound Machines, How are Big Machines Made?, Bob's Machine, Michael Built a Bicycle Poem* found in the documentation masters in this addendum.

LESSON 10: Compound Machines

CLASSROOM ACTIVITY

Students (and teacher) bring in examples or pictures of compound machines and discuss what simple machines make them up. Dissect some if possible.

ASSESSMENT ACTIVITY

Student groups are to design and/or build a device using the LEGOs™ in the kit to solve one of these problems:

1. To help Jack and Jill get water safely and easily to the bottom of the hill.
2. To help Humpty Dumpty safely up and down from the wall.
3. To help rescue Rapunzal safely without letting her hair down.
4. To prevent the three little kittens from losing their mittens and soiling them.
5. To help Winnie the Pooh get unstuck from the hole in the tree after he's had too much honey.
6. To solve a problem in a story you may think of…

NOTE: The following page may be copied and cut for the instructions of the student group assessment activities.

Design and build a device to solve one of these problems:

1. To help Jack and Jill get water safely and easily to the bottom of the hill.

2. To help Humpty Dumpty safely up and down from the wall.

3. To help rescue Rapunzal safely without letting her hair down.

4. To prevent the three little kittens from losing their mittens and soiling them.

5. To help get Winnie the Pooh unstuck from the hole in the tree after he's had too much honey.

6. To solve a problem in a story you may think of…

Design and build a device to solve one of these problems:

1. To help Jack and Jill get water safely and easily to the bottom of the hill.

2. To help Humpty Dumpty safely up and down from the wall.

3. To help rescue Rapunzal safely without letting her hair down.

4. To prevent the three little kittens from losing their mittens and soiling them.

5. To help get Winnie the Pooh unstuck from the hole in the tree after he's had too much honey.

6. To solve a problem in a story you may think of…

LESSON 11: GEARS

PURPOSE

Students will observe and experience that:

- Teeth of one gear need to mesh with the teeth of another gear to move
- Two gears meshed together turn in opposite directions and adding a third gear between will cause them to turn in the same direction
- Two gears of different sizes meshed together will operate at different speeds
- A crown gear works with another gear to change direction of output (at a right angle)
- A worm gear is used to slow down the output speed of a machine

OVERVIEW

Students will discover that gears are toothed wheels that change direction and speed. There are several different types of gears.

SCIENCE BACKGROUND

Gears are connected together in various ways to transfer motion and force in machines. They are ***toothed wheels*** and come in a variety of shapes and sizes with their teeth straight or curved at a variety of angles. They all act so that one wheel turns either faster or slower than the other, or moves in a different direction. A difference in speed between two gears causes a change in the transferred force. The wheels are toothed for three reasons:

- They prevent gears from slipping when meshed, so that axles connected by gears are always synchronized exactly with one another
- You can determine the exact ***gear ratio*** between two gears by counting the teeth and dividing (e.g. Gear A has 30 teeth and Gear B has 10 teeth, the gear ratio when they are connected together is 3:1)
- Slight imperfections in the actual diameter and circumference of two gears don't matter in determining the gear ratio

There are four basic types of gears: ***spur***, ***bevel*** or ***crown***, ***worm***, and ***rack and pinion***. A spur gear is a common type of gear. It is a basic flat toothed wheel that controls the speed or applied force and can reverse direction. A bevel or crown gear has an angled toothed wheel that changes the direction of rotation, also changing the speed and force if necessary. A worm gear is a shaft with a screw thread that meshes with a toothed wheel to change the direction, speed, and force. A rack and pinion gear has a toothed wheel called a pinion that meshes with a sliding toothed rack to change rotary motion to straight motion and vice versa.

When one gear is turning another next to it, the one applying the force to the other is said to be "driving" it, and is termed the ***driver***. The gear being driven is called the ***follower***. If two gears have the same number of teeth, they will turn at the same speed and the applied force and turning effort, or ***torque***, are changed in direction but are not in size. If the gears have different numbers of teeth, the amount of torque and the speed are also changed. For example, a small gear driving a larger gear increases torque and reduces speed in the larger gear, and a large gear driving a small gear decreases torque and increases speed in the small gear. They will be moving at opposite directions. If a third gear is placed between them, this is called an ***idler*** gear, and allows them to turn in the same direction.

If there is a large gear driving a small gear, and the diameter of the large gear is twice the diameter of the small gear, then the small one will rotate at twice the speed as the large one. The gear ratio in this case is said to be 2:1 (two to one). To create large gear ratios, gears may be connected together, where a smaller gear is connected to a larger gear on the same axle. Multiple sets of these combinations are connected together to form a ***gear train***, where the larger gears mesh with the smaller gears of the next combination.

Some examples of spur gears may be found in clocks, bicycles, salad spinner, push lawn mower, car window winder, odometer. Some examples of crown gears are: egg beater, drill chuck, car differential. Some examples of worm gears are in: a speedometer, lawn sprinkler, electric mixer. Examples of rack and pinion gears are car steering and a handled corkscrew.

MATERIALS

For Classroom Activity:

- LEGO Dacta™ kit
- Examples of machines with gears such as
  - Clock
  - Bicycle
  - Eggbeater

GETTING READY

1. Schedule the Activity

This lesson takes four to six sessions to complete, as time allows. This is a whole class activity. The class is divided into groups such that each group has a LEGO Dacta™ kit.

2. Gather Examples of Gears

When you are discussing various types of gears, it may be helpful to bring in some examples of gears found in machines with which the students are familiar such as bicycles and clocks and mixers. Pictures, posters, and/or examples should be in the classroom and used to supplement any discussion on gears.

3. Setting Up the Activities

Set up a space to hold all the kits where one student from each group can get and return them when completed. There should be sufficient space such that each group has room to build their models and write in their Journals.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing. Other in-class or take-home worksheets on the topic include *Which Way Will It Go?, Machines with Wheels - Gears* found in the documentation masters in this addendum.

LESSON 11: Gears

CLASSROOM ACTIVITIES

Activity 1: Introduction to Gears: LEGO Dacta™ Unit 4 - Yellow Card Activity: "Fun and Games"
Spur gear (flat wheel, identical teeth); clock example

Activity 2: LEGO Dacta™ Unit 4 – Blue Card Activity: "Clown's Eyes"

Activity 3: LEGO Dacta™ Unit 4 – Blue Card Activity: "Guess the Color"

Activity 4: Change Direction: LEGO Dacta™ Unit 6 - Yellow Card Activity: "Turning Round"
Crown gear (beveled wheel, curved teeth); eggbeater or can opener example

Activity 5: LEGO Dacta™ Unit 6 – Blue Card Activity: "Winch"

Activity 6: LEGO Dacta™ Unit 6 – Blue Card Activity: "Turnstile"

Activity 7: Change Speed: LEGO Dacta™ Unit 5 - Yellow Card Activity: "Fast and Slow"
Driver and Follower (small and large gears); bicycle example

Activity 8: LEGO Dacta™ Unit 5 – Blue Card Activity: "Merry-Go-Round"

Activity 9: LEGO Dacta™ Unit 5 – Blue Card Activity: "Food Mixer"

Activity 10: LEGO Dacta™ Unit 7 - Yellow Card Activity: "Slowing Down"
Worm gear (shaft with screw thread); electric mixer example

Activity 11: LEGO Dacta™ Unit 7 – Blue Card Activity: "Car with Crane"

Activity 12: LEGO Dacta™ Unit 7 – Blue Card Activity: "Measuring Wheel"

ASSESSMENT ACTIVITIES

OVERVIEW

There are two assessment activities in this Section which may be used consecutively or separately, the first after Compound Machines and the second after Gears, or even after you have completed Part Three if you do not do Part Four of this module. We leave it up to the individual teacher to assess your own students' skills, both intellectual and motor, as to whether or not you decide to use these evaluation tools as final assessments for the Simple Machines module.

MATERIALS

For Assessment Activity *How does it work?*:

- Illustrations from Leonardo DaVinci and David Macauley showing cross-sectional views of machines and how they are connected together
- Diagrams or expanded views of familiar machines from user manuals showing and identifying parts of the machine
- Examples of compound machines with or without gears

For Assessment Activity *Machine Design Challenge:*

- Drawing paper for students' machine designs
- If making models of designs, provide students with options of building using:
    - LEGO Dacta™ kit
    - Craft sticks
    - Straws
    - Pipe cleaners
    - Cardboard
    - Modeling clay
    - Materials from RI Recycling for Education

GETTING READY

1. Schedule the Activity

Each assessment activity may take one to two sessions to complete, as time allows. This is a whole class activity. The class is divided into groups such that each group has a LEGO Dacta™ kit or compound machine.

2. Gather Examples of Compound Machines

When you are conducting the pre-activity for Assessment Activity 1 (How does it work?), you should bring in some examples of illustrations of machines with which the students are familiar such as bicycles and clocks and mixers. Pictures, posters, and/or examples should be in the classroom and used to supplement any discussion on how to illustrate and label a drawing of a machine.

3. Setting Up the Activities

Set up a space to hold all the kits or model construction material where one student from each group can get and return them when completed. There should be sufficient space such that each group has room to build their models and write in their Journals.

4. Suggested Student Documentation

Students should be writing in their journal any observations they may have about the particular activity they are doing. You may also provide them with another means of supplying you with the response to the assessment selected.

<u>PRE-ACTIVITY for ASSESSMENT ACTIVITIES</u>:

Show and discuss illustrations of various machines using David MacAuley, Leonardo DaVinci, Rube Goldberg examples. Also commercial booklets for modern devices can be used which students can bring from home (i.e. assembly directions/illustrations & parts lists).

<u>ASSESSMENT ACTIVITY 1: *How does it work?*</u>

Have samples of small machines with visible working parts. Each student group has a machine to examine and see how it works. They should be able to answer these questions:

How does it work? What is its function?
How many moving parts does it have?
How are the parts connected together?
What does each working part do?
Which parts are elements of the machine?

Students groups should sketch the machine and label the working parts to show how they connect to each other and make it work.
If time allows, have groups exchange machines.

<u>ASSESSMENT ACTIVITY 2: *Machine Design Challenge*</u>

Students are encouraged to use their creativity and knowledge of machines and illustration to develop a machine to solve one of these problems:

1. Design a gripping device at the end of a rope that will automatically lock onto a load when it is lifted, but will automatically release when the load reaches its destination.
2. Design a machine to push away the scaling ladders of invaders trying to get inside a castle without exposing the castle dwellers to danger.
3. Design a machine that allows a person to make giant wings flap by pedaling with his/her feet.
4. Design a machine that pours standard amounts of cereal and milk into a bowl.
5. Design a machine to trap squirrels who visit a bird feeder and release them safely on the other side of a wall.
6. Design a machine to automate the process of squeezing toothpaste onto a toothbrush.
7. Design a machine to automatically make a bed after it has been slept in.
8. Design a machine to help feed and water a cat or dog in a house.
9. Design a machine to automate the process of toasting a slice of bread.
10. Design a machine to automate the process of putting coins in a piggy bank.
11. Make up their own invention to perform an everyday task.

Students should draw their designs along with labeling the primary parts that make it work, also write the procedure (outline of steps) used for the machine to perform the function it was designed to do. You could extend this by having them actually make a model of the machine, either with the LEGOs™ in the kit, or with craft sticks, straws, pipe cleaners, cardboard, or other materials from RI Recycle.

NOTE: The following pages may be copied and cut for the instructions to the student groups of the Assessment Activity problems.

ASSESSMENT ACTIVITY 1: *How does it work?*
Each student group has a machine to examine and see how it works.

Answer these questions on the recording sheet when looking at your machine:

1. How does it work? What is its function?

2. How many working parts does it have?

3. How are the parts connected together?

4. What does each working part do?

5. Which parts are the basic simple machines of the machine?

Sketch the machine and label the working parts to show how they connect to each other and make it work.

ASSESSMENT ACTIVITY 1: *How does it work?*
Each student group has a machine to examine and see how it works.

Answer these questions on the recording sheet when looking at your machine:

1. How does it work? What is its function?

2. How many working parts does it have?

3. How are the parts connected together?

4. What does each working part do?

5. Which parts are the basic simple machines of the machine?

Sketch the machine and label the working parts to show how they connect to each other and make it work.

ASSESSMENT ACTIVITY 2: *Machine Design Challenge*

Be creative and design a machine to solve **ONE** of these problems:

1. Design a gripping device at the end of a rope that will automatically lock onto a load when it is lifted, but will automatically release when the load reaches its destination.
2. Design a machine to push away the scaling ladders of invaders trying to get inside a castle without exposing the castle dwellers to danger.
3. Design a machine that allows a person to make giant wings flap by pedaling with his/her feet.
4. Design a machine that pours standard amounts of cereal and milk into a bowl.
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9. Design a machine to automate the process of toasting a slice of bread.
10. Design a machine to automate the process of putting coins in a piggy bank.
11. Make up your own invention to perform an everyday task.

Draw your design and label the primary parts that make it work.

Write the procedure (outline of steps) used for the machine to perform the job it was designed to do.

If there are materials available, make a model of the machine.