Introduction for Teachers

Machines That Help -- version 2.0

Where the <u>Machines That Help</u> Unit Fits in Learning By Design™

<u>Machines That Help</u> is a replacement middle-school science curriculum unit, as are all the units that make up Learning by Design™ series. As of this writing (Janurary 2001), there are six LBD™ units that are in various formative stages of development, testing and use. These include:

- Apollo 13 (introduction to LBD™)
- Vehicles in Motion (Kinematics and Newton's Three Laws of Motion)
- Work and Energy (Conservation Laws)
- Machines That Help (Simple machines and mechanical advantage)
- Erosion
- Tunneling

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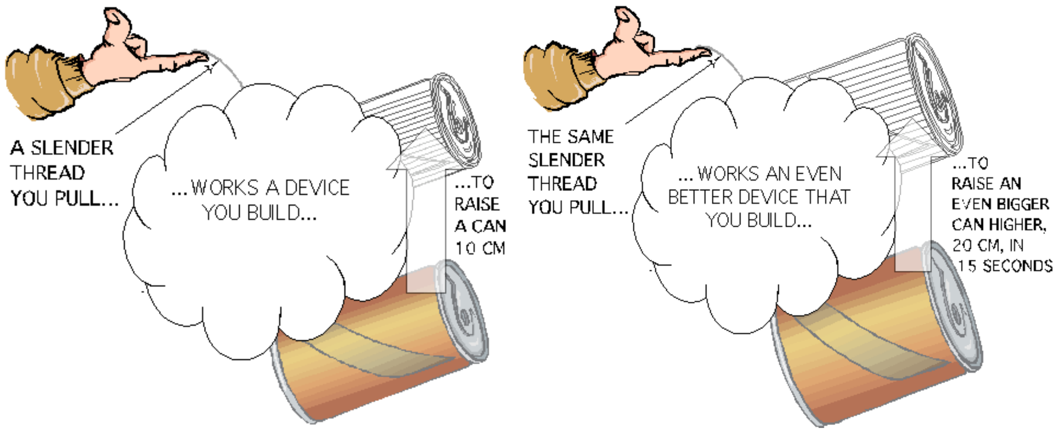
Quick Overview: What is <u>Machines That Help</u> all about?

<u>Machines That Help</u> is a physical science unit deals mainly with simple machines (levers, screws, wheels-and-axles, inclined planes, and pulleys) and how they can help a person do things they otherwise could not, albeit with trade-offs. The unit's main design challenge has a name: the "Can-Lift" Challenge, and has two manifestations – one for each of the two sections in MTH. Section 1's Can-Lift Challenge has the students attempt to raise a medium-sized can of food or juice up 10 cm with only a very small force – actually, the force that can be transmitted through a single strand of cotton thread. The thread and can are selected so that what students need to devise is a device that will multiply the force they can supply to the machine they build through the thread. Section 2's challenge asks students to raise an even heavier can 20 cm, and this time within a period of time – 15 seconds. The essence of this unit's main design-and-build challenge is shown in the following illustration:

SECTION 1 SECTION 2



Throughout the two sections of the Machines That Help unit, students will be attempting to build and improve upon a composite device that uses one or more simple-machine ideas to get the needed mechanical advantage to multiply the force needed to lift the heavy can.

Students start by trying to lift the can with the string on its own. They collect data, and report back to class. They then work in design teams and choose one of four simple-machine approaches (the four sets of plans are on pages 14-29), plus a throw-back from LBD™'s *Vehicles in Motion*, wheels-and-axles bearing Coaster Car (pages 30-32).

As its title suggests, the main thrust of this unit is to show how devices can help people and to design with that in mind. Students will learn science ideas and invent their own "Can-Lift" machines with something more grand in mind than raising tin cans with thread. The unit starts on pages 4-5 with them reading "Things That Help Make Lifting Easier," and find out about four different groups of people, all who need help in one form or another, and whose needs are met in a practical and sustained way with the help of simple machines. Students will be asked to keep one of the four groups in mind and then at the end of *Machines that Help* (see page 60), act as consultants and design a device that will meet the needs of one of the following groups of people: elderly who are homebound; a teenager in the workplace; a person with limited strength; and people in a village without electricity or devices.

To get a quick sense of what *Machines That Help, Version 2* is about, read the following from the Student Book: the introduction to the Can-Lift Challenge (page 6 and 10), and the suggested sequences of activities for Section 1 (pages 12-13) and Section 2 (pages 48-49). Pages containing the key science ideas of the unit can be found in three readings: Trade-Offs & Simple Machines (pages 34-37), The Science of Simple Machines: Work and Mechanical Advantage (pages 54-55), and Measuring & Figuring Out How Much Machines Help (pages 56-57). The main technology ideas deal with making a certain kind of explanatory drawings Making How-It-Works Drawings (pages 40-42) and putting design ideas together (Combining Plans to Get the Advantage You Need, pages 50-51).

Materials You Need To Get To Teach With This Unit

There are some materials you will want to gather before starting version 1.0 of the Machines that Help unit. Please note that if you choose to have students crack nuts in the messing about activity (page 10-11) or product comparison task (page 22-25), nuts with shells are only available seasonally, not year round in some parts of the country. You may have to buy bags of mixed, unshelled nuts around the winter holidays in order to have them available for use when the time comes to use Machines That Help.

Other materials you will need to do this unit include:

<u>Page 4-5 – Things That Help Make Lifting Easier</u> (initial demonstration)

1	Medium-sized can of food or drink (≈1.4 kg)
1	Large-sized can of food or drink (≈3.1 kg)
1	Spool of single-strand cotton thread
1	2 x 6″ 8′ or longer board of lumber

You'll be using the cans and thread to show what the challenge is, and the board to demonstrate that while you can't lift something heavy (like a person) directly, you can with the help of a simple machine (board as lever).

<u>Page 8-9 – Doing a Deadlift With a Single Thread</u>

1 per team	Medium-sized can of food (≈1.4 kg) (Use lighter can if desired.)
1 per class	Spool of cord or kite string
1 per class	Roll of duct tape
1	Spool of single-strand cotton thread

Hint: Check to make sure that the cotton thread you use breaks when lifting the can. It should take between 2-3 strands of thread to lift the can directly up.

<u>Page 11 –First Can-Lift Challenge</u>

Removing Bolts - Homework

1 per team	Socket to fit the bolt's head
2 per class	Ratcheting socket wrenches (see page 11)

Cracking Nuts - Homework

1 per team	Dozen nuts of various types including walnuts, pecans, and almonds
1 per team	Lever-type nutcracker or 4″ C-Clamp
2 per team	Short pieces of lumber, e.g., 1″x2″x4″

Page 14-17 – Can-Lift Plan 1: Using Levers

1 per team	3 x 35-cm long piece of pegboard
1 per team	30-cm long piece of handle moulding, with sandpaper glued to the top
1 per class	Box of paper clips
1 per team	8-10 1/4″ washers (in a plastic bag)
2 per team	Wooden yardsticks (or meter sticks)
2 per class	Low-temperature glue guns (with glue sticks)
1 per team	Cord or kite string, 1 meter
1	Collection of cases of lever-based simple machines (scissors, pliers, crowbar, nail clippers, toothbrush, flyswatter, and so on)

Page 18-21 – Can-Lift Plan 2: Using Ramps & Inclined Planes

1 (opt. demo)	Door stop, wedge for splitting lumber
1 per team	Cardboard box, lid or bottom (banana box, box for copy paper)
2 per team	Lumber 2x4″, lengths between 1 and 3′
1 per class	Roll masking or duct tape
1 per team	Heavy-duty scissors
1 per team	Cord or kite string, 1 meter

Page 22-25 – Can-Lift Plan 3: Using Pulleys & Block-and-Tackle

1 (opt. demo)	Pulley, come-along, block-and-tackle
1 per team	Plastic straw, large [slide over wire axle]
2 per team	wire coat hangers
2 per team	empty wooden thread spools
1 per team	Cord or kite string, 1 meter
1 per 2 teams	Pliers: lineman and needle-nose pliers

Page 26-29 – Can-Lift Plan 4: Using Cranks & Windlasses

1 per team	10 x 40 cm piece of pegboard
1 per team	Small cardboard box
4 per team	Regular hex nuts, washers, 1/4" coars thread
1 per team	8"-long carriage bolt, 1/4" dia coars thread
1 per team	3"-long carriage bolt, 1/4" dia coars thread
1 per team	Plastic straw, large [slide over axle]
1 per team	Cord or kite string, 1 meter
1 per team	Duct tape, 1 meter

Page 30-32 –Can-Lift Extra Helper Plan: Using Wheels & Axles

1 (opt. demo)	Coaster car, assembled

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1 per team          Foamcore or cardboard, 10 x 30 cm piece
2 per team     6"-long carriage bolt, 1/4" diam coarse
thread
4 per team     Nuts, 1/4" coarse threads
4 per team     Wing nuts, 1/4" coarse threads
8 per team     1/4" washers (optional)
1 per team     Duct or masking tape, 1 meter
1 per team     Plastic straw, large [slide over axle]
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Ideas You Need To Know To Teach With This Unit

Machines That Help was designed to put a human face, or at least link a human need, to the study of simple machines. The key idea related to , most simple machines is that things like levers and screws and block-and-tackles can multiply the forces we apply to them, which enables us to do things we could not otherwise do. Put simply, a piece of relatively easy-to-break cotton sewing thread cannot lift a medium-sized tin of food or juice, but if it is attached to the right simple machine in the right way, the machine can help you do it. What that help is called is *mechanical advantage (MA)*, and can be figured out and predicted – things that science loves to do – when basic principles for doing this are learned and practiced. How much the machine multiplies the Applied Force in acting on a Load is the MA.

The big idea of *trade-offs*, which designers have to deal with all of the time in looking at the costs and benefits of materials and techniques they use in designing things, is also neatly addressed in a science fashion when designing with simple machines. Science's definition of work fits in nicely here, which says that the Distance a Force travels TIMES the Force itself is the work done by a device, or person, or system. Forgetting about friction of a moment, the work done by the person on the machine is going to be equal to the work done by the machine on the Load. This is expressed in t he equation, Force X Distance = Force X Distance, and is probably the equation you will be using most both qualitatively and quantitatively in this entire unit. The trade-off contained in this formula can be shown simply by writing each term either with a large or small font. A person using a car jack to raise a car applies a small Force over a long Distance in order to apply a large Force to raise the car up a small Distance. Kids can relate to these balancing act of large and small entities related to machines when they see them in a formula as:

$$\text{Force} \times \text{\Large Distance} = \text{\Large Force} \times \text{Distance}$$

Science Standards

During the creation and redesign of *Machines That Help,* we've kept the *National Science Education Standards* in mind. Their emphasis on understanding technology as a critical and parallel application of science ideas is central to Learning by Design™ is shown in an analogy that appears in its Science & Technology section of the Content Standards:

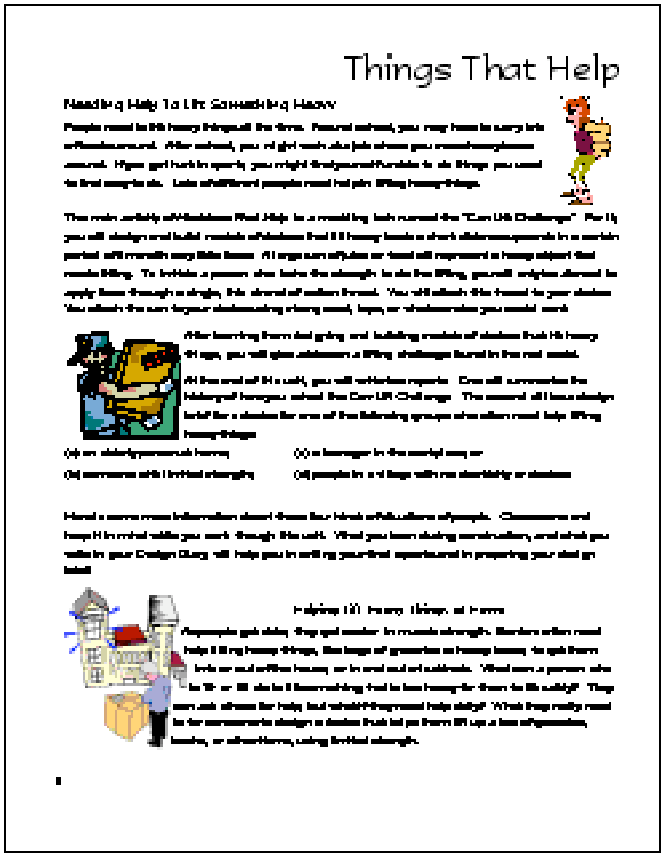
> "This standard helps establish design as the technological parallel to inquiry in science." (p. 135)

According to the *Standards*, students should be able to tell the difference between science and technology (p. 161), compare designed artifacts (p. 165) and understand how things work (p. 165). The notion of balancing competing criteria and trade-offs, so important in design, is also mentioned (p. 166) and may be the central theme of *Machines That Help*. Unfortunately, *NSES* did not specifically include key topics like simple machines, mechanical advantage, work and torque – you will have to refer to your own local or state Standards to see how these topics, which are typically included in science curricula, are spelled out there.

A number of models of what designing entails list repeated three strategies: analysis, synthesis and evaluation (Evans, 1990). *Analysis* gets engaged when designers makes sense of and structure the design problem. *Synthesis* involves the generating of solutions, combining of ideas to make new approaches, and so on. Finally, *evaluation* includes the appraisal of those solutions that have been generated for consideration, and is compared with the goals and specifications that were generated in the analysis stage. These very strategies appear as the three highest-order educational objectives in Bloom's taxonomy (1950).

Keep in mind that *NSES'* "Teaching Standards" can be addressed in doing activities in *Machines That Help* and other *Learning By Design™* units. These activities regularly have students doing work in teams where they “share responsibility for their own learning” (*NSES*, p. 36), do extended investigations (p. 43), and assess their own work and processes (p. 38). The *NSES* “Unifying Concepts and Processes” goals can also be addressed that include thinking of products as systems (p. 116) and describing products according to their form and function (p. 119). Making and defending design decisions can help students achieve *NSES’* “Scientific Inquiry” goals – including creating oral and written reports (p. 144), using mathematics to represent situations with numbers, graphs and tables (p. 219), gathering, analyzing and interpreting data (p. 145), and evaluating and using evidence (p. 145).

Things That Help Make Lifting Easier

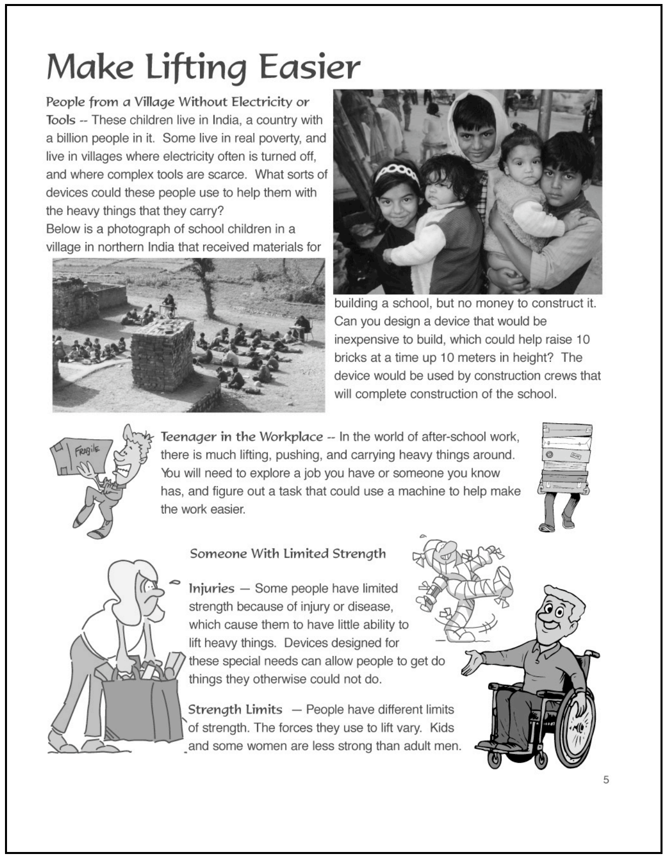

Things That Help

Overview

The first two pages of the Machines That Help gives students a number of contexts involving people who can't lift heavy things, and who could use a devise that could give them some help. It mentions that students will be working on scaled-down model that involves lifting of cans of juice with a piece of thread, and then gives more details about the four groups who will be the focus of the final report students will write at the end of *Machines That Help*:

(a) an elderly person at home;
(b) a person with special needs;
(c) an adult in the workplace; and
(d) a 10-year old in a village with no machines.

0.5 Period



Make Lifting Easier

People from a Village Without Electricity or Tools -- These children live in India, a country with a billion people in it. Some live in real poverty, and live in villages where electricity often is turned off, and where complex tools are scarce. What sorts of devices could these people use to help them with the heavy things that they carry?
Below is a photograph of school children in a village in northern India that received materials for building a school, but no money to construct it. Can you design a device that would be inexpensive to build, which could help raise 10 bricks at a time up 10 meters in height? The device would be used by construction crews that will complete construction of the school.

Teenager in the Workplace -- In the world of after-school work, there is much lifting, pushing, and carrying heavy things around. You will need to explore a job you have or someone you know has, and figure out a task that could use a machine to help make the work easier.

Someone With Limited Strength

Injuries — Some people have limited strength because of injury or disease, which cause them to have little ability to lift heavy things. Devices designed for these special needs can allow people to get do things they otherwise could not do.

Strength Limits — People have different limits of strength. The forces they use to lift vary. Kids and some women are less strong than adult men.

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Teaching Strategies and Research Notes

It is assumed that this is not the first *LBD*™ unit that students have done -- the opening design scenarios should seem familiar. Most teachers find reading these pages together with their students helps uncover initial confusions and questions students might have, and gives a first glimpse into how students think when encountering simple machines from the context of using them in the real world rather than studying them in the classroom.

Getting students to link the human need for a device to their own needs is something you should think about before having students do this reading. Research that says that students can ask their own meaningful questions they understand the context of what they are learning – a number of examples in these two pages of readings are geared towards the students themselves. Other research shows that female can be turned off by challenges involving mechanisms and getting them to work better or optimally. They do get engaged, it has been found, when doing mechanism-oriented design tasks *when it* *involves helping people* – talking about simple machines in the abstract is death to many in this population of students.

You might want also to avoid until it comes up in the readings any mention of "simple machines" (see page 35). Some questions you might want to encourage students to investigate include: How much do machines help and how can you determine this? What is mechanical advantage? Does it always involve machines? Do machines work by magic, or is there some science principle that explains how they work? What sorts of machines are at home and school? Can these cases help me with my challenge?

Activity Planning & Materials Needed

Reading this and the next article in preparation for the day's events in class – you should be able to do the four pages in a single class period. Demonstrations of situations your kids can relate to involving lifting, where a device makes something difficult easier to do, would help in setting the stage for the work in *Machines That Help*.

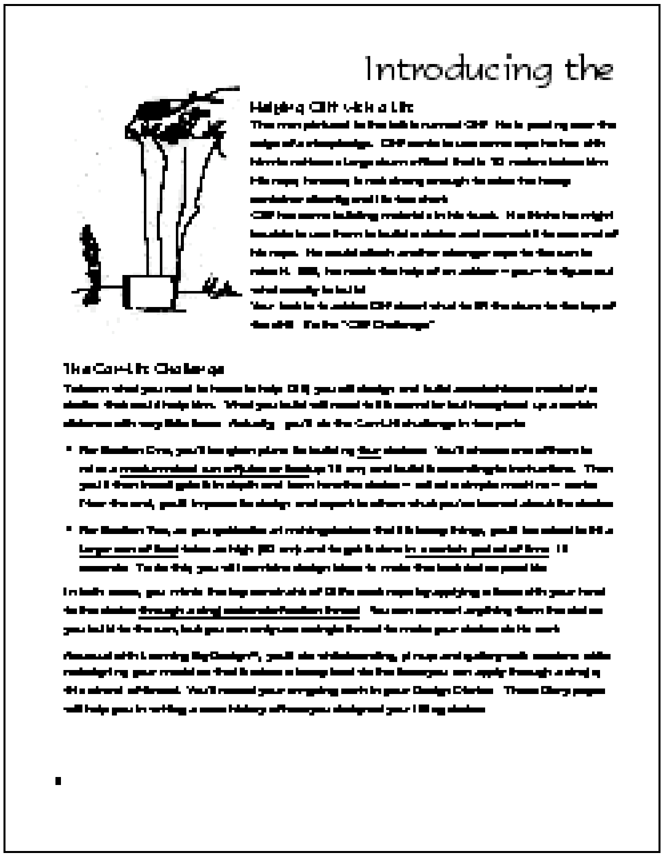
The following demos were developed by Earl Carlyon of Farmington HS in central Connecticut. One class demo has a student lift a cinder block by hand, and then with a block-and-tackle suspended from the ceiling. Ask: Which method was easier? A second demo could involve having a student attempt to push a heavier-set person from the side with an aim of moving them. Once this attempt failed, the person to be moved would be asked to stand (carefully) on a wooden plank (2x10″ or 2x12″ and 8′ long) placed on top of a series pipes or lab-stand poles placed parallel to one another and underneath the plank so that they act as rollers. Then ask the same student to push the more massive person. Ask, "Does a simple machine make this task easier?"

The third demo was especially compelling. Earl has a student of diminutive size try to lift him straight up (Earl's a big guy!). When this attempt failed, he then asked the class a key physical science question: "Did I move? Did she apply a force?" Some students typically think that because there is no motion, there is no force being applied. Then another student volunteer, of the same size as the person attempting the lifting, is asked to participate in the experiment. The same student then ties to lift this other diminutive classmate (be sure to remind students to be safe, not to strain themselves). When the effort was successful, Earl asked the question, "Did she apply a force then? So why didn't I [the teacher] move but she [the second student] did?" Students who have learned the notion of net forces may be able to analyze the different behaviors with this idea.

The final demo had Earl ask for two students to stand on either side of a lab table and hold a lab-table pole firmly to near the end of the table, parallel to its edge. Earl then asked the student who first attempted to lift him if she was willing to try one more time to lift him. He then placed the lumber on top of the pole, that now would be acting as a pivot for a lever. Earl carefully climbed up on the lab table, and had two students raise the lumber to the table. He then stood on piece of wood, on one side of the pivot pole, and then gradually extended the piece of lumber so that it extended beyond the table. Earl then placed his full weight on the makeshift see-saw, and asked the student to apply a downward force on the lumber. By adjusting the placement of the pivot, the student was able to apply a force and raise Mr. Carlyon! For safety reasons, as soon as he started to be raised upwards, Earl stopped the demonstration. For the rest of the day, all of this student's teachers reported to Mr. Carlyon that she was breathlessly reporting that she was able to lift Mr. Carlyon! Such a demo can give students a visceral sense of just how much a simple device, like the lever, can help.

An interesting follow-up question to such a demo is to ask students: "So how does a lever work?" Asking such an open-ended question will solicit students to use their own words, terms and ideas to explain what on the surface seems like a simple phenomenon. Be ready to be surprised. More importantly, in asking some preliminary questions, you are learning more about your students, and following the National Research Council's rule-of-thumb of good pedagogy: "Effective instruction begins with the knowledge and skills that learners bring to the learning task" (<u>How People Learn</u>, 1999, page 38).

Introducing the Can-Lift Challenge


Introducing the

Helping Cliff with a Lift

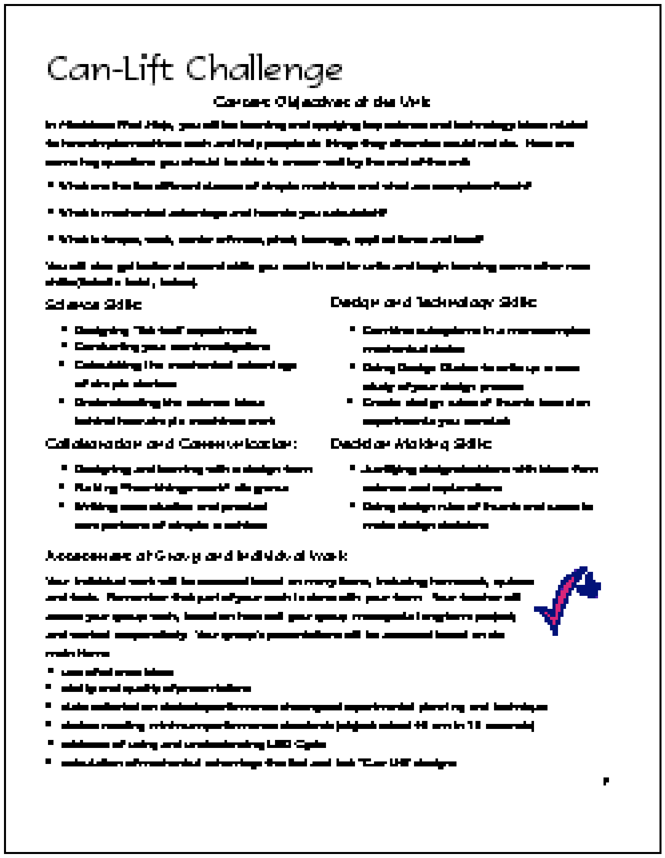
The Can-Lift Challenge

Overview

The first page of reading gives students more details on the challenge they will spend the most time with in *Machines That Help* – involving Cliff and the Can-Lift Challenge. Key ideas and constraints about the work for the two sections that make up this unit are discussed.

The second page of the reading introduces some questions that will drive the study of simple machines . A description of particular skills in science, design & technology, communication and decision-making are then bulleted and highlighted, and the piece ends with a description of how your students will be assessed during and at the end of the unit.

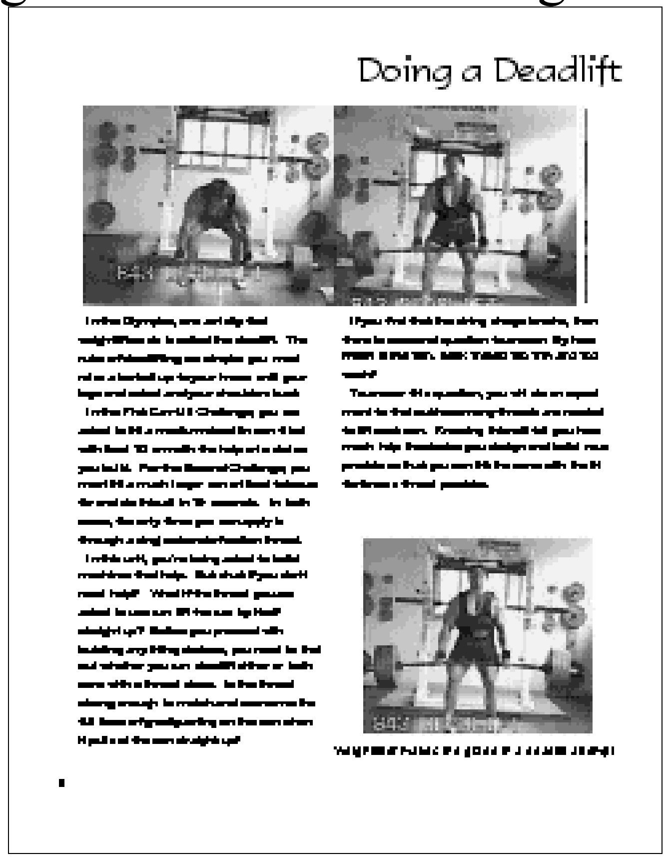
0.5 Period



Teaching Strategies and Research Notes

Having students read over these pages will be helpful for both you and them. Students should be able to grasp, at least superficially, the nature of the problem they will be facing – the creation of a device that multiplies force. They may know little else, and will only have a fleeting understanding of the concepts and skills they must exhibit by the end of the unit. Reviewing the objectives and skill goals described on page 7, as well as the ways they will be evaluated during the unit, would be time well spent throughout the unit. In fact, some effective LBD™ teachers make it almost a ritual to begin the class with students summarizing what they have done the previous day, and relating this statement to items found on this page.

Doing a Deadlift With a Single Thread


Doing a Deadlift

Overview

The Deadlift activity aims to give a “need to know” to students the big picture of the entire Machines That Help unit. The first page establishes the “need to know” about simple machines for lifting a heavy can of food. The second page gives explicit instructions for setting up the materials for the experiment.

All teams will conduct experiments to find out whether their single-strand of string can “deadlift” the can. If it cannot, teams will add one string after another until they *can* lift the can directly. Teams will report on how many strings it took to lift their can, and compare how they went about their experiments when reporting their results.

1 Period

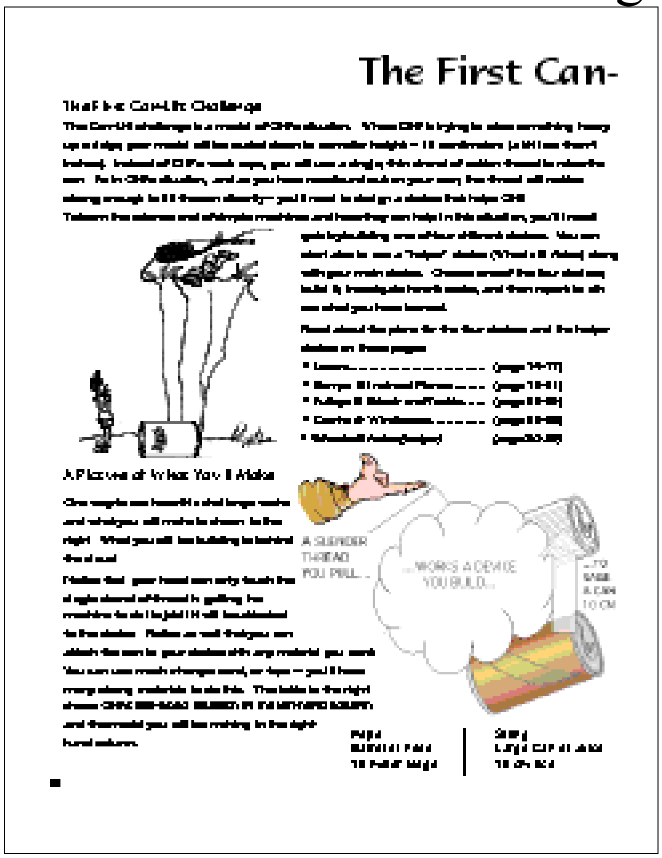
Teaching Hints and Research Notes

Ask students if they have ever seen the weightlifting competitions in the Olympics. What are the different tasks or lifts, and in what competition do people lift the most weight? [Deadlift, where the lifter raises the bar until the person's back is straight and shoulders back.] Then read the activity together – making sure that students know what will be expected of them when they report their results. Depending on the can used, 2-4 strings will be needed to lift up a single can.

Planning for the Activity & Materials Needed

Have one copy of the "My Experiment" Design Diary page for each of your students. You might want to prepare all the cans, rather than having students spend their class time tying the string and taping it to the can with duct tape. If you choose to you're your students do this, it may be wise to have at least one can already done and available so that students can see what is expected of them.

The First Can-Lift Challenge

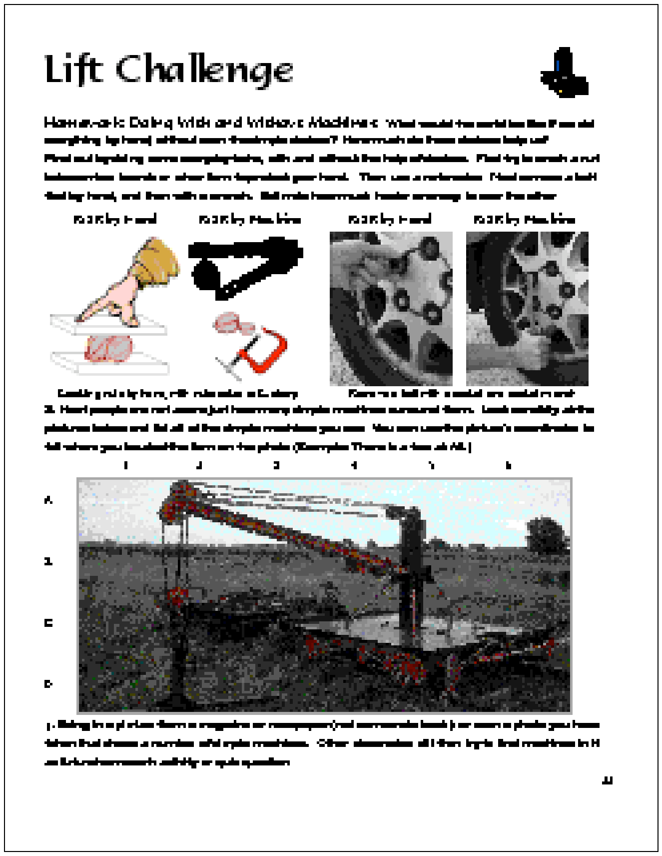

The First Can-
A SLENDER THREAD YOU PULL...
...WORKS A DEVICE YOU BUILD...
...TO RAISE A CAN 10 CM

Overview

The “First Can-Lift Challenge” activity give students both the specifics of the challenge they will be attempting to answer in Section 1, and as well as gives an overview of what is contained in this first portion of *Machines That Help*. Students see two major “pictures” of what is expected of them – a bulleted list of four items they can build as a first-attempt solution to the Can-Lift Challenge, and then a pictural representation of Section 1’s challenge.

The second page of the activity is a homework assignment that aims to get students to make connections between what they are starting to do in class and their world around them.

0.5 – 1 Periods



Lift Challenge

Teaching Hints and Research Notes

As you and your students can see on page 10, this unit takes a somewhat different approach to doing an initial design than in others in the *Learning By Design*™ collection. *Machines That Help* gives students a choice from among four options of devices (for the most part, different simple machines) to build. After building and testing them, they share their mini-expertise in this type of device with others, and then combine all the different ideas to make their best solution to the Can-Lift challenge.

Have students read the first page aloud and make sure they can summarize its contents and the main aim of the challenge in their own words. You can read over and assign the homework, and then review results the next day. You might want to have some materials for the homework available in class. The first homework activity aims to get your students to think what the world would be like without the devices that we take for granted but make day-to-day life much easier.

Planning for the Activity & Materials Needed

The two suggested tasks for homework aim to give students a hand-on feeling for the advantages that devices provide by doing nutcracking and bolt loosening by hand and with the appropriate tool. (Use other tasks that can be done with and without the help of a tool, as you or your students think of them.) Here are the materials you might want to bring for the tasks shown on page 11:

Removing Bolts - Homework

1 per team	Socket to fit the bolt's head
2 per class	Ratcheting socket wrenches (see page 11)

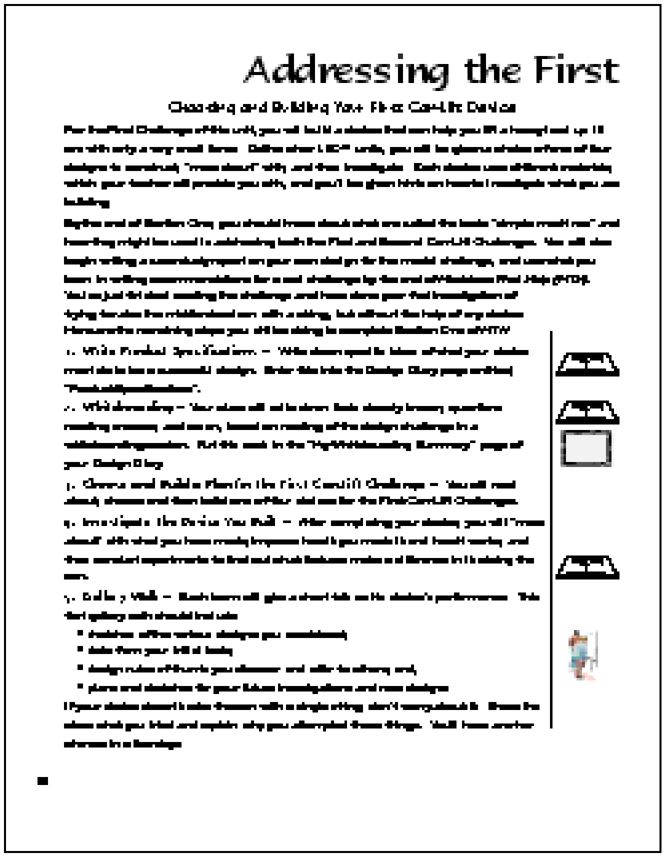
Cracking Nuts- Homework

1 per team	Dozen nuts of various types including walnuts, pecans, and almonds
1 per team	Lever-type nutcracker or 4″ C-Clamp
2 per team	Short pieces of lumber, e.g., 1″x2″x4″

Actually, the two devices help in more ways that multiplying forces – which makes the tasks easier for the user to do. The nutcracker shown on page 11 not only is a lever, but it also is made of metal, which is stiffer and doesn't feel pain when forces are applied to it – unlike your hand. Also, the nutcracker has serrated jaws that can concentrate forces, causing the nut's shell to crack with less force. (Actually, another nutcracker is written up as a model for a case study report – see page 39 of the Student Textbook.) Similar advantages can be assigned to the ratcheting wrench shown in the second homework example – benefits arise from the long handle and the increased torque it provides, as well as the metal socket that can grip the bolt without deformation or pain.

The photo of the farm equipment appears to have the main aim of lifting heavy things at a distance from the moveable platform. Pulleys can be found in A5, A2, and B2. A winch with crank might be visible to students at B4. Various wheels can be seen in C/D3 and C/D5 – these might act to move the platform, or for torquing a connected shaft. Straight-arm levers can be seen in C6.

Addressing the First Can-Lift Challenge

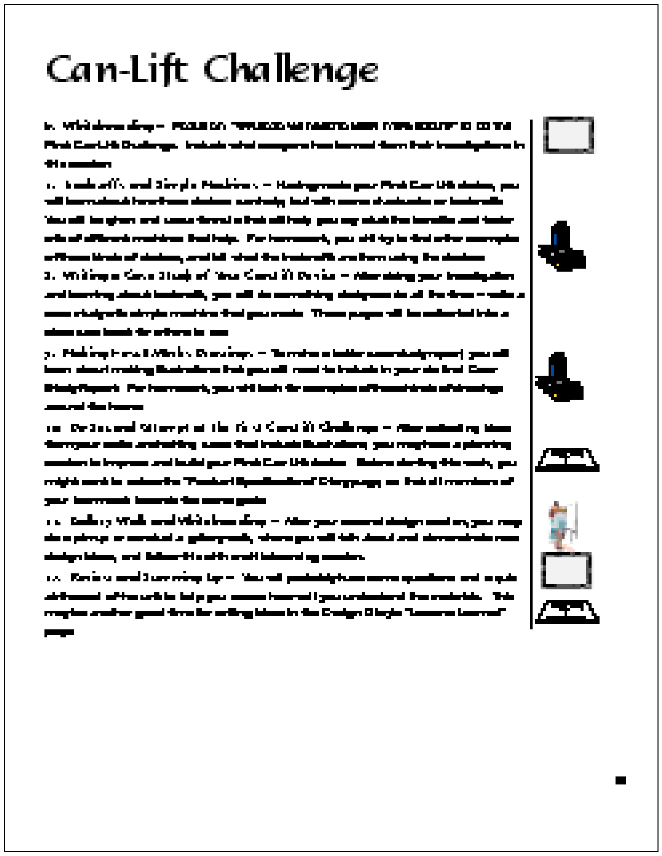

Addressing the First

Choosing and Building Your First Can-Lift Device

Overview

"Addressing the First Can-Lift Challenge" provides students with an overview of activities they will do in Section 1 of *Machines That Help*. Have students read over the recommended steps for achieving the first challenge. For each step, some instructions and/or pointers are provided, along with recommendations when to use pages from the Design Diary.

0.5 Periods

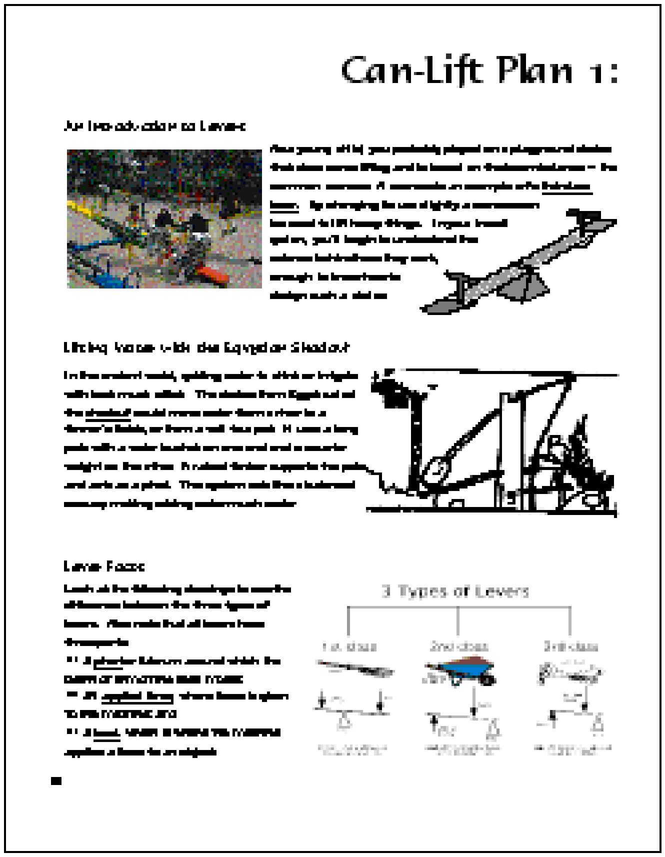

Can-Lift Challenge

Teaching Hints and Research Notes

These pages of procedures perform two functions: give an overview to students of what the unit will be and feel like, and offer suggestions and guidance for how student will be doing the activities. Spend only a short time going over the procedures for now -- there's no need for students to understand everything about every step. They simply need to get the gist of how it all fits together.

> Section 1's activities has students do the following: (Steps 1-2) reading and describing in their own language the challenge for Section 1, and noting those initial ideas in a Whiteboarding session; (Steps 3-6) building one of four devices, improving it and reporting what gets learned in a gallery walk and updating the Whiteboard; (Steps 7-9) learning about trade-offs and simple machines, how to write a case-study report a simple machine, and how to do illustrations for that report; and finally (Steps 10-12) improving on the design, reporting and recording what is learned and doing questions at the end of Section 1.

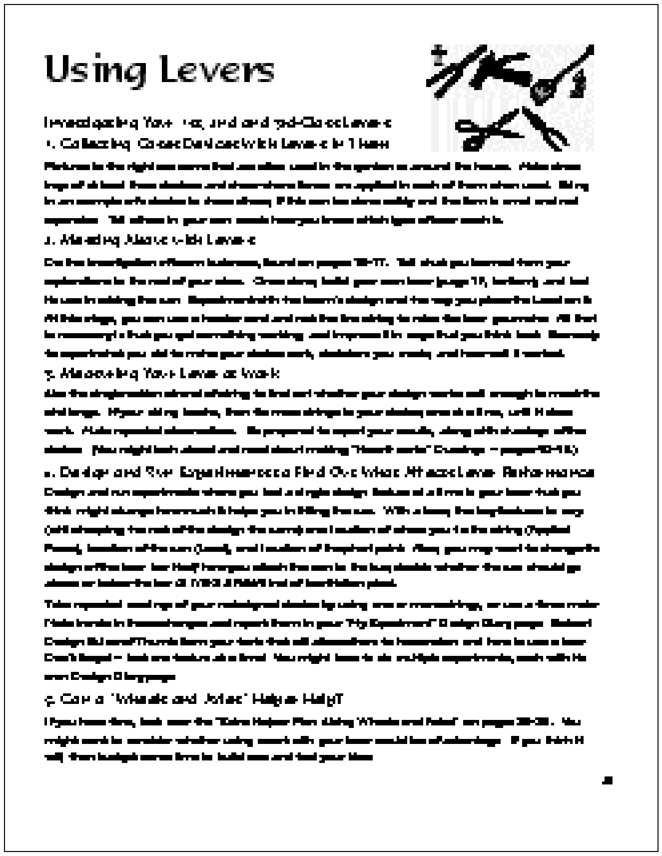
Can-Lift Plan 1: Using Levers



Overview

This activity introduces students who choose to build them to levers – by describing a familiar case (see-saw), a case from history (a level called a shadouf that was used for raising water), and a pictorial description of the three classes of levers. Students read about three key terms related to levers: Applied Force, Load and Pivot. Page 15 details the sequence of activities for an investigation of levers, and first attempt of using levers to address the Can-Lift challenge. The second half of the activity (pages 16-17) offers suggestions of things to do to investigate levels via a beam balance, where the notion of Torque = Force X Distance from Pivot can be learned and practiced.

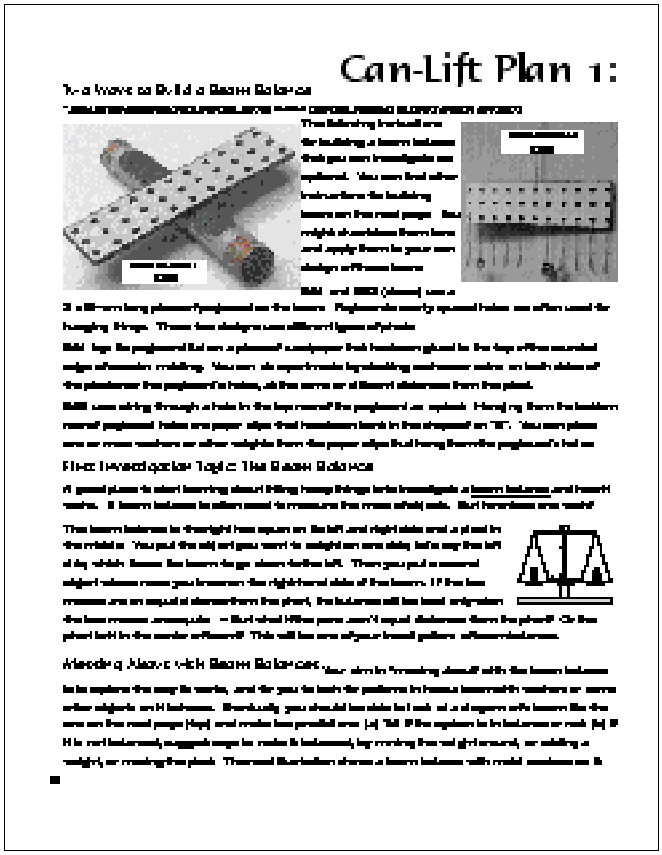
2-3 Periods



Teaching Hints and Research Notes

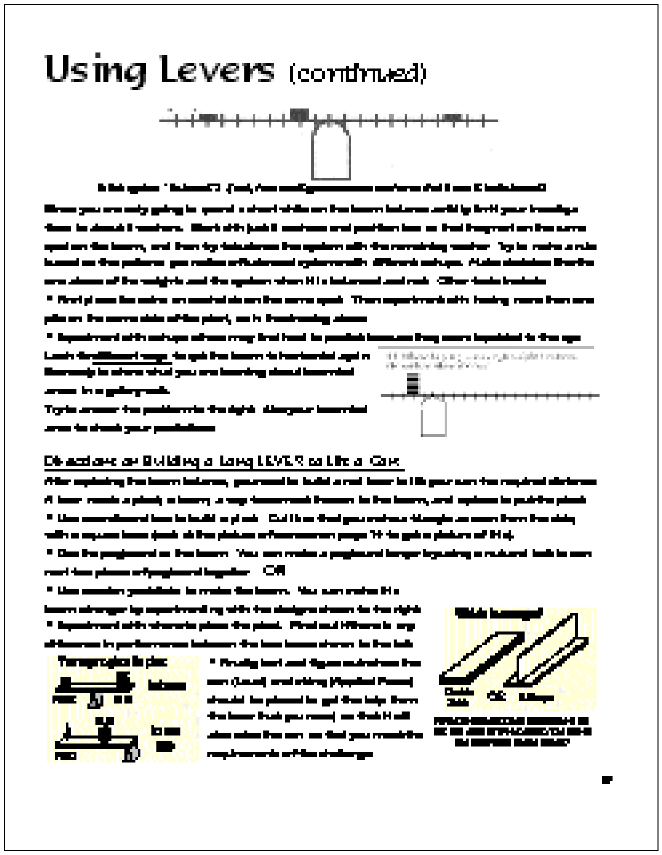
You might begin this class by having students read over the four different devices that they can choose to build for their first Can-Lift device. Teams then must make decisions of what they will do for the first days of their work. Remind students that in the end they are responsible for either *using* all the types of devices described in the unit – levers, ramps, pulleys and windlasses – or by *learning from others* about these products.

Suggest to students that teams studying levers should be able to report on many cases involving this simple device. Investigations using the beam balance could continue for weeks – you want to get students to use the appropriate formula for determining if the beam is in balance or not. Investigating with just a few weights and the middle of the board placed over the pivot. Using washers placed over the pre-measured holes in pegboard can speed things up. Students should be able to make the following basic prediction – is the board going to be balanced or not.


Can-Lift Plan 1:

Suggest that students doing the lever investigations keep notes and especially diagrams of the different board configurations that they test during their "messing about" phase. Suggest that they show interesting cases for their gallery walk when they talk about what they learned about levers, how they work, and how to predict whether they are in balance or not.

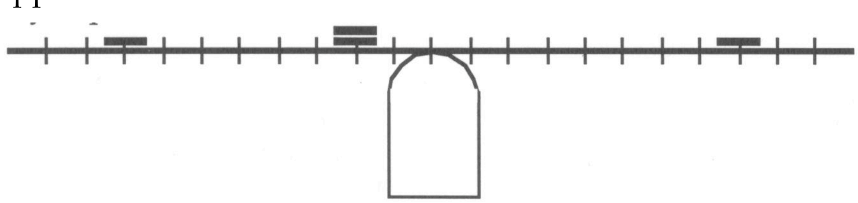
One problem students have with the balance beam involves the "zero out" problem. As with much instrumented observations in science, as well as taking your weight on a bathroom scale, you have to make sure that before taking a reading that your machine reads "Zero." Even though the sandpaper that is glued or taped to the wooden molding that acts as a pivot, the pegboard can easily shift and not be balanced before placing the washers on it, or suspending washers from the paper-clip hooks. Students should regularly check that their beam is balanced before beginning a new configuration. (Notice that the number of paper clips in the upper right-hand figure on page 16 has an equal number of clips to the left and right of the pivot.)



Using Levers (continued)

The key relationship between weights on a beam show a trade-off between the size of the mass and the distance from the fulcrum. The formula for torque [Torque = Force X Distance of Lever Arm] is similar to that for work (Work = Force X Distance Traveled). Students encounter the latter on pages 36 and 53.

An application of this formula can be seen below.



❒ Put check if system is balanced. If not, circle where to put one washer to make it so.

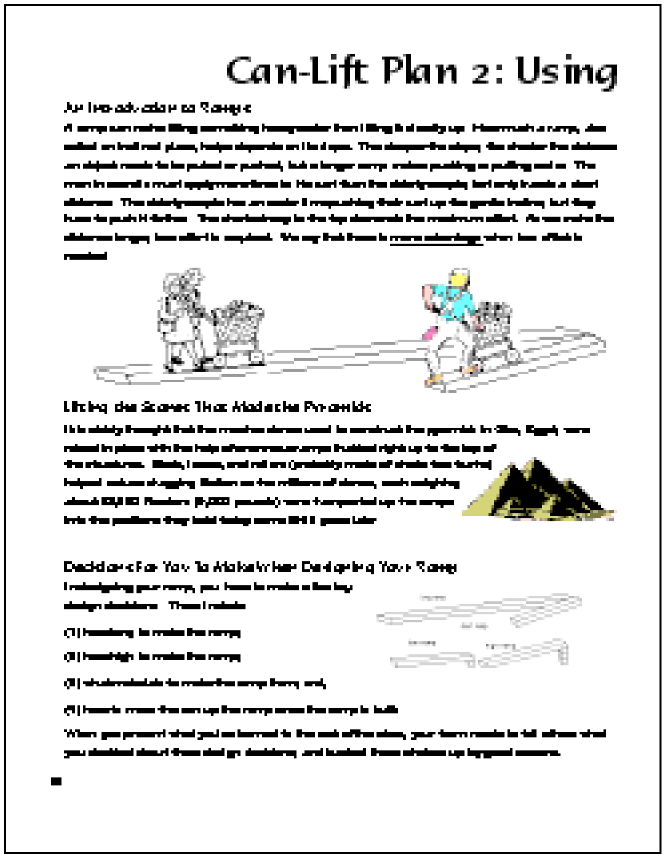
Each washer causes a torque, expressed as the (# of washers) X (distance from the pivot). The torques for Left washers equal the torques to the Right for the beam to be balance. The configuration above has on the left: (1 washer X 8″) + (2 Washers X 2″) = 12 W-Inches. To the right, you have 1W X 8″. You have to move one of the two washers over 4″ to balance the system: 10 W-Inch = 10 W-Inch.

Planning for the Activity & Materials Needed

As was indicated in the Introduction to *Machines That Help* essay in these Teacher Materials, you will be gathering lots of materials so that the design teams can choose and work on one of four different designs – these are the materials needed for building a beam balance for the investigations on pages 16-17, and the beam for a longer lever, described at the bottom of page 17.

1 per team	3 x 35-cm long piece of pegboard
1 per team	30-cm long piece of handle moulding, with sandpaper glued to the top
1 per class	Box of paper clips
1 per team	8-10 1/4″ washers (in a plastic bag)
2 per team	Wooden yardsticks (or meter sticks)
2 per class	Low-temperature glue guns (with glue sticks)
1 per team	Cord or kite string, 1 meter
1	Collection of cases of lever-based simple machines (scissors, pliers, crowbar, nail clippers, toothbrush, flyswatter, and so on)

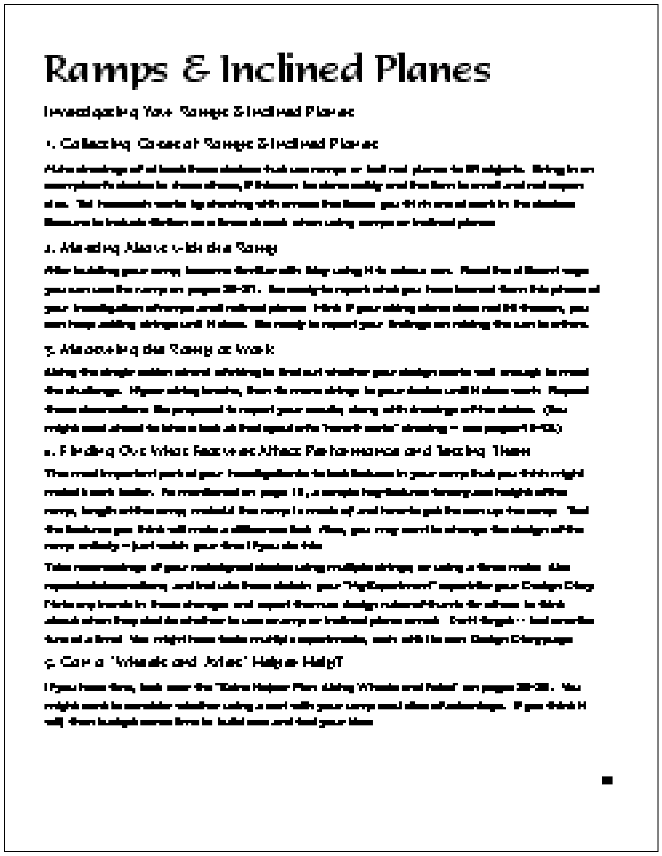
Can-Lift Plan 2: Using Ramps & Inclined Planes



Overview

This activity introduces students who choose to build them to the ramps and incline planes – by describing a familiar case (a short and long ramp), a case from history (the probable use of ramps for raising the stones that make the Pyramid), and a pictorial description of the key things you can vary when designing with ramps. Page 19 details the sequence of activities for an investigation of ramps and inclined planes, and a first attempt at using them to address the Can-Lift challenge. The second half of the activity (pages 20-21) gives instructions for constructing two kinds of ramps, and offers suggestion for how to get a can to go up a ramp, while using less force than is needed to lift it directly up, against the force of gravity. Students will have time to build and use the Coaster Car with their ramps.

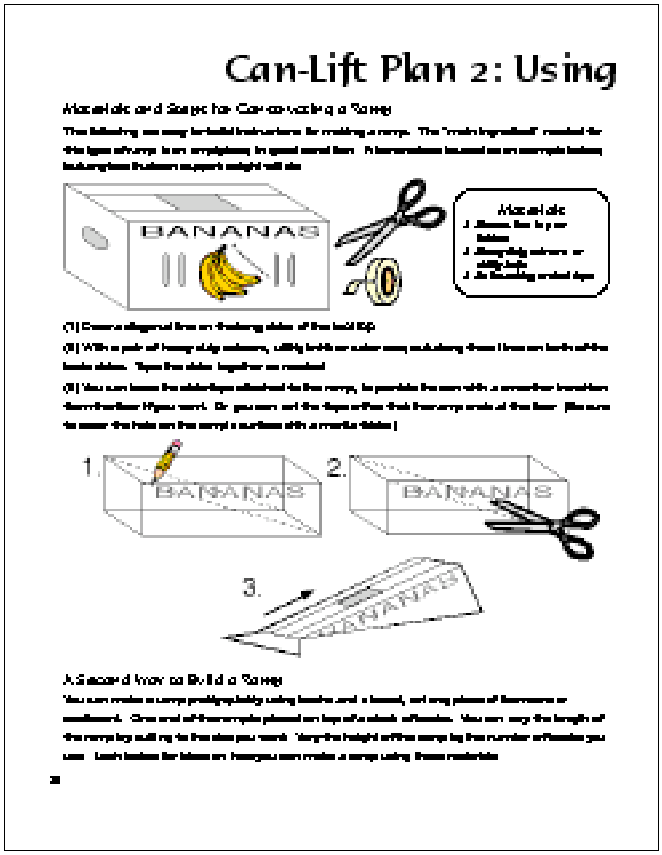
2-3 Periods


Ramps & Inclined Planes

Teaching Hints and Research Notes

You might begin this class by having students read over the four different devices that they can choose to build for their first Can-Lift device. Teams then must make decisions of what they will do for the first days of their work. Remind students that in the end they are responsible for either *using* all the types of devices described in the unit – levers, ramps, pulleys and windlasses – or by *learning from others* about these products.

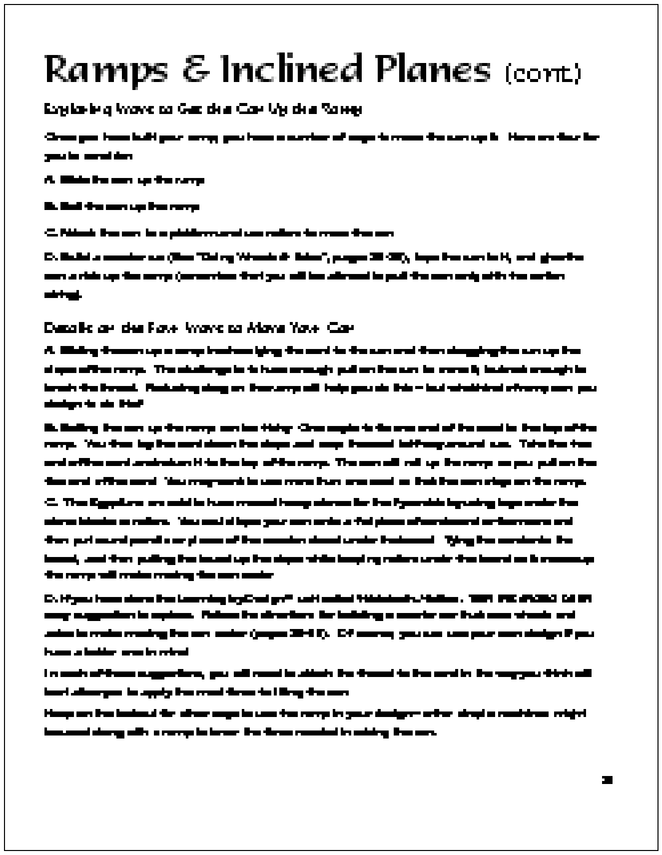
Suggest to students that teams studying ramps should be able to report at least a few cases from their everyday lives involving this simple device. Investigations using the ramps should not take that much time to conduct – although getting a system where the can rolls or is slid or carried up the ramp might take some revising and refining.



Can-Lift Plan 2: Using

Suggest that students might be more successful doing experiments by first using the "Second Way to Build a Ramp" for initial experiments. It is far easier to vary the key parameter – how high the ramp goes – than when using the banana-box approach. Once a height and length of ramp has been decided upon, then the banana box may be employed.

The key relationship that students need to learn with ramps involves the Work formula, which students will encounter formally on pages 36 and 53. The work done in traveling up a ramp, no matter what the slope, is going to be the same. Use the large font / small font distinction to show the qualitative relationships between Force and Distance traveled. For a steep ramp you would have Force X Distance being equal to the reverse for a gently sloped ramp = Force X Distance. Students studying ramps should be able to use this concept to defend their own design decisions, as well as apply it to other designs involving inclined planes.

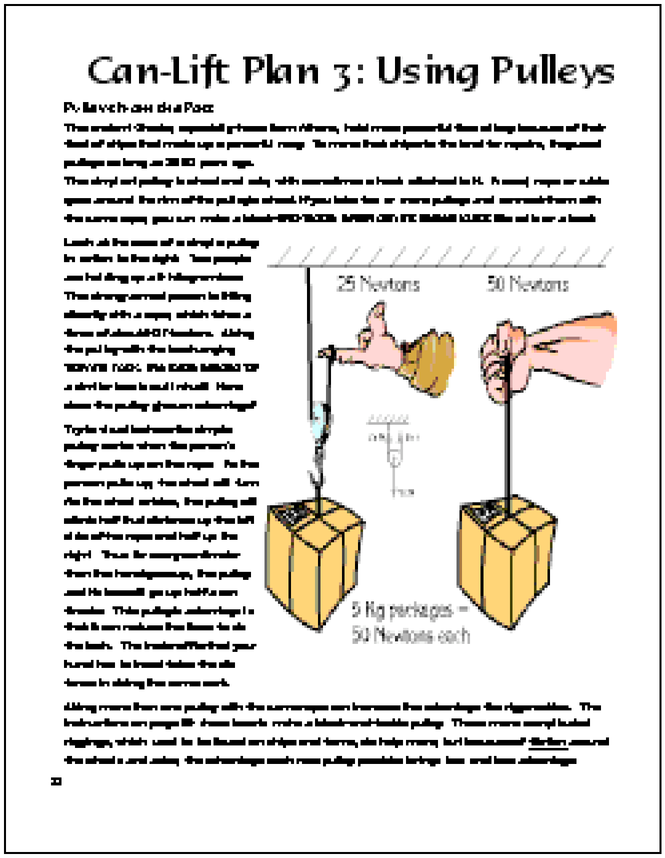

Ramps & Inclined Planes (cont)

Planning for the Activity & Materials Needed

As was indicated in the Introduction to *Machines That Help* essay in these Teacher Materials, you will be gathering lots of materials so that the design teams can choose and work on one of four different designs – these are the materials needed for building a ramp for the investigations on pages 20-21.

1	(opt. demo)	Door stop, wedge for splitting lumber
1	per team	Cardboard box, lid or bottom (banana box, box for copy paper)
2	per team	Lumber 2x4", lengths between 1 and 3'
1	per class	Roll masking or duct tape
1	per team	Heavy-duty scissors
1	per team	Cord or kite string, 1 meter

Can-Lift Plan 3: Using Pulleys & Block-and-Tackle

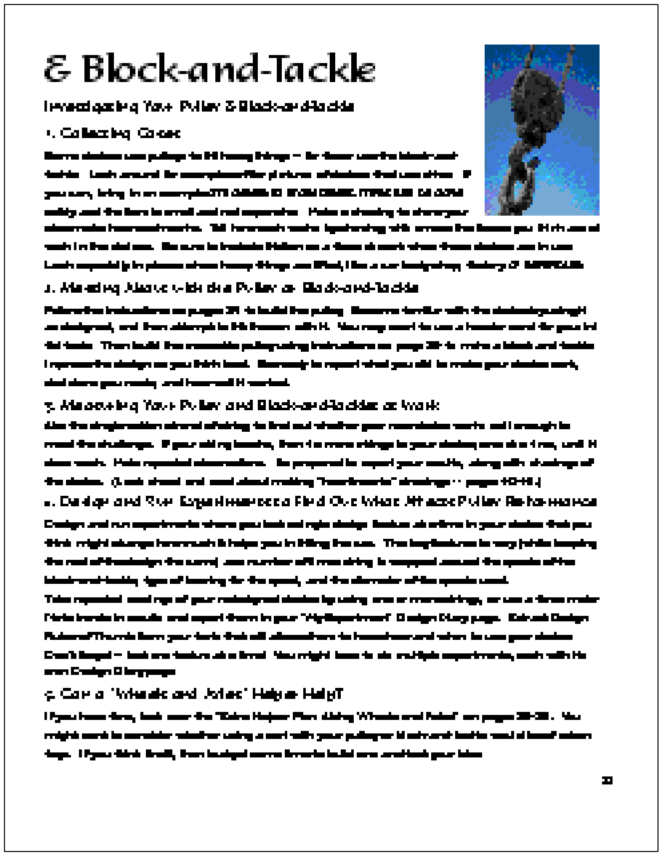


Can-Lift Plan 3: Using Pulleys

Overview

This activity introduces students who choose to build them to the moveable pulleys and block-and-tackle arrangements. It first describing a case of these devices used in history (Greek naval superiority and its ships), and a graphic that attempts to illustrate how the simple moveable pulley helps by cutting force required to lift something in half. Page 23 details the sequence of activities for an investigation of the pulley and block-and-tackle, and a first attempt at using them to address the Can-Lift challenge. The second half of the activity (pages 24-25) gives instructions for constructing a simple pulley, and then a block-and-tackle, which uses the pulley just build in its more complex arrangement.

2-3 Periods

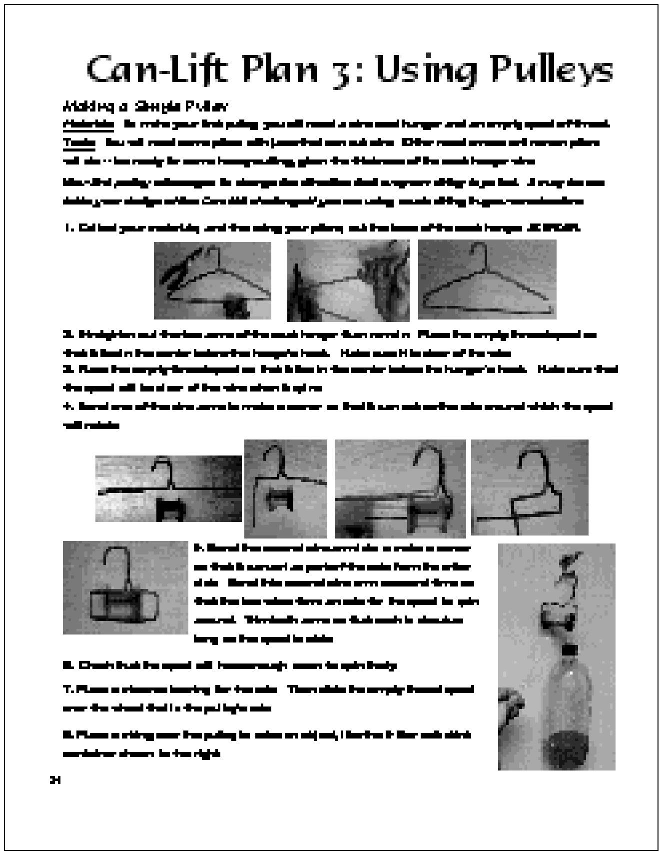


& Block-and-Tackle

Teaching Hints and Research Notes

You might begin this class by having students read over the four different devices that they can choose to build for their first Can-Lift device. Teams then must make decisions of what they will do for the first days of their work. Remind students that in the end they are responsible for either *using* all the types of devices described in the unit – levers, ramps, pulleys and windlasses – or by *learning from others* about these products.

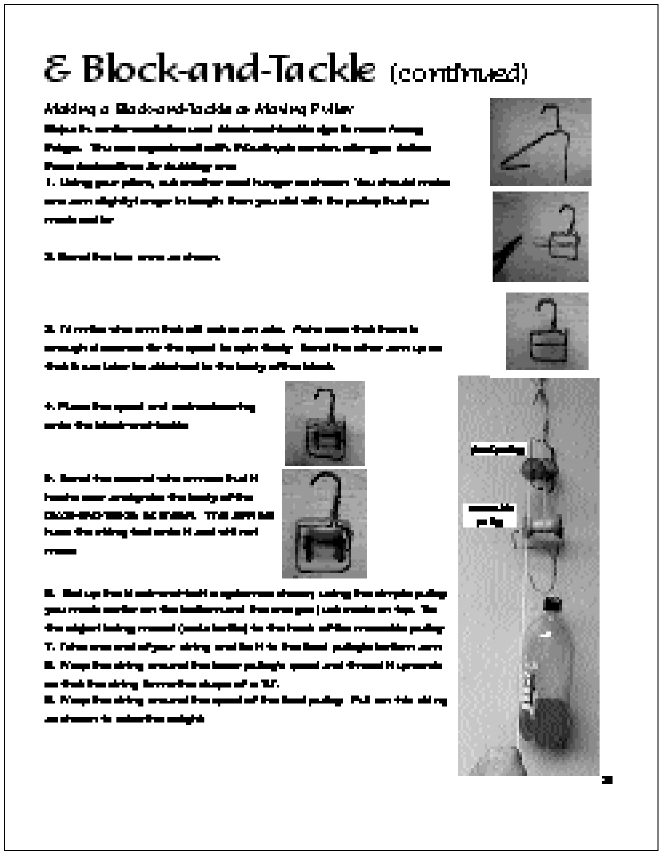
Suggest to students that teams studying pulleys should be able to report at least a few cases from their everyday lives involving this simple device. Lots of investigation time regarding these two devices will be spent getting the devices to work properly. A poorly constructed block-and-tackle will produce so much internal friction that any advantage it might have offered will get lost in the internal drag that a poor bearing system or poorly wound string might produce.


Can-Lift Plan 3: Using Pulleys

Making a Simple Pulley

Suggest that students might be more successful doing the constructions in the order presented. They will need the pulley whose building instructions appear on page 24 in order to complete the block-and-tackle described on page 25. The key parameters to vary in the pulley – how many times the string is wrapped around the spools and how much frictions the devices generate when used – need to be explored thoroughly during the investigations.

The key relationship that students need to learn with ramps involves the Work formula, which students will encounter formally on pages 36 and 53. The more times the cord goes around the pulleys, the more distance the cord needs to be pulled to raise the load up a given distance. More importantly though, the more times you wrap around the pulley and block-and-tackle, the more friction will be generated. Use the large font / small font distinction to show the qualitative relationships between Force and Distance traveled.



& Block-and-Tackle (continued)

Making a Block-and-Tackle or Moving Pulley

The simple pulley shown on page 22 would have the load being raised by a large force going a small distance -- Force X Distance – while the user is pulling a long distance with less force = Force X Distance. Students studying ramps should be able to use this concept to defend their own design decisions, as well as apply it to other designs involving inclined planes.

Planning for the Activity & Materials Needed

As was said in the Introduction to *Machines That Help* essay in these Teacher Materials, you need to gather lots of materials for the initial construction activities of Section 1– these are materials needed for building a pulley and block-and-tackle:

1 (opt. demo)	Pulley, come-along, block-and-tackle
1 per team	Plastic straw, large [slide over wire axle]
2 per team	wire coat hangers
2 per team	empty wooden thread spools
1 per team	Cord or kite string, 1 meter
1 per 2 teams	Pliers: lineman and needle-nose pliers