SMALLab Learning

Lifting Gears Game – FLOW Teacher Guide

Grade Levels: 4th through Adult

Learning Goals: In this scenario paired gears turn in both directions as students learn about the effects of gear diameter on input and output distance, input vs. output force, work, and mechanical advantage.

Duration: Each pair of students should be allowed up to 4 or 5 minutes with the game to fully understand the subtleties. Go through the game sequence until all students can explain the choices they are making and why things happen in terms of gear diameter, input force and output force.

Prerequisite: Students must have gone through the Gear Size Explorer and Gear Ratio Game so that they understand the mechanics of how the right hand must orbit the shoulder joint.

Common Core Standards:
Relevant Common Core Math Standards (7th & 8th grade):

- developing understanding of and applying proportional relationships
- developing understanding of operations with rational numbers and working with expressions and linear equations
- formulating and reasoning about expressions and equations
- grasping the concept of a function and using functions to describe quantitative relationships

Representative National Science Education Standards (grades 5 – 8):

Physical Science: Content Standard B:
- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.
- Energy is a property of many substances & is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
- Examine forces and motion through investigations using simple machines (e.g., wedge, plane, wheel and axle, pulley, and lever).

Science and Technology: Standard E
- Abilities of technological design
- Understandings about science and technology

Deeper Competencies:

- Graphing
- Representational Fluency
- Proportional Reasoning
- Systems-thinking
- Positive attitudes toward science

How is this embodied and/or socio-collaborative? It is embodied because the gesture of cranking or circling with the arm determines the direction and speed of the input gear. Collaborative because pairs of students are competing; in addition, peers are encouraged to give guidance to the students who are actively winching. It is not intuitive that a smaller gear is needed for a larger boulder. Often, the students who are observing realize this before the active students and the shared cognition is a breakthrough moment.

Section	Action	Teacher
Introduction	The interface	Tell your students – Now we will play the big game that the Gear Size Explore and Gear Ratio Game got you ready for. Let's look at the interface first.
Start simple with only most relevant components	You have control over which components are present at each stage. Press **Ctrl-C** to open the configuration panel. Click on 'Show Upper Data' to start with 'Weight Lifted' and 'Total Boulders Lifted' on the screen. 'Show Gear Data' will give you the size of the gears. Also in the configuration panel you can adjust the 'Lift Force' for each player.	As you will see, the main goal is to lift the moving boulders from the mine below and get them onto the conveyor belt up on top. You get points for every boulder lifted. Next to the 'Total Boulders Lifted' score is the cumulative 'Weight Lifted' amount. Greatest cumulative weight wins. You can think of the connector as being a magnet that is able to attach to the iron ore boulder, but you must use your strength to winch it up. To raise and lower your winch, circle your arm clockwise and counterclockwise. Keep in mind that player actions are opposite! The connector turns red when it's carrying a load. You only have so much input force to do this and so you will see that you need to adjust the gear size to maximize your strength and make sure you can hold out the entire round. Let's discuss the difference between input and output force.
	Pick or ask for two volunteers Press space bar to start or use a remote clicker.	I need two students to try this. The first students have it the roughest because I am not going to tell them any of the tricks. But, I will let you two brave ones come up again at the end, so you can use what you have learned from watching others. When I say 'go,' a timer will start. Your goal is to lift as many boulders you can in 60 seconds. **Go.**
	Start Game Analyze during and afterwards	What are some of the tricks? If you want to bring the magnet down as fast as possible, what would you do with the input gear – would you make it smaller or larger? Do you have to turn it in a specific direction? (*Let them discover*.) Which boulders are harder to lift?

		What do you see happening when you try to pick up a larger boulder?
	Ctrl-C to open the configuration panel and click on 'Show Force Data' to show 'Max Input Force' and 'Max Output Force' on the screen.	Let's look at some more of the components that we can alter. Now I will display for you: *Input force and* *Output force* Let's revisit these terms and see what happens when I change them on the configuration panel. Should I change the time of the game, or do you like it at 60 seconds? It can last for up to two minutes.
	Gear Ratio In the configuration panel (**Ctrl-C**) you can adjust: Lift Force for each player Round Time Minimum Weight (of boulders) Maximum Weight (of boulders)	We need to also focus on **gear ratio**. What does that mean? Watch and see which ratio is optimal for the large boulder. What have we discovered? What is the relationship between the size of the input gear and the weight of the rock you can lift? Why might this be? Let's count the number of revolutions on the output gear as it turns…
	Input and Output	A distinction needs to be made between the input and output side of the equation. Ask the class: Where is the input? How do we measure force here? How do we measure distance? The number of times it spins fully around? Now let's look at the output. Which gear is that again? How do we measure force here? How do we measure distance? Will these two be equal or not? Why?
	Mechanical Advantage and Work	The factor by which the input force is multiplied when you use a machine to do work is called **mechanical advantage.** A machine's mechanical advantage is the ratio of output force to input force.

	Since there are two forces and two distances in the picture and all are measured very differently, it is important to be very clear about each one.	Since work is the product of force and distance, you would calculate the **work** done by multiplying the weight lifted (recall that weight is simply a force in the downward direction) by the distance it has been lifted. The input work would be the force applied by you (the student) as you crank the gear, times the distance (or number of times) that the marker on the outer edge of the gear has been moved. Input work is the product of input force and input distance. The distance is measured by determining the path length on the outer edge of the gear. The output work is the product of the weight of the boulder (which is a force in the downward direction) and the distance the boulder has been moved. Or in this case, the height the boulder has been lifted as well…
		Because we are playing a game, we need to maximize ALL our time and energy in the game. You figured out how to get a big boulders up – how will you bring the empty magnet down in the most efficient way possible? Put these two components together to see which team can winch the most boulders up in the shortest time.
		Great, let's see who can be a master at the game. Let's write down top scores… compare.

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