# Le Tour de Force – FLOW Teacher's Guide

**Grade Levels**: $6^{th}$ through College

**Learning Goals**:

1. Understand the effects of input gear diameter on output gear force in terms of distance covered and speed (revolutions per second), input vs. output force, work.
2. Understand energy interactions in terms of transfer and storage.
3. Develop the concept of work as a mechanism for energy transfer.
4. Identify system of interest for energy transfer.
5. Apply concept of conservation of energy.
6. Define and show comprehension of the following two concepts (all students expected to present on a picture/animation of their choosing from their own environment):
   a) Power (*the rate at which energy is transferred*) and
   b) Mechanical advantage (*the factor by which the input force is multiplied by the use of a machine to transfer energy*).

**Duration:** This game only: one to two days depending on number in class.

**Prerequisite**: Students should have experienced **Gear Size Explorer** first.

**Standards:** Next Generation Science Standards:
Core and Component Ideas:

PS2.A: Forces and Motion
PS3.A: Definitions of Energy
PS3.B: Conservation Of Energy and Energy Transfer
PS3.C: Relationship between Energy and Forces
PS3.D: Energy in Chemical Processes and Everyday Life

Crosscutting Concepts
Patterns
Cause and Effect: Mechanism and Explanation
Systems and System Models
Energy and Matter: Flows, Cycles, and Conservation
Science and Engineering Practices
Asking Questions and Defining Problems
Developing and Using Models
Planning and Carrying Out Investigations
Analyzing and Interpreting Data
Using Mathematics, Information and Computer Technology, and Computational Thinking
Constructing Explanations and Designing Solutions
Engaging in Argument from Evidence
Obtaining, Evaluating, and Communicating Information
Standards for Mathematical Practice

Make sense of problems and persevere in solving them
Reason abstractly and quantitatively
Construct viable arguments and critique the reasoning of others
Model with mathematics
Use appropriate tools strategically
Look for and make use of structure

Mathematics Content Standards
Ratios and Proportional Relationships
Expressions and Equations
Functions

**How is this embodied and/or socio-collaborative?** It is embodied because the students must move their arms to simulate the diameter and motion of a gear. It social because students are competing against one another to win – it can be collaborative if the teacher sets up teams to give advice on which gear size to use to get to the end of the course first.

| Section | Action | Teacher |
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| Introduction | The interface | Ask for volunteers or designate two students to come to the front and stand approximately eight feet in front of the *Kinect* camera.<br><br>They should have gone through Gear Size Explorer first. It is important to figure out where is the pivot point is –<br>The shoulder that the hand must circle around is the pivot. |
| | Explore the interface | Question students in the space:<br>If you stand here and start swinging your arm what happens?<br><br>Where is the pivot?<br><br>Yes, the shoulder is the fixed point and the hand makes the gear spin. The top bike is the player on the left. The bottom bike is the player on the right.<br><br>The gear you are turning is called the "input gear." You are able to change its size. The other one, the gear on the rear wheel, is called the "output gear." Its size is fixed and cannot be changed. |
| | Input and Output Gear | Now let's explore the relationship between the rate at which the output gear turns and the size of the input gear.<br><br>Notice the rate at which the output gear turns when I make the input gear small.<br><br>When you make input gear larger, what do you notice about the rate at which the output gear turns? |

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| | | Can you come up with a general rule about the relationship of size of the input gear to the rate at which the input gear turns? |
| | Explore the text onscreen<br><br>**Input force**<br>**Required force**<br>**Output force** | Let's discuss some of these numbers now.<br>What do you think the numbers on the gears mean?<br><br>This could mean anything metric, but for now think of it as the diameter from the edge of one sprocket to the other sprocket all the way across the gear. Perhaps in this case it could be decimeters in diameter.<br><br>**Input force –** This is the amount of force your hand is exerting on the bicycle's pedal, which is attached to the input gear seen here as 1 N or one newton.<br><br>**Required force –** This is the force required that is needed in order for the bicycle to keep going forward.<br><br>**Output force –** This is the force the output gear (which is attached to the rear wheel) is now exerting on the ground to keep the bike moving forward.<br><br>**Gear ratio** – A ratio of the output to the input gear, this represents the mechanical advantage of this gear system. I to O.<br><br>Is a mechanical advantage of $\frac{1}{2}$ going to produce a faster or slower speed than a mechanical advantage of $\frac{4}{5}$? |
| | Other terms to discuss<br><br><br><br><br><br><br>Input Force X<br>Input Distance<br>= **Work**<br><br><br><br>**Weight** is a Force in the downward direction. | What does km/h mean?<br><br>What does RPM mean?<br><br>One revolution of the output gear corresponds to one revolution of the rear wheel. How far will the bike have traveled when the output gear has made one complete revolution? (A distance equivalent to the circumference of the wheel).<br><br>Riding a bicycle requires energy. Energy is transferred from the rider by means of a process called **Work**, which is the product of the Input Force times the Input Distance travelled (the hand is traveling around a path that is defined by the circumference of the input gear).<br><br>What is the output work? The result of the work done is that the **Weight** of the bicycle is moved some distance which is determined by the number of revolutions of the output gear. |

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| Playing the game | | Let's see if we can figure out the minimum revolutions per minute needed to keep the bicycle moving forward on a flat surface with a small input gear. Now with a larger input gear.<br><br>How would this be different if the bike were moving up a moderate hill?<br><br>More energy would be required because the bicycle must not only be moved forward but also moved up—that is, lifted against gravity.<br><br>Play with gear size on this hill to see how the gear size affects your speed – given the constrained amount of input force your hand is able to generate (Note: that is  fixed quantity that is configured in the config panel).<br><br>What happens when you alter the force that can be applied to the pedals – what does this correspond to?<br><br>A gold trophy signifies the winner. |
| Charting a course | Press **Ctrl-C** to open the config panel<br><br>At the bottom of guide is a pasted example. | You can create new configuration files for this game and save them in a newly named file. Below we describe the default file.<br><br>The first variable that can be altered is pedal force, the default = 10 N.<br><br>Then next configurable variable is the weight of the bicycle.<br><br>The default = 1 bicycle-weight.<br><br>Next, you can alter the length of the course by positioning a number of waypoints. The positions of these waypoints are set in both the horizontal and vertical dimensions.<br><br>For example, setting an X-value of 27 and a Y-value of 2 means that the first waypoint is 27 units from the origin and 2 units in vertical elevation. This means that the cyclist is going up a gentle hill.<br><br>The default number of waypoints is 16, but you can add and delete waypoints to customize your journey. |
| | Waypoint alteration **and opportunity for students to graph** | Waypoints are sequential.<br><br>Again, waypoint positions define an X and Y position for a point on the course with respect to a starting position situated at the point of origin, (0, 0). |

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| | | A waypoint at (10, 1) is 10 meters to the right of the starting point, and 1 meter higher in elevation. Each consecutive waypoint must be greater in distance from the previous waypoint.<br>For example, a second waypoint could be added at (20, 1) in order to generate a flat section on the course. However, a second waypoint at (8, 1) would be invalid because it would be to the left of the first point.<br><br>A waypoint at 20, 7 would be where? Higher or lower than a 20, 2 waypoint?<br><br>Get students to think through how the coordinates work. |
| Student Challenges | Team design of course | You can split your class into teams and have them design race courses for others to play.<br><br>First, have the students draw out what they would like a course to look like. Then get them to think through the coordinates before they configure the routes for the other team to play! Based on what they know about gear size and its relationship to speed, require them to design a course that is not impossible given the input force specified in the system configuration.<br><br>Alternatively, give students maximum parameters (length and elevation) that the course must satisfy and then challenge them to build the fastest possible course that meets these design specifications.<br><br>Explore the variables of input force and bicycle weight (output force) as well. |

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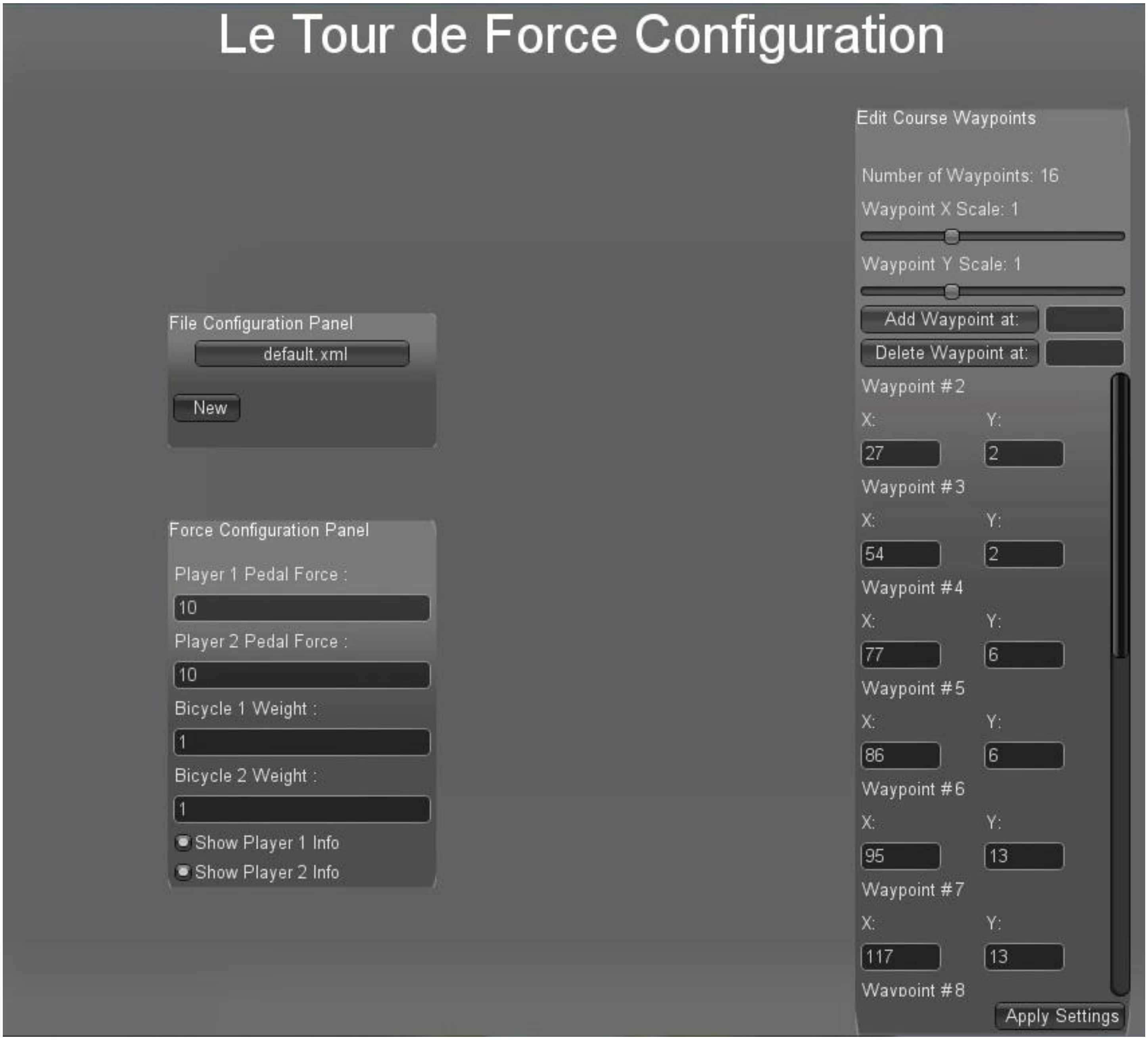
Le Tour de Force Configuration
File Configuration Panel
default.xml
New
Force Configuration Panel
Player 1 Pedal Force :
10
Player 2 Pedal Force :
10
Bicycle 1 Weight :
1
Bicycle 2 Weight :
1
Show Player 1 Info
Show Player 2 Info
Edit Course Waypoints
Number of Waypoints: 16
Waypoint X Scale: 1
Waypoint Y Scale: 1
Add Waypoint at:
Delete Waypoint at:
Waypoint #2
X: 27 Y: 2
Waypoint #3
X: 54 Y: 2
Waypoint #4
X: 77 Y: 6
Waypoint #5
X: 86 Y: 6
Waypoint #6
X: 95 Y: 13
Waypoint #7
X: 117 Y: 13
Waypoint #8
Apply Settings