MIND TREKKERS
Moment of Inertia Spinner Lesson Plan

**Amount of time Demo takes:** 1-2 min

**Materials:**
1. Spinning plate
2. Weights (or water bottles to use as weights)
3. Bike wheel(s)

**Set up instructions:**
1. Find an open area to place spinner, so a person can hold their arms straight out and not hit anything.
2. To draw people over, demonstrate. Stand on plate, have someone give you a spin, and use the weights to change your moment of inertia. Hold the weights close to your body to speed up then hold them out far away from your body to slow down.

**SAFETY!**
1. Give instructions before they start, how to make it go faster and slower. Make sure they hold onto weights tightly, and that the area is clear around them while spinning.
2. If it is a smaller or younger student, have them sit on spinner.
3. Tell participants to let you know when they want to stop.
4. To help them stop, you can put your foot on the disc. Try to only touch shoulders, arms, and hands when assisting. Help them off spinning disk.

**Lesson’s big idea**
- A demonstration of the conservation in angular momentum when the moment of inertia of a spinning object changes.

**Instructional Procedure**
After reviewing how it works and necessary safety, have the participant sit/stand on the spinner. Give them either the weights or the bike tire. Tell them to let you know when they want to stop.

1. **For the weights/arms:** Explain that when you start them spinning with their arms out, if they bring their arms in they will speed up. If they want to slow down, they can put their arms out again and control their speed. When they want to stop put your foot on the plate and softly slow plate down.
2. **For the bike tire:** Have the participant hold onto the bars on either side of the wheel and get it spinning. If they tilt the tire, they’ll rotate one way; if they tilt it the other way, they will find that their spinning is reversed. They are basically a giant human gyroscope - the angular momentum of the spinning tire pushes them to spin the opposite way.
Background Information

1. This is the same concept as how an ice skater controls their speed while spinning. They will start spinning with their arms and one leg extended, and it will be a slower rotation. As the skater brings their arms and leg in closer to their body they speed up.

2. Why does this work? There are a few different things going on in this demonstration.
   - A demonstration of the conservation in angular momentum when the moment of inertia of a spinning object changes.
   - **Newton’s First Law:** An object in motion will stay in motion unless something else acts on it. On the spinning plate, there is some friction that will (over time) stop the person from spinning. Your foot on the plate is also an opposing force that will change (in this case, stop) their motion.
   - When you start the person spinning you are applying **torque**. The harder you push or the farther from their center you push, the more torque you apply. Using more torque gives them a higher velocity and thus a higher angular momentum.
   - To have a large **moment of inertia**, the person can start spinning with their arms out. As the person draws their arms in moment of inertia will change, causing them to speed up in order to conserve momentum.
   - How fast you spin depends on your **mass** and how its distributed, which is your moment of inertia. When you put your arms out, more of your mass is farther away from your axis of rotation so you slow down. The closer all your mass is to the center of rotation, the faster you spin.

3. The math behind it:
The moment of inertia provides a measure of the difficulty of changing the rotational motion of a body. The conservation of angular momentum establishes that:

\[ I_i \omega_i = I_f \omega_f \]

\( I_i \) and \( I_f \) are the initial and final moments of inertia
\( \omega_i \) and \( \omega_f \) are the corresponding angular velocities.

The spinners arm’s are treated as a dumbbell, approximated as the moment of inertia of a mass at the end of a rod: \( I = mr^2 \), where \( r \) is the distance from the axis of rotation to the center of mass of the ends of the dumbbell; then

\[ \left( \frac{I_i}{I_f} \right)^2 = \left( \frac{\omega_f}{\omega_i} \right) \]


Assessment, sample questions you can ask:

1. Did you feel the change in speed as you brought the weight closer to your body?
2. Were you able to control your speed by where you held the weights?
3. Where do you see this concept in real world?
4. How is this similar to an ice skater spinning?

**Clean Up**
Gather the weights/wheels and pack everything away.

**References:**
http://btc.montana.edu/olympics/physbio/biomechanics/cam02.html

**National Standards:**
K-4 Content Standard B: Physical Science, Position and motion of objects
5-8 Content Standard B: Physical Science, Transfer of energy, Motions and forces
9-12 Content Standard B: Physical Science, Motions and forces, Interactions of energy and matter