Title of Session: May the Force be with You

Materials:

- Ping Pong Balls
- Flexible Straws
- Whacker™ with Stand
- Golf balls
- Foam Balls
- Rubber Balls
- 2 Protractors
- Meter Sticks
- Index Cards
- String
- Balloons
- Paper Clips
- Small Washers
- Regular Straws
- Masking Tape

Overview and Rationale:
Participants will use a straw and the force of their own breath to try to move a ball across the table as a partner tries to blow the same ball in the opposite direction. They will use a Whacker™ as a force to move two balls of differing masses, observing qualitatively, the acceleration of each ball as it is hit by the Whacker™ and apply Newton’s Second Law to the acceleration of the balls. Through a demonstration, participants will see how the formula F=ma explained first, by looking at the inverse proportional relationship and then by plugging in numbers and working through some simple problems. Balloon rockets will also be made using a string, index cards, and some washers. They will be able to change the force (number of balloons) of the rocket or the mass of the rocket (adding washers) to see how either changes the acceleration of the rocket. Finally, participants will look at data on graphs to evaluate how acceleration changes due to changes in force or mass.

Science Standards:
- Science as inquiry
- Physical Science – Motion and Forces
- Science and Technology
- Unifying Concepts and Processes

Science Process Skills:
- Observing
- Communicating
- Interpreting Data
- Measuring
- Making Graphs
- Collecting Data
- Identifying and Controlling Variables
- Inferring
- Investigating
- Predicting
Mathematics Standards:
- Mathematics as Problem Solving
- Mathematics as Communication
- Mathematics As Reasoning
- Patterns and Relationships
- Mathematical Connections
- Measurement
- Patterns and Relationships
- Reasoning and Proof

Key Vocabulary Terms to Develop and Use:
- Newton’s Second Law of Motion
- Acceleration
- Velocity
- Mass
- Force
- Net force

Important Scientific and Pedagogical Ideas:

Newton’s Second Law of Motion
Any net force acting on an object will change its motion; this is acceleration. How much change there is depends on the object’s mass and the size of the resultant force.

Note: Remind participants what acceleration is at this point.

There is a formula for the second law: F=ma (force equals mass times acceleration).

Please note, this information is not given to the students prior to the lesson. It can be brought in during the explain section of the lesson. In elementary school it is difficult to do an activity to quantify the above formula. It is appropriate to make qualitative observations that apply to this law.

Note: It is important that the teacher knows that none of the background information should be given to the students at this point.

Engage:
Give each pair of participants one rubber ball and two flexible straws. Tell them that they will be exerting a force on the ball by blowing through the straw. Have them sit across from each other. One will blow through their straw and try to get the ball moving. Once the ball is moving, the other person will blow through their straw to get the ball moving in the opposite direction. Once both participants have had the chance to get the ball moving, they will try to get the ball to move while they are both blowing on through the straw. The objective is for each participant to get the ball to move to the opposite side of the table.

Explore:
Each group will need two Whackers™, and one set (2 balls of each type) of two types balls of distinctly different masses. (Since these observations are qualitative in nature, they do not have to find the mass of the balls.)
Ask the participants the following question:
If you apply the same force to two balls, of different masses, what will be the difference in acceleration?
Note: Acceleration, make certain that there is a clear understanding of the definition for the participants. (Net forces cause acceleration).

In their groups, have them discuss a hypothesis to the question. Arrange the Whackers™ side by side, on the same type of surface. Explain that they will be making qualitative observations of three different set ups. They may have to perform each set up several times to make their observations. During the explanation of the set up, have a Whacker™ set up to show how it is used. Pull the™ back to 90° and let go. Pull it back to 45°. Ask about the difference in the force at the bottom of the Whacker™ when the “arm” falls to the bottom. (There is greater force exerted at the bottom at 90° than at 45°)
Note: Make sure that the participants understand that the farther back the Whacker is pulled, the greater force it will exert at the bottom.

Setup #1
Take two of the same type of ball. Place a ball at the base of each Whacker™ (different balls). Pull one of the Whackers™ back to 45° and the other to 90°. Let go and observe how the balls accelerate off the Whackers™. Record observations.

Setup #2:
Take two different balls and place them at the base of each Whacker™. Pull both of the Whackers™ back to 90° and let go. Observe how each ball accelerates off the Whackers™. Record observations.

Setup #3:
Take two different balls and place them at the base of each Whacker™. This time they will try to get the two different balls to accelerate at the same rate. Record the strategy they used as well as any observations they have made.

Once all set ups have been completed, have participants make a claims and evidence chart in their notebooks. As a group, they need to make some claims about what happened during the set ups.

Explain:
Discuss the claims and evidences from the groups. Lead discussion based on claims and evidence to Newton’s Second Law (see Important Scientific and Pedagogical Ideas). Discuss each of the set-ups in the Explore. Have participants explain what they observed qualitatively and tie into F=ma. For example: The first set up, the balls are the same, the mass is the same, the forces applied are different. Since there is more force on one ball than the other, the acceleration of the ball off the Whacker with the greater force accelerates more off of the Whacker.

Discuss mass as the numerical measure of inertia. This is also a good time to discuss the difference between weight and mass.

Go back to the Engage, tie this back into Newton’s Second Law. When they blow harder through the straw, the ball accelerates more. If they switch the angle in which the air hits the ball, the ball will change direction (also acceleration). If both people are blowing on the ball at the same time with the same force, the ball doesn’t move, but if one person is blowing harder, the resulting net force will cause the ball to accelerate. The F in the F=ma refers to the net force acting on an object. Thus, an object with forces acting on it will only accelerate if the total force, taking into accounts both magnitude and direction of the acting forces, is nonzero.
Note: Help teachers with specific examples of how F=ma applies qualitatively to what was done in Explore.
Discuss the Engage activity in the context of Newton’s Second law. Keep in mind that the Engage is just another
Explore. If we don’t discuss it, then it was just a waste of time.

Do the following demonstration:

1. Newton’s second law deals with F=MA. When written A = F/M one sees that the acceleration will vary
directly with the force applied and inversely with the mass of the body.
2. Take three index cards and labeled A on one card, F on the second, and M on the third. Tape the F card to
a meter stick hanging down at the 50 cm mark. Tape the A card at 0 cm and the M card at 100 cm.
3. Explain that if the force is constant (either flip the F card up or cover it with your hand), when acceleration
increases (raise the 0 cm end of the meter stick at a 30 angle) mass must decrease.
4. Note that the 100 cm end now angles down. This shows an inverse proportional relationship.
5. Cover the acceleration card with your hand (or flip it up). When force or mass increases or decreases the
other variable will do the same. This shows the direct proportional relationship.
6. Lastly, do the same for the M card.
7. Use the meter stick to help visualize what the answer will be (greater or smaller). Finally brainstorm everyday
applications, some examples are listed below:
   a. kicking a soccer ball, the harder the kick, the faster the ball goes
   b. accelerating a car
   c. a loaded versus an unloaded pickup truck

Note: At this point, pass out Bill’s Mass and Weight article. Tell participants they should read the article and
relate it to the experiences we had today. The first step to be taken in the next session will be to discuss how
this article relates to today’s experiences.

Extend:
Each group of participants need: string, several balloons, 2 paper clips, non-bendy straw, washers. For set up see Stop
Faking It, Force and Motion, page 30. Point out here that wrapping the tape around the balloon doesn’t work as well
as double siding the masking tape and use that to stick the balloon to the card rather than attaching it to the card.
Have participants blow up their balloon and work to change the acceleration of their “rocket” by adding or
removing washers (this changes the mass) or adding or removing balloons (this changes the force) to the card. In
their notebooks, they need to explain what is happening in terms of Newton’s Second Law.

Evaluate:
Have participants look at the following graphs (one at a time). Discuss, and then explain, in terms of Newton’s
Second Law, what is happening in each of the graphs in their notebook.
See below each graph for an explanation and example.

This graph shows that with the addition of mass to an object, the acceleration decreases if the force remains the same.

For example, you are sitting in a wagon that is being pulled by a child. If the wagon is empty the child can pull it easily. If
a friend gets into the wagon and they begin to pull it with the same force as when the wagon was empty, it’s more difficult
to accelerate the wagon. If a second friend gets into the wagon, and the child pulls it with the same force as before, it’s
even more difficult to accelerate the wagon.
In the second graph, if the mass of an object remains constant and the force applied to the object increases, the acceleration of the object will increase as well.

Back to the wagon example: If a child is pulling a wagon with one friend in it and a second friend joins them and helps to pull the wagon, more force is being applied to the wagon and it accelerates more. If a third friend comes along and helps to pull the wagon, it accelerates even more than with two friends pulling the wagon.

Resources:

http://wings.avikids.com/Curriculums/Forces_Motion/blowfootball_howto.html
http://www.clas.ufl.edu/users/rhatch/NSF-PLANS/2-2_NEWTON.htm
http://www.walter-fendt.de/ph14e/n2law.htm