MIT Blossoms: Hanging By A Thread
Teacher Guide

NGSS-PE (Performance Expectation)
HS PS2-1: Motion and Stability, Forces and Interactions
Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]

Learning Objectives:
1. Ss will apply their understanding of Newton's Laws to predict the outcome of a demonstration.
2. Ss will develop a model to explain the cause and effect of two strings being pulled with unequal forces acting upon 2 identical masses.
3. Ss will plan and conduct an investigation to find evidence to validate their claim.

Introduction:
This demonstration is one that I have been using for years as part of a lab on Newton's Laws. The lab involves a series of demonstrations in which each demonstration is described and students are asked to make a prediction. After the demonstration is performed, students are asked to record their observations and connect the demonstration to one of Newton's laws.
Over time I realized that one demonstration was sufficient to achieve a deeper understanding of Newton's laws if students were provided the time to investigate using the dimensions of the NGSS to explain the phenomenon. The result is this lab investigation, Hanging By A Thread.

A good place to start is by having students recite Newton's laws of motion; a simple task. Then the teacher would present a simple motion demonstration (i.e. releasing a balloon) and ask students to identify, citing evidence, which of Newton's laws were demonstrated; not so simple. Encourage students to argue from , but let students ponder the responses. Hopefully, more than one law is presented. Tell the students you will return to this question. Introduce the BLOSSOMS video and begin.

Activities:
1st segment: (2:35) Provide paper or whiteboards to groups and have them create 2 force diagrams to serve as models based on the scenarios. (Draw 2 cylinders or dots on the board to initiate the force diagrams, ask them to draw arrows representing the forces

to <u>model</u> the forces acting on the object.) Using their <u>model</u>, have groups make a prediction about which thread will break (top/bottom?) After a few minutes, groups will share out their predictions using their <u>models</u> to explain their thinking.

2nd segment: (2:40) After recording their observations of the demonstration, have the groups make revisions to their force diagram <u>models.</u> Does the force diagram <u>model</u> make clear which thread will break? If necessary, remind them that the thread that broke experienced the larger tension force.

3rd segment: (3:00) Have students write down a possible explanation, while you pass out materials. (Provide masses between 200g and 500g. Thread will provide the necessary tension to make this demonstration work well and one spool should be sufficient for a classroom.) Each group needs to come to consensus on their <u>investigation</u> <u>design</u> and what will be measured. Keep referring back to the force diagram <u>models</u>; does the evidence support the diagram? Again this is an opportunity for prompt "Do the forces acting on the objects in the system described in your model provide a basis for your explanation?"

4th segment: (2:20) Return to the initial motion (i.e. balloon) and ask again, "Which of Newton's laws are demonstrated?" The correct answer , "All of them."

Using crosscutting concepts embedded within prompts are important tools for teachers to use. Whenever possible, redirect student conversations back to the force diagram and Newton's laws using prompts built upon crosscutting concepts. These prompts will focus the student's thinking. For example: "Describe how the forces within your system <u>model</u> cause the threads to break?" "What role does the mass play within the system?" "Which of Newton's laws do you think is best represented by your model?" The lesson template has a number of suggested prompts that you may find helpful.

Explanation: What's Happening?
1st Law: Law of Inertia
- 'An object at rest…' When the thread is pulled quickly, the mass is at rest and *wants* to remain at rest. All of the pulling force, which becomes tension, remains in the bottom thread and causes it to break.
- 'An object in motion…' When the thread is pulled slowly, the thread begins to stretch ever so slightly, setting the mass in motion. This allows the tension in the bottom thread to be transferred to the top thread. The top thread, in addition to the weight of the mass, will always have the greater tension and break first.

2nd Law: $F = ma$ (better expressed as $a = F/m$)
This one is more difficult. Focus on the acceleration of the system and recognize we must achieve the same minimum force in each scenario to break the thread.

- Quick pull: The system will be defined as the bottom thread only, since the mass does not accelerate. (See 1st Law.) The (constant) force divided by a small mass will result in a large acceleration of the thread.
- Slow pull: The system will be defined as the 2 threads and mass since all are accelerating. The force divided by a large mass will result in a small acceleration of the system. This gives the force time to transfer to the top thread, causing it to break first due to the additional force (weight) of the mass.

3rd Law: Action - (equal and opposite) Reaction
The action is the pulling force; the reaction is the mass resisting the pull.
- When the action occurs quickly, the mass reacts equally, buffering the top thread from any of the forces.
- When the action occurs slowly, the mass reacts slowly allowing a new action/reaction pair to form between the mass and *top* thread. This results in a greater tension force in the top thread due to the weight of the mass.