Teacher's Guide for the BLOSSOMS Learning Video:
Boomerangs
By Darren Tan, Science Samurai

This video lesson explores the physics behind boomerangs and other rapidly spinning objects. I hope that the combination of hands-on exploration and a "magical" demonstration at the end can help bring the lesson alive for your students, and fire their imagination and sense of wonder.

The following **prerequisites** will allow students to fully appreciate the discussion of precession:

a. Basic ideas of forces,
b. Newton's second law relating force to the rate of momentum change, and
c. Vector addition and time derivatives.

You may also wish to consider using Walter Lewin's wonderful BLOSSOMS module (Ice Skater's Delight: The Conservation of Angular Momentum[1]) to introduce the concept of angular momentum beforehand.

Conceptually, the explanation begins with understanding angular momentum, and using the analogy of Newton's laws for linear motion to explain to students how torque causes a change in angular momentum. The actual physics of the boomerang are briefly described to show how:

1. The spinning motion imparts an angular momentum to the boomerang,
2. The spinning motion results in greater lift on the upper blades,
3. The difference in lift forces results in an unbalanced torque,
4. The torque causes the angular momentum vector to change direction,
5. The direction change implies the precessional motion of the boomerang.

Getting the students **involved** in making and throwing the boomerang should motivate them to follow the explanation, and also gives them the real-life experience of the physics involved. A robust discussion of the effect of adding mass to the boomerang would serve to further consolidate students' understanding of the physics. The demonstration of the bicycle wheel provides yet another trigger for students to think more deeply about the physics, and highlights how different systems obey the same underlying physical laws.

The **materials** required should be easily obtainable. Each student will need some cardboard (roughly the size of a postcard), and the class should have enough of the following to go around:

- Rulers,
- Pencils/pens,
- Scissors,
- Protractors, and
- Staplers.

You may wish to get students to bring these materials themselves. That said, the trickiest and most crucial is the **cardboard**, which needs to be both stiff and thin. You would need to experiment with various kinds of cardboard to test the flight characteristics. If you find the boomerang experiencing too much air resistance

[1] URL: http://blossoms.mit.edu/video/lewin.html

(having difficulty spinning), try shortening the blades equally. I strongly advise making and throwing your own boomerangs before using this module in class, as students are sure to ask for troubleshooting advice.

This lesson takes approximately one class session of 50 minutes. The video itself takes about 25 minutes. The suggested **activities** for the class during the breaks are as follows:

<u>After Segment 1 (5 min)</u>. Students to construct their boomerangs, paying attention to accuracy when measuring the angles between the blades.

<u>After Segment 2 (10 min)</u>. Find a nice open area for students to throw their boomerangs, paying attention to safety from traffic and obstacles. Encourage them to make mutual swaps to test out different boomerangs. This is the time for them to really have fun and to experiment!

<u>After Segment 3 (3 min)</u>. This break is for students to consolidate their sense of the concepts of angular momentum and torque, and the relationships with variables such as the moment of inertia. To enhance the link between these concepts and their practical experience, you could hold up a boomerang to "show" the angular momentum and torque in 3-d, and get the students to do the same with their boomerangs.

<u>After Segment 4 (7 min)</u>. This break challenges students to make a prediction on how increasing the boomerang's mass affects its motion. An in-class discussion around this will be useful for students to clarify and test their understanding of the theory. You may wish to ask trigger questions such as "which other variables are unchanged if the spin is the same?" or "how is the moment of inertia affected?".

<u>After Segment 5</u>. The lesson is formally complete at this point, though there are several options to take it further. Students could be assigned a homework problem on drawing diagrams to explain the motion of the bicycle wheel, or be allowed to discuss this in class if time permits. You could even bring in a bicycle wheel yourself! Another nice way to cap off this lesson is to show the students a toy gyroscope balancing on its tip with its axis horizontal.

Thank you for considering this module; I do hope you have lots of fun with it, and inspire a renewed sense of wonder in your students. Feel free to drop me a note at darren.tan@gmail.com if you have any questions, comments, or feedback!