

Integrated STEM through Tumblewing Gliders

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Abstract

Teachers have the opportunity to use technology and engineering design problems to engage students in integrated STEM education. "Tumblewing" gliders are easy-to-make paper gliders that can challenge, excite, and engage students. As students emphasize the practices of science and engineering while completing a tumblewing design challenge, they will engage in both scientific inquiry and the engineering design process.

Integrated STEM Education

Beginning with the space race in the 1950s and culminating in recent years with the emphasis on Science, Technology, Engineering, and Mathematics (STEM) education the face of education has continued to change and evolve in an effort to prepare workforce ready graduates (Bybee, 2010; Sanders, 2009a; Woodruff, 2013). Legislation, research, and policy changes have brought an increasingly sharp focus on STEM, STEM education, and Integrated STEM education (STEM Education Act, 2015).

Integrated STEM education, which emphasizes teaching the content from the STEM areas through activities with explicit connections, has been advocated as a way to increase student learning and 21st century skills development (Partnership, 2011; Reeve, 2015; Wells & Ernst, 2015). According to Wells & Ernst (2015, p. 1) Integrative STEM education can be defined as:

"the application of technological/engineering design based pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education. Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels."

In Integrative STEM situations teachers can use engineering design problems as facilitators of learning for students in STEM areas. As teachers work to intentionally teach integrated science and mathematics content through technology and engineering design problems students may facilitate better connections and learning for students (Honey, Pearson, & Schweingruber, 2014).

Scientific Inquiry

A variety of teaching methodologies have been advocated for teaching STEM content and principles including problem-based learning, project-based learning, scientific inquiry, and design-based learning (Honey, Pearson, & Schweingruber, 2014; Kelley, 2010; Sanders, 2009b). Scientific inquiry, a methodology which involves students forming hypotheses, collecting data, and analyzing results in problem-based scenarios, has been advocated for integrative STEM and assisting students in solidifying skills related to the practices of science and engineering (Sanders, 2009b; NGSS, 2013). As students utilize these skills their own 21st century skills and workforce preparation may expand and increase (Partnership, 2011). The included lesson plan and resources (see Appendix) provide an opportunity for teachers to engage students in a scientific-inquiry experience while learning about, creating, and testing their own flying tumblewing glider.

Tumblewing Gliders

Tumblewings (also known as “tumble wings” or “tumbling wings”) are a type of glider that exhibit lift through alternately flying and stalling as the tumblewing rotates about an axis. One common form of tumblewing is confetti which produces a visually exciting effect as it “tumbles” through the air. Tumblewings can take “flight” utilizing similar principles to walkalong gliders—upward air is deflected from a surface towards the tumblewing glider by a rigid surface which facilitates lift (see Figure 1).

Instructions, variations, and templates for the construction of tumblewings abound on the internet but the first published resources on tumblewings come from *Fantastic Flight* by John M. Collins—also known as “the paper airplane guy” (Collins, 2004). While variations exist tumblewings generally consist of a small rectangular-shaped piece of phonebook or tissue paper with the ends and sides folded. As air is deflected from a rigid surface (e.g., a piece of cardboard) upwards towards the tumblewing the folded edges catch the air and cause rotation. A slight tilt in the rigid surface also facilitates forward movement as the tumblewing rotates (see Figure 1).

Teachers are encouraged to use the following lesson plan (See Appendix) as an example of possible lesson materials, and resources for an integrated stem learning opportunity using tumblewings in the classroom. Teachers should feel free to modify, deviate, and utilize all or select portions of the provided example. An internet search will also reveal dozens of additional resources that may assist teachers in creating their own integrated STEM lesson plan using tumblewings or other gliders/kites.

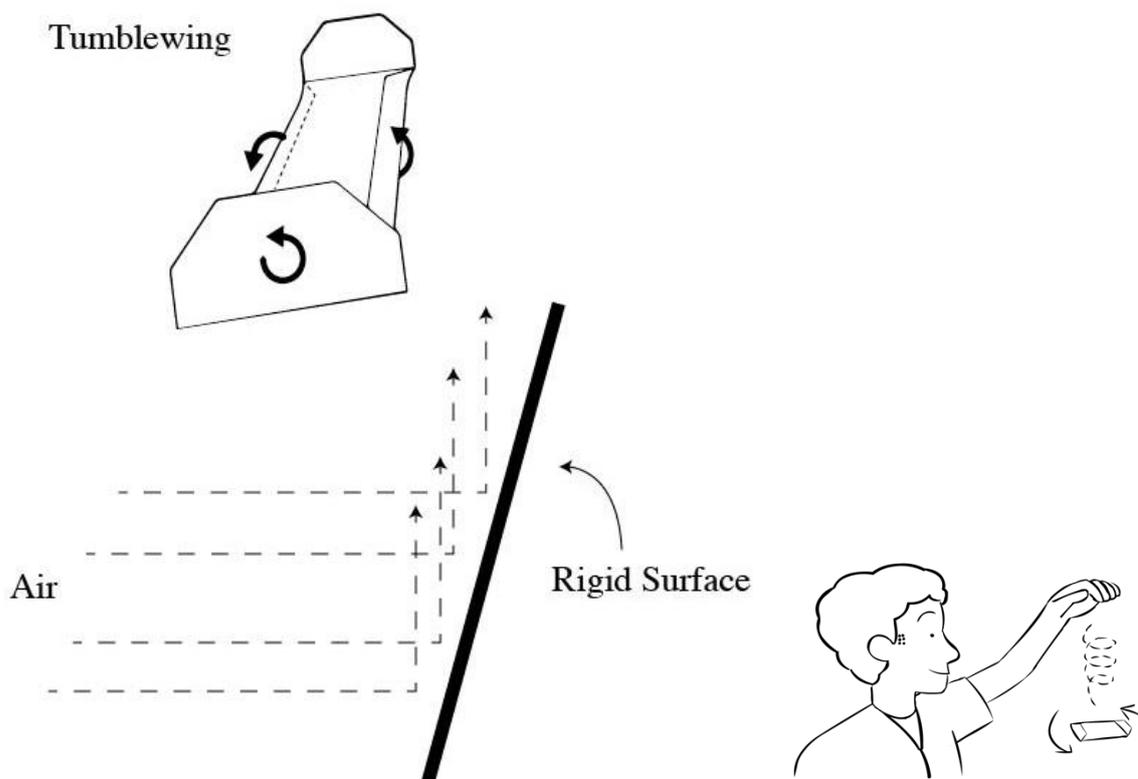


Figure 1a – Tumblewing Adapted from an image found on AirSpaceMag.com - <http://www.airspacemag.com/articles/paper-airplane-flies-forever-180950340/>

Figure 1b - Playmeo.com.
<https://www.playmeo.com/activities/fun-large-group-games/tumblewing-glider/>

In the Classroom

Important skills, necessary for the workforce of the future, are embedded in the practices of science and engineering (NGSS, 2013) and can be cultivated in students through the use of integrated STEM practices and approaches (Wells & Ernst, 2015). As teachers embrace opportunities to incorporate technology and engineering design challenges, such as tumblewing gliders, into their classes they can move towards a truly integrated STEM curriculum (Wells & Ernst, 2015). Our experience suggests that involving students in these types of hands-on learning opportunities will not only increase engagement and retention of new content knowledge (ITEEA, 2007), but will also add a new level of excitement for students and teachers as they work together to solve these challenges.

For interested readers, useful and relevant resources about the topics discussed in this article are listed in References below.



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APPENDIX 1

Create a flying Tumblewing

INTRODUCTION

A **tumblewing** is a type of glider or kite that rotates about an axis and exhibits **lift** as the tumblewing alternates between **flying** and **stalling (free fall)**. One common example of a tumblewing is confetti, which “tumbles” as it falls. The alternating flying and stalling of the confetti creates the visual appeal.

ACTIVITY OBJECTIVES

1. Students will understand and be able to explain the **forces of flight** as they relate to the tumblewing.
2. Students will work together in a collaborative setting to experiment with tumblewing modifications (**practices of science and engineering**).
3. Students will design, construct, test, modify, and re-test their tumblewing (**engineering design process**).

HOW DOES A TUMBLEWING WORK?

To understand how a tumblewing works we need to first understand flight. There are four forces that act on an object in flight: **weight/gravity, lift, thrust, and drag**. In order for an object to stay airborne the **lift** must overcome the **weight/gravity** and the **thrust** must overcome the **drag**. If you simply drop your tumblewing you will notice that it spins about its axis and slowly descends – in this case the **drag** and the **weight/gravity** will slowly bring the tumblewing down. If you walk behind the tumblewing with a piece of cardboard you push air in front of the cardboard (this upward draft in air is called **ridge lift**), which acts as an upward **lifting** force as well as a forward **thrust** force. Balancing these forces allows the tumblewing to maintain steady flight.

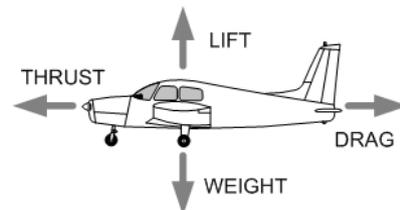


Figure 2 - LangleyFlyingSchool.com.
<http://www.langleyflyingchool.com/Pages/Private%20Pilot%20Program.html>

KEY TERMS

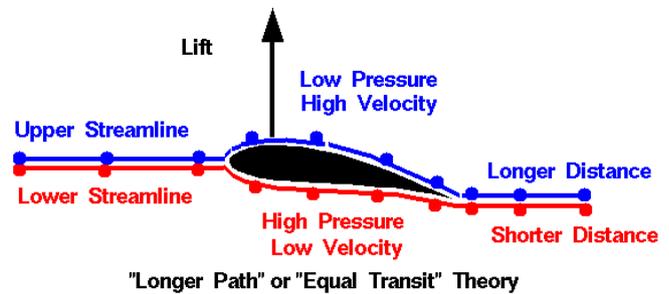
- **Forces of flight**
 - **Weight/gravity** – the force pulling an object towards the Earth’s surface
 - **Thrust** – the force pushing an object forward (i.e. created by the airplane engine)
 - **Lift** – a force which pushes an object upward (in a tumblewing this is **ridge lift**)
 - **Drag** – the force that acts opposite to the direction of motion - caused by friction and differences in air pressure.
- **Flying** – achieved when weight/gravity and drag are not greater than lift and thrust
- **Stalling** – when an aircraft does not have enough lift to continue in flight
- **Engineering Design Process** – a series of steps used while solving a problem

APPENDIX 2

STEM Concepts & Practices

Science

- Principles of flight
 - Thrust
 - Drag
 - Lift
 - Weight/gravity
 - Ridge lift
- Newton's laws of motion
- Bernoulli's principle
- Practices of Science & Engineering (NGSS)



Technology

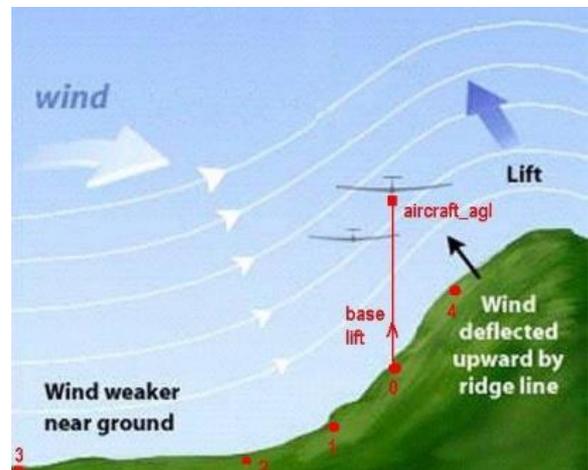
- Aircraft: Types, purposes, basic components
- Tools: Measuring & cutting instruments;
- Information sources

Engineering

- The Engineering Design Process
- Aircraft design, building, and testing
- Practices of Science & Engineering (from the *Next Generation Science Standards*)

Mathematics

- Measuring: Diameter, Length, Height



ADDITIONAL WEB-BASED HELP RESOURCES

- <http://www.sciencetoymaker.org/tumblewing/makeTumblewing.htm>
- <http://www.sciencetoymaker.org/tumblewing/index.htm>
- <http://www.scienceworld.ca/resources/activities/tumblewing-glider>
- <https://www.youtube.com/watch?v=iob8IcbgJ58>
- <http://www.instructables.com/id/Walkalong-Glider-Made-from-Phone-Book-Paper/>
- <https://www.mansfieldct.org/Schools/MMS/staff/hand/flight4forcesoverview.htm>

APPENDIX 3

The Engineering Design Process

- 1. Identify a Challenge**
 - *Make sure you have a good understanding of the challenge or problem that needs to be solved.*
- 2. Explore Ideas**
 - *Brainstorm possible solutions to solve the problem.*
 - *Research ideas related to solving the problem.*
- 3. Plan and Develop**
 - *Choose a solution and develop a solution (i.e., a prototype).*
- 4. Test and Evaluate**
 - *Test and evaluate the solution.*
 - *Modify the solution as needed*
- 5. Present the Solution**

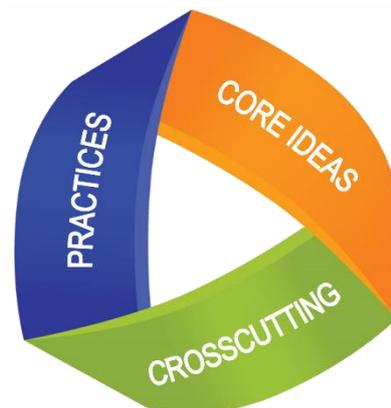


Figure 3 - The Engineering Design Process

Practices of Science & Engineering

The *Next Generation Science Standards* outline 8 essential practices for Science and Engineering. This activity will focus on 2 of them.

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
- 4. Analyzing and interpreting data**
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
- 7. Making an argument from evidence**
8. Obtaining, evaluating, and communicating information



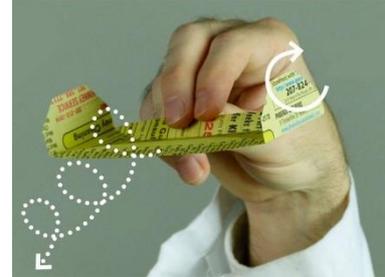
APPENDIX 4

Engineering Design Challenge

Construct a Tumblewing that travels the furthest distance

I. Challenge

In this engineering design challenge, you will work in small teams (2-3 students) and be given the resources needed to design and build tumblewings. A bonus will be given for the tumblewing that travels the furthest distance without touching the ground



II. Criteria and Constraints

- The tumblewing must be constructed from only phonebook paper.
- The tumblewing must be constructed from no more than 1 single sheet of phone book paper.
- The tumblewing must be powered by nothing other than the air deflected from one piece of cardboard (12" x 12" / 30 cm x 30 cm).
- Team members may "drop" the tumblewing to start flight but may not touch the tumblewing following the initial drop.
- Team members may modify the tumblewing shape in any way.
- The Internet can be used to search for ideas.

III. Resources

- 5 pieces of phone book paper
- Tape
- Scissors
- Tumblewing templates

IV. Evaluation

- 10 Points: Built and flies more than 30' (~9 meters).
- 9 Points: Built and flies less than 20' (~6 meters).
- 5 Points: Not completed or launched - effort shown.
- 0 Points: No effort shown.

APPENDIX 5

Practices of Science & Engineering

Testing, Evaluating, Analyzing, Interpreting, and Acting on evidence

Introduction

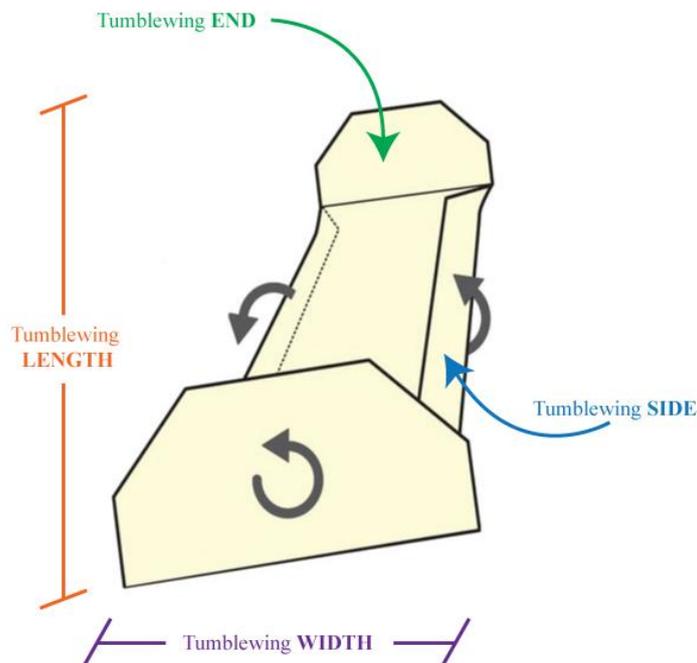
In the “Engineering Design Challenge” part of this activity, your team was challenged to construct a tumblingwing that would travel at least 30’ (~9 m), with a bonus for traveling the furthest. One step of the engineering design process involves **“Testing and Evaluating.”** As part of the testing and evaluating process you will record several pieces of data that will lead you to a practice of Science and Engineering: **analyzing and interpreting data.**

Following your testing you should work as a group to analyze the data, interpret the results, and then decide on a course of action for constructing the best possible tumblingwing. This decision to pursue a particular course of action is another principle of Science and Engineering: **making an argument from evidence.**

Procedures

In this activity, you will use the practices of science and engineering to explore the best possible specifications to maximize flight for your tumblingwing. Use the tables below to **test and evaluate** different combinations of bend in your tumblingwing. After you are done with the **testing and evaluating** use the space below to **make an argument** as to which combination of variables will produce the longest flight for your tumblingwing.

- *Test only one variable (change) at a time. For example, choose a set fold measurement for the ends and test the side folds at different measurements. Then choose the best fold for the sides and test the ends at different measurements. By holding all variables except for one constant we can better see the impact of a single change in the tumblingwing!*



Adapted from an image found on AirSpaceMag.com - <http://www.airspacemag.com/articles/paper-airplane-flies-forever-180950340/>

Example

Trial #	Length* of tumblewing	Width* of tumblewing	Fold length* (ends)	Fold length* (sides)	Results (how far did it go)*
Ex. 1	5"	2"	1/4"	1/8"	12'
Ex. 2	5"	2"	1/2"	1/8"	10'
Ex. 3	5"	2"	1"	1/8"	9'

* 1 inch (") = approx. 2.5 cm; 1 foot (') = approx. 30 cm

Test different **fold lengths (sides)** here

Trial #	Length of tumblewing	Width of tumblewing	Fold length (ends)	Fold length (sides)	Results (how far did it go)
1					
2					
3					
4					

Test different **fold lengths (ends)** here

Trial #	Length of tumblewing	Width of tumblewing	Fold length (ends)	Fold length (sides)	Results (how far did it go)
1					
2					
3					
4					

Test different overall tumblewing **widths** here

Trial #	Length of tumblewing	Width of tumblewing	Fold length (ends)	Fold length (sides)	Results (how far did it go)
1					
2					
3					
4					

Test different overall tumblewing **lengths** here

Trial #	Length of tumblewing	Width of tumblewing	Fold length (ends)	Fold length (sides)	Results (how far did it go)
1					
2					
3					
4					

Make an argument based on evidence

Now that you have conducted several **tests** and **recorded your results** it's time to **analyze the data**. Look through your trials for each variable and as a team decide what combination of measurements will produce the longest flight for your tumbling. Record your argument below (make sure to base your argument off of the evidence [results] you collected).

Example: Based on our experiments we have chosen to make our final tumbling 4" (10 cm) long and 2" (5 cm) wide with side folds on 1/2" (1.3 cm) and end folds of 1" (2.5 cm). When using these measurements we recorded the longest flights with our tumbling.

FINAL MEASUREMENTS:

Fill in the final measurements you chose for your tumbling in the blanks below:

Principles of Flight

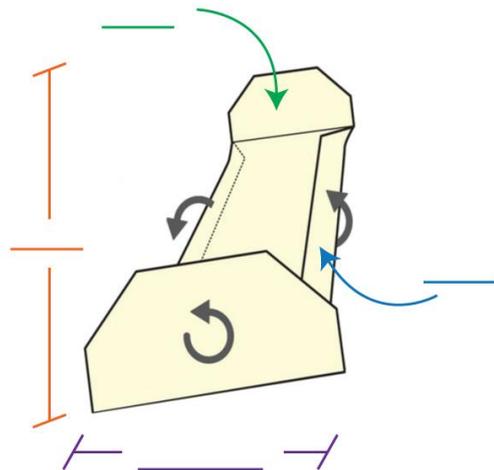
Describe each principle of flight as it relates to your tumbling. What provides each force and how do they interact with each other?

Lift:

Weight/Gravity:

Thrust:

Drag:



Adapted from an image found on AirSpaceMag.com - <http://www.airspacemag.com/articles/paper-airplane-flies-forever-180950340/>