Wind Farm Design Challenge

Subject:
Math

Strand:
Geometry

Grade:
Seventh and eighth grade

Estimated Instructional Time:
5 class periods, 50 minutes each

Related Kit(s):

- Wind Farm

Abstract:
In this middle-school engineering design challenge, students are challenged to create the most efficient wind turbine while balancing cost constraints. Students will apply their knowledge of surface area and graphing while testing their 3D-printed designs using Tinkercad.

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Learning Objectives

Students will:

- use the engineering design process and teamwork to create a wind blade that balances efficiency and cost.
- demonstrate the efficacy of their wind turbine by applying their knowledge of surface area and graphing to test the 3D printed models and graph their results.
- research the information needed to understand a problem and devise a prototype solution.
- explain why they designed their wind blades by using evidence from their tests and knowledge of surface area to support their claims.

Standards and Practices

Common Core State Standards

CCSS.MATH.CONTENT.7.G.B.6

Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

CCSS.MATH.CONTENT.8.F.B.4

Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (*x, y*) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.

MAFS.8.SP.1.1

Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

CCSS.MATH.PRACTICE.MP1

Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP2

Reason abstractly and quantitatively.

CCSS.MATH.PRACTICE.MP4

Model with mathematics.

CCSS.MATH.PRACTICE.MP5

Use appropriate tools strategically.

CCSS.MATH.PRACTICE.MP6

Attend to precision.

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

CCSS.MATH.PRACTICE.MP7

Look for and make use of structure.

NGSS Science and Engineering Practices

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
8. Obtaining, evaluating, and communicating information

Florida Standards

MAFS.7.G.2.6

Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

MAFS.8.F.2.4

Construct a function to model a linear relationship between two quantities. Determine the rate of change and initial value of the function from a description of a relationship or from two (x, y) values, including reading these from a table or from a graph. Interpret the rate of change and initial value of a linear function in terms of the situation it models, and in terms of its graph or a table of values.

MAFS.8.SP.1.1

Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.

MAFS.K12.MP.1

Make sense of problems and persevere in solving them.

MAFS.K12.MP.2

Reason abstractly and quantitatively.

MAFS.K12.MP.4

Model with mathematics.

MAFS.K12.MP.5

Use appropriate tools strategically.

MAFS.K12.MP.6

Attend to precision.

MAFS.K12.MP.7

Look for and make use of structure.

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

SC.7.E.6.6
Identify the impact that humans have had on Earth, such as deforestation, urbanization, desertification, erosion, air and water quality, changing the flow of water.

SC.7.L.17.3
Describe and investigate various limiting factors in the local ecosystem and their impact on native populations, including food, shelter, water, space, disease, parasitism, predation, and nesting sites.

Guiding Questions

- What are some reasons that wind farms are built?
- How can we make the most efficient wind turbine?

Notes

In this activity, students will use an engineering design process developed by NASA: Engineering Design Process. Students will work in teams to go through the steps of the engineering design process to brainstorm, develop, test, and improve their models. The engineering design process is a systematic process; students must base their designs on a reasonable hypothesis, carefully conduct tests, and redesign if needed based on their results. They should be able to make an argument from evidence about how they determined their final design.

The teacher acts as a facilitator during this process, guiding rather than directing students to create a solution to the problem. There is no one best answer to the problem; some students may prioritize cost over efficiency and vice versa. However, students should try to come up with an optimal solution that takes into account all of the client’s needs even though tradeoffs must be made.

The challenge begins with a memo from a wind farm company that asks students to test and then modify their designs to make a more efficient wind blade. Students will have several opportunities to test and revise their 3D-printed blades.

This activity allows students to apply their knowledge to solve a realistic problem. In order to be successful at this activity, students must have background knowledge of how to calculate surface area of composite solids and graph the information from their wind blade tests. To meet the grade 8 math standard, students can respond to the following questions after constructing their graphs:

- Construct a function to model a linear relationship between two quantities.
- Describe the patterns of association between the two variables (e.g., clustering, outliers, positive or negative association, linear association, nonlinear association).

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Content Review

Wind energy

The U.S. Department of Energy's page "Advantages and Challenges of Wind Energy" has an overview of wind energy.

The following text about how wind turbines work was taken from the U.S. Department of Energy page "How Do Wind Turbines Work?" which also contains images and videos for further information.

Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity.

So how do wind turbines make electricity? Simply stated, a wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity.

Wind is a form of solar energy and is a result of the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and the rotation of the earth. Wind flow patterns and speeds vary greatly across the United States and are modified by bodies of water, vegetation, and differences in terrain. Humans use this wind flow, or motion energy, for many purposes: sailing, flying a kite, and even generating electricity.

The terms wind energy or wind power describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity.

MyStemKits.com

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Scatterplots
"Construct a Scatter Plot," a student-friendly video from Learnzillion, explains how to construct bivariate scatter plots.

Surface area
The following links provide video resources for finding the surface area of composite solids.

- Khan Academy, "Area of composite shapes"
- Mathspace, "Surface Area of Composite Solids"

Procedure

Preparation:

1. Before beginning the activity, you should print the four default sets of wind blades and set up the room for testing (for more information, see the Wind Farm MyStemKits.com model guide).

2. It is highly recommended to test your fan before class to ensure that it is powerful enough to spin the printed windmill blades. If the fan has multiple settings, be sure that students use the same setting throughout all testing of the wind blades.

3. Be sure that the same length of string is used in all tests for the whole class so they can combine results and compare from one group to the next.

Day One:

1. Introduce the activity by showing the YouTube video "Energy 101: Wind Turbines - 2014 Update" from the U.S. Department of Energy, which gives an overview of wind farms and provides context to the activity:

2. Next, pass out a copy of the client letter to each student. Students should read the letter and answer the readiness questions. Go over the correct answers when students are finished.

3. Divide students into heterogeneous groups. You may wish to have each team choose a particular role for each member (e.g., scientific notebook recorder, Tinkercad modeler, grid paper artist, etc.).

4. Tell students that they are going to test the four scaled models of wind blades that are currently manufactured by Blown Away, the company asking for their help.

5. Each team of students will test the designs. They should test each of the four blades several times (the worksheet includes four suggested tests). As students test the design they should fill out the relevant information in the Testing Worksheet for trial 1. (If needed, the testing can be done as a class to save time).

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

a. Students will calculate the average time based on their four tests. It may be necessary to provide a quick review on calculating the mean if students need a refresher.
b. Encourage the students to ensure that the relative location between wind blade and fan doesn't change. It may be helpful to mark a forward and backward track for the fan to sit along and then keep the front of the blade consistent to the fan power (e.g., 8" or 5").

Day Two:

1. Ask teams to fill out the brainstorming worksheet. Students should use the information from the Trial 1 testing worksheet to better justify their reasoning. The teacher should circulate to ensure students are filling this out thoughtfully and prompt student thinking when necessary by asking open-ended questions such as: Why do you think that? What will happen if the blade length is longer/shorter? Why might surface area be important? It is not important that students have the correct answer at this point; they should respond thoughtfully and explain their reasoning.

2. Tell students that they will have the opportunity to design their own blade by modifying the template models in Tinkercad, and that they can print out their blade design and test it. Stress to students that they will have a limited number of trials so they should start with what they think will be the best design. They should look at the four wind blade models and brainstorm what modifications are needed to best meet the client's needs.

3. Students should receive grid paper to begin sketching their prototype; what design they think will best meet the client's needs. As teams are drawing, the teacher can circulate and ask guiding questions about their models (e.g., why did you choose this length?).

4. Provide students with an overview of Tinkercad. It may be helpful to familiarize students with the platform before this activity.

5. Each team should access the wind blade templates in Tinkercad.

6. When finished drawing, students should translate their drawings to Tinkercad by modifying one of the provided templates.

7. Print students' designs before the start of the next class.

Day Three:

1. Set up the room for testing the wind blades.

2. Hand out the 3D-printed blades that each team designed in the previous class session.

3. Students will receive the Trial 2 worksheet and the graph worksheet that they filled out with their previous tests. Before testing their new model, students should make predictions about how their blade will work on the graph and trial worksheet.

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

4. Students should test their design. They should test each blade several times (the worksheet includes four suggested tests). As students test the design they should fill out the relevant information in the testing worksheet for Trial 2 and include their data on the graph worksheet. Students should also respond to the questions on the Trial 2 worksheet.

5. After filling out the Trial 2 worksheet and the graphs, a brief class discussion can take place. The class discussion is important because due to the time to print the blades, it is not possible for students to test many combinations of their own designs. Hearing what other class members did will improve students' understanding of how the variables work.

6. Tell students that they will have another opportunity to revise their model. If students believe they already have the best model, tell them that it's important to compare the first model and to make an attempt to make the first model even better. Students will have the chance to modify and test their new design.

7. Students will modify their designs on Tinkercad. Stress that in order to test a variable, the others must be held constant. For example, if students are modifying the length of the blade, they need to hold the other variables (e.g., angle, number of blades) constant.

8. Print students' new designs before the start of the next class.

Day Four:

1. Set up the room for testing the wind blades.

2. Before testing their second original model, students should make predictions about how their blade will work on the graph and trial worksheet.

3. Students will test their designs and fill out the Trial 3 worksheet and add their new data points to the graph worksheet.

4. As before, lead students in a class discussion about their findings.

5. Give students another chance to redesign their blade. Print students' designs before the beginning of the next class.

MyStemKits.com

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Day Five:

1. Set up the room for testing the wind blades.
2. Before testing their new model, students should make predictions about how their blade will work on the graph and trial worksheet.
3. Students test their blades and fill out the Trial 4 worksheet.
4. Students will present their best designs to the rest of the class, followed by class discussion.
5. Students should fill out the Summative Worksheet.
6. Review students' surface area calculations and graphs as a summative assessment.

Review and Assessment

Teachers can assess the accuracy of students' surface area calculations and graphs as a summative assessment. The Summative Worksheet may also be used for assessment purposes. Additionally, students could be asked to answer the following guiding questions after the activity.

- What impacts might wind farms have on the environment?
- What are some of the key pros and cons of wind farms? Do you think the pros outweigh the cons? Why or why not?

Required Materials

MyStemKits Kit: Wind Farm Kit

Additional Supplies:

- String
- High-Powered Fan
- Scale
- 3D printer
- Rulers
- Computers with internet connection

Student Handouts:

- Client Letter and readiness questions
- Brainstorming worksheet
- Testing worksheets
- Summative worksheet

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

- Graph paper

Optional/alternative materials:

- Calculators

Extension Opportunities

- Students can design a wind blade from scratch depending on their level of proficiency with Tinkercad.
- Various constraints can be put into place such as a fixed angle, a budget, fixed length of blade, fixed number of blades, etc.
- Students can create star plots for graphing more than two points of data at a time (e.g., time, surface area, blade angle).

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Dear students,

I am the director of Blown Away, a fairly new company that designs windmills. Unfortunately, our company is struggling financially because we have experienced customer complaints with all three of our wind blade designs that is leading to low sales. Apparently, our wind blades are not as efficient as our customers would like.

I heard that your classroom has the right skillset in 3D modeling, math, and science that can help my company get back on its feet. Can you help my company by designing a more efficient wind blade?

I am providing you with our four current wind blade designs as computer-generated 3D design models in Tinkercad. You can use these as a starting point and modify one into the most efficient (fast) design possible. You can manipulate the number of blades used on the windmill, the angle of the blades, the surface area, the weight, and the length. Of course, since my company is short on funds lately, we need to keep the costs of producing the wind blades as low as possible. Each millimeter of surface area on the blade costs us $1.00. Your designs will be scaled up when you have provided us with your final prototype, so the costs will be scaled, too.

Thank you in advance for your help. My company is counting on you.

Sincerely,

Wendy Ventoso
Director, Blown Away

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

1. Who is the client (the person asking you to solve this problem)?

2. Who will use your design?

3. In your own words, state the problem.

4. What are the criteria (design requirements)?

5. What are the constraints?

6. What do you anticipate as some challenges in solving this problem?

MyStemKits.com

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Brainstorming

1. How will you choose what shape the blades should be?

2. How will you calculate surface area of the blades?

3. How will you choose what lengths to make the blades?

4. How will you choose what angle to make the blades?

5. How will you choose how many blades to use?

6. Predict how the weight of a blade might change the time variable.

7. Predict how the shape of a blade might change the time variable.

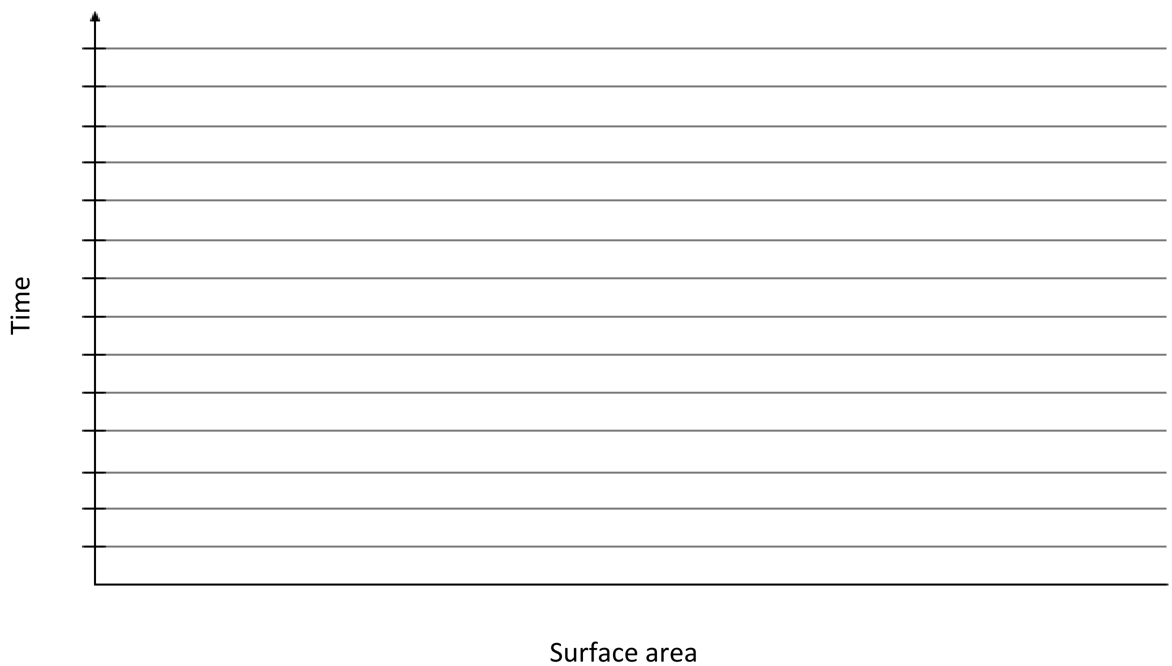
8. Explain how you think changing the weight and shape of the blade changes the amount of time it takes for the weight to reach the top (time variable).

9. What blade elements (variables) are you going to test? How are you going to test them?

MyStemKits.com

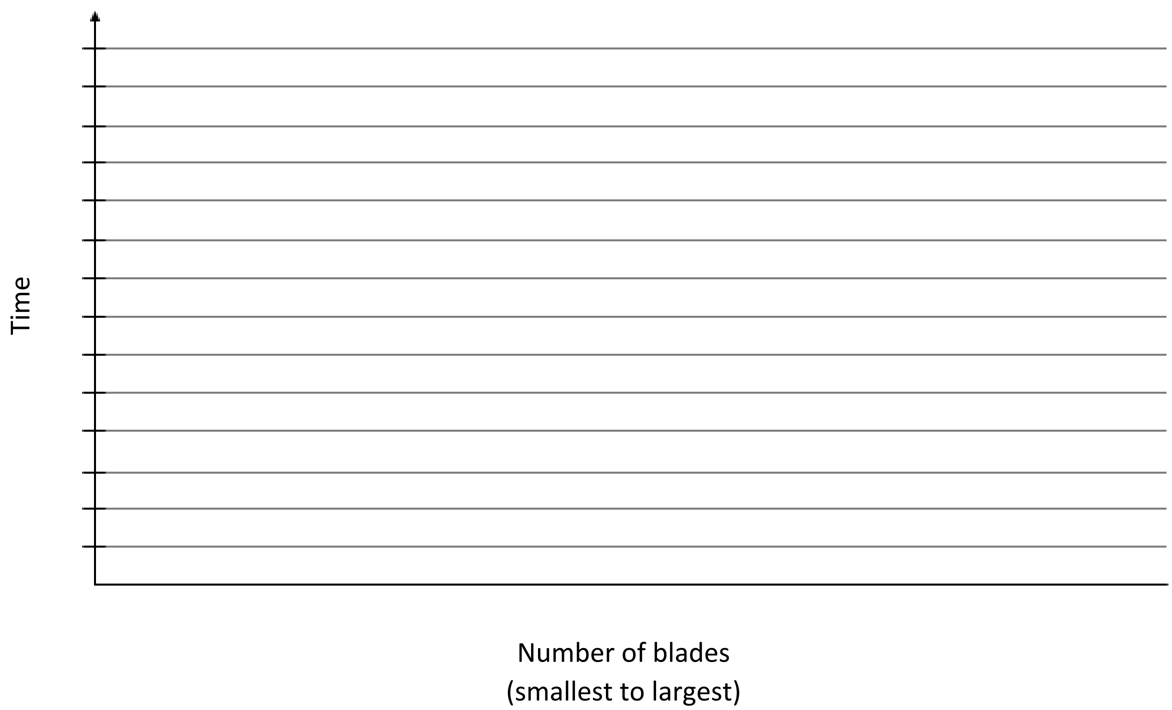
Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Graphing Worksheet 1



MyStemKits.com
Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Graphing Worksheet 2



MyStemKits.com
Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Testing

Trial 1

Blade	Surface area (SA)	# of Blades	Blade weight (g)	Time (test 1) seconds	Time (test 2) seconds	Time (test 3) seconds	Time (test 4) seconds	Time (average) seconds
1								
2								
3								
4								

Note: time = seconds it takes to pull the weights all the way up

1. Test each of the four blade designs and fill in the table above for Trial 1.

2. Graph the average time (seconds) for each of the four trials versus the surface area. Be sure to label your data points (blade 1, blade 2, blade 3, blade 4).

3. Graph the average time (seconds) for each of the four trials versus the number of blades. Be sure to label your data points (blade 1, blade 2, blade 3, blade 4).

4. Did anything surprise you when you tested the blades? Explain.

5. Compare and contrast the four blade designs. Which one was most efficient? Why do you think that?

MyStemKits.com

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Trial 2

1. What modification(s) did you make to the original blade design? Why?

2. Before testing your new blade design, fill in the graphs with your predicted values for time vs. surface area and time versus the number of blades. Label this data point on the graphs, “P1.” Explain why you made each prediction.

Blade	Surface area (SA)	# of Blades	Blade Weight (g)	Time (test 1) seconds	Time (test 2) seconds	Time (test 3) seconds	Time (test 4) seconds	Time (average) seconds
Original prototype 1								

Note: time = seconds it takes to pull the weights all the way up

3. Test the new blade design and fill in the table above for Trial 2.

4. Fill in the two graphs with the actual values from your tests. How well did they match up with your predicted values?

5. Did anything surprise you when you tested your design? Explain.

6. What modifications do you want to make to your design? Why?

MyStemKits.com

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Trial 3

1. What modification(s) did you make to the original blade design? Why?

2. Before testing your new blade design, fill in the graphs with your predicted values for time vs. surface area and time versus the number of blades. Label this data point on the graphs, “P2.” Explain why you made each prediction.

Blade	Surface area (SA)	# of Blades	Blade Weight (g)	Time (test 1) seconds	Time (test 2) seconds	Time (test 3) seconds	Time (test 4) seconds	Time (average) seconds
Original prototype 2								

Note: time = seconds it takes to pull the weights all the way up

3. Test the new blade design and fill in the table above for Trial 3.

4. Fill in the two graphs with the actual values from your tests. How well did they match up with your predicted values?

5. Did anything surprise you when you tested your design? Explain.

6. What modifications do you want to make to your design? Why?

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Trial 4

1. What modification(s) did you make to the original blade design? Why?

2. Before testing your new blade design, fill in the graphs with your predicted values for time vs. surface area and time versus the number of blades. Label this data point on the graphs, “P3.” Explain why you made each prediction.

Blade	Surface area (SA)	# of Blades	Blade Weight (g)	Time (test 1) seconds	Time (test 2) seconds	Time (test 3) seconds	Time (test 4) seconds	Time (average) seconds
Original prototype 3								

Note: time = seconds it takes to pull the weights all the way up

3. Test the new blade design and fill in the table above for Trial 4.

4. Fill in the two graphs with the actual values from your tests. How well did they match up with your predicted values?

5. Did anything surprise you when you tested your design? Explain.

6. Do you still want to make any modifications to your design? Why or why not?

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

Summative Worksheet

1. What shape of blade did you find worked best? Explain.

2. What length of blade did you find worked best? Explain.

3. What angle of blade did you find worked best? Explain.

4. How many blades did you use? Why?

5. How did the weight of the blade change the time variable?

6. How did the shape of the blade change the time variable?

7. How did the surface area of the blade change the time variable?

8. How did the cost of materials factor into your design?

9. Describe your final design and why you chose it. How does it meet what the client asked for?

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.

0.5 cm. Graph Paper

MyStemKits.com

Copyright © 2017 Florida State University - Florida Center for Research in Science, Technology, Engineering, and Mathematics. All rights reserved.