Engineering a Kinetic Wind Sculpture

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Unit Overview

This 21-day integrated STEAM unit challenges students to apply their knowledge of kinetic energy to create wind power. Students collaborate to master art, engineering, geometry, and physics standards by designing and building wind turbines capable of lighting light-emitting diodes (LEDs). During the project, the class is divided into groups, where each is responsible for designing a specific part of a kinetic sculpture. The unit culminates with the class presenting their final design to a real-world client.

Standards Addressed

1. **ELAGSE9-10SL1:** Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
   c. Propel conversations by posing and responding to questions that relate the current discussion to broader themes or larger ideas; actively incorporate others into the discussion; and clarify, verify, or challenge ideas and conclusions.

2. **MGSE9-12.G.SRT.1:** Verify experimentally the properties of dilations given by a center and a scale factor.
   a. The dilation of a line not passing through the center of the dilation results in a parallel line and leaves a line passing through the center unchanged.
   b. The dilation of a line segment is longer or shorter according to the ratio given by the scale factor.

3. **MGSE9-12.G.SRT.2:** Given two figures, use the definition of similarity in terms of similarity transformations to decide if they are similar; explain, using similarity transformations, the meaning of similarity for triangles as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides.

4. **MGSE9-12.G.SRT.3:** Use the properties of similarity transformations to establish the AA criterion for two triangles to be similar.

5. **MGSE9-12.G.SRT.6:** Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

6. **MGSE9-12.G.SRT.7:** Explain and use the relationship between the sine and cosine of complementary angles.

7. **MGSE9-12.G.SRT.8:** Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

8. **MGSE9-12.G.C.1:** Understand that all circles are similar.

9. **MGSE9-12.G.C.2:** Identify and describe relationships among inscribed angles, radii, chords, tangents, and secants. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.

10. **MGSE9-12.G.C.3:** Construct the inscribed and circumscribed circles of a triangle, and prove properties of angles for a quadrilateral inscribed in a circle.

11. **MGSE9-12.G.C.4:** Construct a tangent line from a point outside a given circle to the circle.

12. **SP5:** Students will evaluate relationships between electrical and magnetic forces.
    a. Describe the transformation of mechanical energy into electrical energy and the transmission of electrical energy.

13. **STEM-EC-5:** Explain a whole systems approach to the engineering design process to solve a technical problem.
    5.2 Apply the engineering design process to the solution of a technical problem.
    5.3 Optimize and justify design solutions based on cost, time, schedule, and performance constraints.
    5.6 Demonstrate an understanding of the continuous improvement process as it applies to new designs and modifications of existing designs for new applications.

14. **STEM-EC-7:** Summarize and apply engineering solutions through the audience appropriate application of engineering graphics and technical writing.
    7.1 Communicate design specifications through Engineering drawings and multiple medias.
    7.2 Apply tools to mathematically analyze engineering design problems.
    7.3 Apply accurate dimensions to a technical drawing, including size and geometric tolerances.
    7.4 Prepare a persuasive proposal for an engineering solution.
    7.6 Prepare a report of engineering design activities including a description of analysis, optimization, and selection of a final solution.
    7.7 Research and benchmark a technological problem or idea.
    7.8 Use oral and visual communication skills to deliver an engineering design presentation.

15. **STEM-EC-8:** Apply basic engineering tools and resources to aid in data collection and problem solution sets.
    8.1 Demonstrate understanding and application of various measurement systems.

8.2 Demonstrate understanding and application of various base units in both English and international systems (SI).

16. **STEM EC-9:** Cite evidence for the role of troubleshooting, research and development, inventions, and innovations in problem solving.
    9.2 Use appropriate evaluation tools while troubleshooting during the design process.
    9.3 Examine business and industry research to prepare devices and systems for the marketplace/client.
    9.4 Use an interdisciplinary approach to problem solve.

17. **VAHSVAPR.1:** Uses formal qualities of art (elements and principles) to create unified composition and communicate meaning.
    a. Uses sketchbook journal to research and experiment with artistic conventions to communicate ideas.
    b. Uses principles of design to organize elements to communicate meaning and unified compositions concepts, such as activating negative space, visual weight, paths of movement, non-centered focal point, dominance and subordination of design elements, and variety within repetition.
    d. Discusses and applies concepts, such as activating negative space, visual weight, paths of movement, non-centered focal point, and variety within repetition.

18. **VAHSVAMC.2:** Finds and solves problems through open-ended inquiry, the consideration of multiple options, weighing consequences, and assessing results.
    a. Uses sketchbook journal to research and experiment with artistic conventions to communicate ideas.
    b. Generates more than one solution to a single artistic problem and assesses merits of each.
    c. Analyzes, in both written and oral form, the implications of artistic decisions.
    d. Solves artistic problems through discussion and interaction with peers.
    e. Supports peers though informal, on-going critique of works in-progress.

Days 1 – Mini-Engineering Design Process

Standards Addressed: 12, 14

Essential Question: How do I use the Engineering Design Process to light LEDs?

1. Do now (10 minutes): Instruct students to draw a dowel in Sketchup.

2. The hook activity is a mini project which will give students an opportunity to practice the Engineering Design Process and concepts they will use during the windmill project.

3. Put students into groups of three or four. Distribute the **Mini-Engineering Design Project** activity sheet to groups. Provide students with a box of materials that includes random items (such as cotton balls, popsicle sticks, etc.), as well as wires, motor, housing for the wind turbine blade, a multimeter, some dowels and light emitting diodes (LEDs). The goal for the students for the project is to light an LED using the items in the box and a fan (that you will provide students) which will serve as the energy source. Tell students that they may not conduct research for this mini project.

A Note from the Teacher

Students must have some prior knowledge before beginning this unit. Specifically,

- *Students must have experience with Single Point Perspective.*
- *Students must have some experience with Sketchup. You may consider having students practice using Sketchup for 10 minutes a day for about 15 class periods in preparation for designing the windmill sculpture.*
- *Students must be familiar with the Engineering Design Process, which they will need to use during over the course of the project.*

4. Explain that each student will use this class period is draw a sketch of a device that is capable of lighting LEDs in the space provided on page one of the **Mini-Engineering Design Project** activity sheet. Instruct the students to include labels for materials and measurements. The group will select one of the designs to move forward with building the following day (making sure to incorporate feedback from group members and the teacher).

5. Daily Assessment: Instruct each individual student to submit their drawing with labels describing where the energy is coming from and how it gets to the LEDs. Analyze each drawing to check for understanding and misconceptions only. Provide feedback.

Day 2 – Mini-Engineering Design Process, continued

Standards Addressed: 12, 13, 14, 15, 16

Essential Question: How do I use the Engineering Design Process to light LEDs?

1. Do Now: Tell students to revisit the dowel they drew the previous day in Sketchup. Instruct them to draw a wind turbine blade on the dowel. Display an image of a Mini Wind Turbine Blade.

2. Distribute the drawings from day one, which now includes your feedback. Use the **Wind Energy Infographic** to explain the flow of energy from the fan, which causes the turbine to turn through the motor, which converts kinetic energy into electrical energy and lights the LEDs.

3. Instruct groups to discuss the teacher feedback, as well as provide feedback of their own. Instruct groups to select one drawing with which to move forward with the build. Distribute the box of materials to each group and situate the fan at the front of the room. Instruct students to build the selected design.

4. Using pages two and three of the **Mini-Engineering Design Project** activity sheet, students are now tasked with identifying the independent variables that affect the voltage generated. Variables given are: the number of wind turbine blades, the angle of the wind turbine blades, and the distance from the fan to the turbine. Before students begin on their own, work as a whole class to identify and discuss one example of an independent variable (the wires). Then discuss how you would design an experiment to determine if the color of the wires affects the voltage generated.

5. Daily Assessment: Ask students to answer the following questions on a sheet of paper that they will submit. What did you learn today? Cite experimental evidence to back up your conclusion. Analyze the student submissions to intercept any students or teams that gathered erroneous data (ask to redo experiment).

Day 3 – Mini-Engineering Design Process, continued

Standards Addressed: 12, 13, 14, 15, 16

Essential Question: How do I use the Engineering Design Process to light LEDs?

1. Do Now (20 minutes): Display the following problem on the board for students to complete: One of your friends keeps getting a stomach ache after the school lunch on Wednesdays. On Wednesdays he usually eats chips with jalapenos, tomatoes, and nacho cheese. Design an experiment in your STEAM notebooks to determine what ingredients, if any, could be the cause of the stomach ache. Ask volunteers to share out their experiments.

2. Revisit the task from the previous day. Ask students to determine additional remaining independent variables and design experiments to test their impact on the voltage generated. Examples may be the width of the wind turbine blades, the shape of the wind turbine blades, the motor they are using, etc.

3. Students should finalize the tables listing the independent variables and the results of their voltage tests.

4. Ask groups to volunteer to share their findings. Lead a structured class discussion and require students to back their claims with evidence.

5. Daily Assessment: Ask students to answer the following questions on a sheet of paper that they will submit. Use these questions to determine if all students are on the right track and to catch any misconceptions:
    a. What is one of the independent variables that you identified today that affects the amount of voltage harnessed by the wind turbine?
    b. How did you test?
    c. How did you know that it impacted voltage?

Day 4 – Voltage Contest

Standards Addressed: 12, 13, 15, 16

Essential Question: How do I use the Engineering Design Process to light LEDs?

1. Do Now: Instruct students to design a model of the optimal wind turbine blade in Sketchup. Students should use data to select the variables of the blade that are optimal and then build them into the model in Sketchup.

2. Use the "Do Now" activity to segue the class into a discussion about optimizing the wind turbine blade while considering multiple variables. We discuss what an optimal wind turbine looks like, referencing the data table that each group completed last class period.

3. Explain that each group will participate in a voltage contest, in which the design which generates the most voltage will win. One by one, instruct each group to test their design using the fan at the front of the room. As each group tests their design, take note of the voltage generated by each design. You may consider providing a prize to the student group with the highest voltage generated.

A NOTE FROM THE TEACHER

You may use a faculty member with a specific need as your client. However, consider selecting a community-member or local business owner with a specific need as your client. If the client is external, make sure you plan necessary arrangements as far in advance as possible. Alternatively, if you cannot acquire a client., consider creating a fake client and developing a back story for the client.

Day 5 – Introducing the Kinetic Wind Sculpture Project/Meeting the Client

Standards Addressed: 1, 14, 16

Essential Question: What information do I need to gather from the client to create the kinetic sculpture?

1. For the past few days, the students have been prepared for the introduction to their client without knowing much about the larger project.

2. Do now: Provide students with the **Kinetic Wind Sculpture Project Brief.** Discuss the goal of the project and the various deliverables. Let the students know the client will be arriving shortly.

3. Before the client arrives, they must work in their groups to generate questions for the client for about 20 minutes. Instruct the students to use pages two and three of the **Kinetic Wind Sculpture Project Brief (Research: Interview Questions for The Client)** to generate interview

questions for the client. Take about 10 minutes to discuss the questions that the students developed to ensure they are on the right track.

4. Once the client arrives, instruct the class to ask him/her questions. During the interview each student needs to ask a new, unique, appropriate question that helps the class get a better understanding of the client's needs. Each student is also tasked with taking notes about the client's needs. In addition, one student from the class should serve as the recorder during the interview, which includes writing down questions and client answers on a Google document, which will be shared with the whole class.

Day 6 – Generating a List of Constraints

Standards Addressed: 1, 14, 16

Essential Question: How do the client's needs inform the list of constraints?

1. Do Now: Instruct students to answer the following questions in their STEAM notebook: What were the main takeaways from your interview with the client? What appeared to be the most important theme to the client about the Kinetic Wind Sculpture? Briefly discuss students' answers.

2. Instruct students to turn to page four of the **Kinetic Wind Sculpture Project Brief (Research: Constraints List).** Instruct students to use their notes from the client, as well as their knowledge of wind turbines, to develop a list of project constraints for the sculpture. Instruct students to organize the list into "needs" and "wants." Students should prepare this list to submit at the end of class.

3. Once students submit the constraints list, instruct them to research existing kinetic sculptures by using page five of the **Kinetic Wind Sculpture Project Brief (Research: Existing Kinetic Wind Sculptures).**

4. Daily Assessment: Students will submit their synthesized list of project constraints. Review it and provide feedback.

Day 7 – Rapid Prototyping

Standards Addressed: 15, 17

Essential Question: How do I incorporate principles and elements of visual art in our kinetic wind sculpture?

1. Do Now: To implement this unit, students should be familiar with principles and elements of visual art. As a review, display a picture and engage students in a discussion about the elements and principles of art. This discussion is not graded, but used to help students review the material, which they will apply to the sculpture.

2. Instruct the class to turn to pages six through eight of the **Kinetic Wind Sculpture Project Brief (Research: Elements & Principles of Sculpture).** Instruct students to individually take notes on the definitions of each of the words on pages six through eight. Instruct students to get into groups of three. Give groups 90 seconds to "rapid prototype" an example of a particular element or principle of 3D art given a simple set of tools and materials. Tools and materials may include: Construction paper (2 sheets per group), X-Acto Knives, X-Acto Mats, Scissors, Hot Glue, and Hot Glue Guns. After the 90 seconds, instruct one student from each group to explain how their rapid prototype demonstrates one of the elements or principles of 3D Art.

3. Daily Assessment: Give students seven minutes to individually create a sculpture that demonstrates three of the elements and principles of 3D art.

Day 8 – Sketching a Thumbnail of the Kinetic Wind Sculpture

Standards Addressed: 18

Essential Question: What elements do I include in a thumbnail sketch for my kinetic wind sculpture?

1. Do Now: Display an image the **Bronze Sculpture** and ask students to identify the elements and principles of 3D art that are applied within the sculpture. Ask students to write a brief analysis of the art piece, and engage the students in a whole class discussion.

2. Instruct students to add one additional constraint to the constraints list, which is to incorporate elements and principles of 3D art into the final sculpture. In addition, students must be able to explain how and why they incorporated the specific elements into their sculptural designs.

3. Next, instruct students to use Sketchup to practice drawing their first thumbnail sketch of their kinetic sculpture, doing their best to meet all of the constraints in their project constraints list.

4. Daily Assessment: Display the **Funny Sculpture** and ask students to evaluate it. Then ask the students to respond to this writing prompt and submit at the end of class:
    a. What is the theme of this sculpture? Why do you think that?
    b. What is the subject? Why do you think that?
    c. Identify two other elements or principles of 3D Art that are at work in this sculpture and explain how, specifically, the artist applies them.

Day 9 – Sketching a Thumbnail of the Kinetic Wind Sculpture, continued

Standards Addressed: 17, 18

Essential Question: How do I use the constraints list to inform my design?

1. Do Now: Create two thumbnail sketches based on the constraints list that the students created. Instruct students to write an evaluation in their STEAM notebooks about the two thumbnail sketches based on the constraints. The purpose of this exercise is to give students the opportunity to evaluate someone else's work so that they can improve upon their designs, as well as familiarize themselves with the constraints. Engage the class in a discussion about sketches you created.

2. Class discussion/reflection Sketchup thumbnail: Did your designs meet all of the constraints? Which constraints are more challenging to meet? Are there conflicting constraints? Which of the elements and principles of 3D Design are you choosing to apply and why?

3. Instruct students to turn to page nine of the **Kinetic Wind Sculpture Project Brief (Idea Development: Thumbnail Sketches).** Students are asked to develop four more (completely different) thumbnail sketches using their constraints list.

4. Daily Assessment: Display the Elements and Principles of 3D Art Quiz found here: https://quizlet.com/212791532/elements-principles-of-sculpture-flash-cards/

Day 10 – Comparing Thumbnail Sketches / Selecting the Semi-Final Thumbnail Sketch

Standards Addressed: 17, 18

Essential Question: How does feedback help me improve my thumbnail sketch?

1. Do Now: Instruct students to turn to page nine of the **Kinetic Wind Sculpture Project Brief (Idea Development: Thumbnail Sketches).** Instruct students to use the constraints checklist to evaluate their neighbor's sketches. Have students check off all of the items that meet the constraints criteria.

2. Instruct students to pair up with another student in their group. Have students discuss whether or not the sculpture meets the constraints (in the mind of the designer) but is not clear based on the sketch; and what they like about their sketches, as well as what they are missing. Tells students to give their partner the opportunity to explain the items that are not visible in the sketch so that partners have a better understanding of their vision and an understanding of what they might be missing.

3. Group familiarity with the constraints list coupled with their understanding of the elements and principles of 3D art, should allow each individual to select one final sketch that the each will present to the client. Instruct each student in the group to complete pages 10 and 11 in the **Kinetic Wind Sculpture Project Brief (Idea Development: Final Kinetic Sculpture**

Sketch), drawing the final selected sketch**.** Each group will present the final sketch for feedback during the client gallery walk next class period.

4. Daily Assessment: Students should submit all their thumbnail sketches for your review.

Day 11 – Gallery Walk and Final Design Selection

Standards Addressed: 1, 14, 18

Essential Question: Which design from each group will the client select?

1. Do Now: Instruct students to formally complete a constraints checklist for their final sculpture sketch and then help with setting them up for a gallery walk.

2. Gallery walk with the client: For the gallery walk presentations, each student from each group gets the opportunity to present their final design to the client. While each student is presenting, instruct the rest of the class to write two specific "I likes" and two specific "I wonders" (where I wonders are when the students have the opportunity to identify improvements to designs and are required to offer a specific suggestion for improvement).

3. The client will narrow down the field of potential kinetic sculptures from each group to one. (Based on student designs, the client may select a design today or he/she may ask for another iteration of designs after narrowing down the designs that are most responsive to her earlier requests.) Direct the client to put a checkmark in the box on the upper right-hand corner of page 11 of the **Kinetic Wind Sculpture Project Brief (Idea Development: Final Kinetic Sculpture Sketch).** This checkmark should remind each group which design the client selected.

4. Daily Assessment: Assess the written feedback that students provided their peers. In addition, students are assessed on their design and interaction with the client.

Day 12 – Creating the Supply List / Signing the Group Contract

Standards Addressed: 1, 13, 14, 17, 18

Essential Question: Who is the best fit for the various roles?

1. Do Now: Remind each group that the client put a checkmark on the winning design in the box on the upper right-hand corner of page 11 of the **Kinetic Wind Sculpture Project Brief (Idea Development: Final Kinetic Sculpture Sketch).** Instruct groups to create a materials list based on the sketch and the constraints list. Instruct each group to submit the **Kinetic Wind Sculpture Order Form.** Tell students that you will provide all tools and some materials, but they will have to procure some on their own. Explain that submitting the order

A NOTE FROM THE TEACHER

Tell students to use recycled materials from home or from the school recycling. Additionally, suggest shopping for materials at the dollar store or a thrift store. Provide basic materials and tools, such as wood planks, cardboard, saws, glue guns, and glue sticks.

form this early will ensure that groups will have the materials they need by the time they begin the build on day 16.

2. Next, explain that each sculpture will be divided into four major parts, of which each team member in the group will oversee the development. The components include 1) base, 2) blades, 3) rotational components, and 4) electrical system. Tell students to take a few minutes to decide who will oversee each component.

3. Provide students with the **Group Contract** document. Instruct students to discuss the following roles and assign one role per person in the group:
    a. Materials Expert: This role serves as the expert on the materials and uses their understanding of the function of the material/product to decide on the material/product. This person is also in charge of giving the exact dimensions of the products to the Computer-Aided Design (CAD) Expert.
    b. CAD Expert: This role creates the geometrically correct CAD file in Sketchup.
    c. Assembly Expert: This role researches the ways that all of the parts will be assembled and is in charge of finding all of the products for assembly. This person is also in charge of giving the exact dimensions of the products to the CAD Expert.
    d. Procurement Manager: This role is in charge of finding the most affordable parts given the products from the Assembly Expert and the Materials Expert. This person's role also includes communicating with other groups about interfacing with the different parts and creates a plan that combines all of the parts of the sculpture.

4. Once the groups have assigned the roles and signed the group contract, instruct them to complete the **Kinetic Wind Sculpture Timeline.** Explain that the only parameters with which they must align is that they have to develop a three-day schedule for designing each piece of the sculpture in Sketchup (for days 13-15) and a four-day schedule for building the sculpture (for days 16-19).

5. Collect the **Kinetic Wind Sculpture Order Form, Kinetic Wind Sculpture Timeline,** and the **Group Contract** at the end of class. Review and provide feedback to the timeline and the drawings.

Day 13 - 15 – Designing the Parts of the Kinetic Wind Sculpture

Standards Addressed: 2-11, 14

Essential Question: How do I design my part of the sculpture in a way that complements every part?

1. Do Now: Instruct each group to respond to the following prompt:
    a. What are our goals for today?
    b. What are the tasks that we can accomplish without help?
    c. What are the tasks that we need help with?

2. Day 13: Instruct students to draw a close up sketch of their part of the sculpture on page 12 of the **Kinetic Wind Sculpture Project Brief (Kinetic Art Sculpture "Section" Sketch)**. Sketches need to include all dimensions and materials labels. Collect the sketches at the end of Day 13 and provide feedback to each.

3. Days 14-15: Instruct students to sketch their respective part of the sculpture in Sketchup. Explain that they should use the feedback you provided. Instruct the students to sketch the part with extreme attention to detail and to include material labels and measurements.

4. As each student in the group works on his/her respective component, serve as a consultant, spending at least 15 minutes per day with each group. Provide guidance where and when needed.

5. On the final day of the design process (day 15), have each individual in each group present their design to the class. Engage the class in a feedback discussion about each piece.

6. Daily Assessment: Instruct each student to respond to the following prompts to turn in:
    a. Students respond to this question: _____ is information I need to move forward next class period. _____ is going to get this information between now and then.

Day 17 - 20 – Building the Kinetic Wind Sculpture

Standards Addressed: 2-11, 14, 15

Essential Question: How do I build a functional kinetic wind sculpture?

1. Do Now: Instruct each group to respond to the following prompt:
    a. What are our goals for today?
    b. What are the tasks that we can accomplish without help?
    c. What are the tasks that we need help with?

2. Most of the materials should be in at this point. Instruct each group to do an inventory of the materials and determine what they have and what they are missing.

3. Students are still in the same group and have the same roles, but the roles have changed slightly:
    a. Materials Expert: This role is responsible for taking the raw materials and making them into the individual components for the design (e.g., cutting 2x4s, stripping wires and soldering them into a working circuit, etc.).
    b. CAD Expert: This role is responsible for providing the materials expert with accurate measurements, as well as organizing and numbering all of the materials as the Materials Expert processes the parts.
    c. Assembly Expert: This role is responsible for assembling the parts as they come available.

d. Procurement Manager: This role is the project/parts integrator. This role is responsible for integrating all components into one cohesive design.

4. As each student in the group works on his/her respective component, serve as a consultant, spending at least 15 minutes per day with each group. Provide guidance where and when needed.

5. Daily Assessment: Instruct each student to respond to the following prompts to turn in:
   a. Students respond to this question: _____ is information I need to move forward next class period. _____ is going to get this information between now and then.

Day 21 – Presenting the Kinetic Wind Sculpture to the Client

Standards Addressed: 13, 16

Essential Question: Does the sculpture meet the constraints and the needs of the client?

1. Organize a date and time for the client to come back to the class for the sculpture unveilings. One person from each group should represent the group as the speaker to explain the way the kinetic sculpture works.

2. Use the **Kinetic Wind Sculpture Rubric** to grade the kinetic sculptures.