**Lesson 4 - Creating the Prototype/Model**

**Problem statement:** The City of \_\_\_\_\_\_\_\_\_ is advertising a Request for Proposal (RFP) from Engineering Firms to develop the area of land next to \_\_\_\_\_\_\_\_\_\_\_\_\_ to encourage physical activity and outdoor fitness, as well accessibility for all in the community.The RFP’s scope would include additional energy resources to supplement the community’s energy needs as well as provide energy back into the development. The RFP would require the developed land to provide the community with sustainable attractions for all ages and abilities. There is an open space next to the \_\_\_\_\_\_\_\_\_\_\_\_ Middle School that has opportunities for potential energy (see attached topography map). Bids for the project are being solicited.

The Request For Proposals criteria set out by the City of \_\_\_\_\_\_\_\_ is as follows:

* Space for the park is limited
* The space must be accessible to all members of community.
* The proposal must provide its own energy requirements.
* Proposals addressing health and fitness needs of the community will be given special consideration.

Our class is going to submit a proposal to design and build a human-fueled energy park - Sustainable Person Powered Areas [SPPA]. Each group in our class will be responsible for a portion of the SPPA. As middle-schoolers, we love to move! Using our understanding of science and working together in engineering groups, how can we channel our energy to have fun, stay healthy, build friendships, and serve our community?

This lesson fits into the Problem Statement as a core lesson where students will use the engineering design process to create and build a prototype /model of an attraction for the park.

**Learning objectives:**

* Students will use the engineering process to design a prototype/model.
* Students will plan and build a prototype/model for their energy attraction.

**Lesson standards (NGSS, CCSS, CTE):**

MS-ETS1-1.

Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS - ETS1-4

Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

MS - PS3 - 2

Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

Ms - PS3 - 5

Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

[CCSS.ELA-LITERACY.RST.6-8.7](http://www.corestandards.org/ELA-Literacy/RST/6-8/7/)

Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

[CCSS.ELA-LITERACY.SL.7.1](http://www.corestandards.org/ELA-Literacy/SL/7/1/)

Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.

[CCSS.ELA-LITERACY.SL.7.1.B](http://www.corestandards.org/ELA-Literacy/SL/7/1/b/)

Follow rules for collegial discussions, track progress toward specific goals and deadlines, and define individual roles as needed.

[CCSS.ELA-LITERACY.W.7.2](http://www.corestandards.org/ELA-Literacy/W/7/2/)

Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.

[CCSS.ELA-LITERACY.W.7.2.D](http://www.corestandards.org/ELA-Literacy/W/7/2/d/)

Use precise language and domain-specific vocabulary to inform about or explain the topic.

MATH: (extension)

[CCSS.MATH.CONTENT.7.G.B.6](http://www.corestandards.org/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.PRACTICE.MP1](http://www.corestandards.org/Math/Practice/MP1/) Make sense of problems and persevere in solving them.

**Soft skills:**

Communication, Collaboration, Critical Thinking, Creativity, Produce Results

**Locally and/or personally relevant for students:**

Middle school students learn best with hands-on experiences, and this lesson, due to the hands-on activities, is highly engaging and meaningful for this age of students.

**Connections to career and educational pathways:**

In this lesson, students will work out details of their plan, build models and make drawings to illustrate and communicate their ideas, and draft a proposal. This connects to careers in mechanical and civil engineering, power generation and green energy, architecture and civic/urban planning, and technical writing.

Students can explore these career paths on this site: <https://kids.usa.gov/teens/jobs/index.shtml>

**Materials:**

Problem Statement and detailed RFP; access to Know/Need to Know results; science notebooks with relevant research; What is a Model? Packet; What is a Model? Answers; Model Graphic Organizer (optional); chart paper; computers; tagboard tents; graphic organizer for additional research, Engineering Design Packet; as well as an assortment of recyclables such as: cardboard pieces (flat and 3D forms); string, tape, paper, wire, paper or plastic cups, straws, etc.

**Lesson preparation:**

Teacher should prepare a materials center with many options for building models. Also, create a poster with the engineering design process for use during the lesson. This poster should be available at all times during the unit.

|  |
| --- |
| **Engineering Design Process Poster (*Sample*)** |
| **Ask: What’s the problem, and how have others addressed it? What are the constraints, and what are the criteria for success?**  **Imagine: Brainstorm possible design solutions.**  **Plan: Make diagrams/sketches of designs.**  **Create: Build designs and test them.**  **Improve: See what works and what doesn’t. Repeat steps as necessary to optimize the design.** |

**Time required:**

2-4 sessions of 45 - 60 minutes

**Grouping of students for instruction:**

Students should be grouped in teams of 3-5 students. Teams could be chosen randomly or by interest/choice.

**What is the instruction? Consider the PBL Procedure that is being addressed here:**

Explore the Curriculum: Students will be engaged in the iterative process of gathering information, sharing information, and generating possible solutions.

|  |  |
| --- | --- |
| **Teacher** | **Student** |
| **Day 1: Initial, individual designs**  Today we will explore the question: What might our park attractions look like, and how will they function to create or store energy?  Let’s look at the **Engineering Design Process** poster and with a partner, decide where our class is in the process and what comes next.  Read aloud from the poster the 5 steps in the process.  Call on student pairs to give ideas. Emphasize the process is **iterative** (define if needed - repetitive), so we may return to these steps several times.  Most likely students will realize, but emphasize if they do not:  Up until now, we have been understanding the problem and its constraints/criteria, brainstorming ideas, researching possible solutions, and learning about energy transfer. Now it is time to actually design and then build possible solutions.  The teacher explains: in the next few days, we will be working in our small groups to:   1. Determine a possible design solution (attraction for the park) using the Engineering Design Process, keeping in mind criteria and constraints in the RFP 2. Draw/sketch out the design on the final proposal 3. List materials needed to build a model/prototype 4. Have initial design approved by teacher 5. Use materials allowed to build a model/prototype of the design   May want to have students write this list of tasks in notebooks.  This may be a good time to have students explore the career paths of designers on the site: <https://kids.usa.gov/teens/jobs/index.shtml>  Now, before we can begin the design and build of our model, we need to remind ourselves of group **norms** (define if needed - an accepted way of behaving that most people agree with) needed for the design process to work. (Teachers use norms as needed).  What are some questions to keep in mind as we create our norms?  Example:   * How will we divide the work fairly?   Talk with a partner and come up with 2 more questions to help guide our norms. Write these in your science notebook.  Have partners share out at least one question and record on chart paper.  Other possible questions:   * What will we do when we have a disagreement? * What will we do if someone is not doing their job? * How will we allow all ideas to be heard?   We will soon get into our teams, and before you can begin your design, you need to:   1. Come up with a set of group norms and record them on your tagboard table tent. 2. Your whole group must come to **consensus** (define if needed - general agreement) on the norms 3. Have them approved by the teacher before beginning design work.   Review criteria and constraints dictated by the problem statement and the RFP. In addition, discuss what parts of the iterative process may need to be repeated today and over the next session. *Example: Students may need to conduct further* ***research*** *as design problems surface. Or, further* ***brainstorming*** *may be required.*  Present a list of materials, with a sample set for students to touch, feel and consider for their design. (10-20 min)  Hand out Engineering Design Document/sheets   * Ask students to independently design 2 prototypes, labeling the materials used in each. * Remind students of Criteria and Constraints.   Teacher reviews student progress. If groups are done, encourage students to begin sharing with their groups their design ideas. Check in with each group to approve designs, facilitate processes and help with next steps.  Wrap Up: (All students should be done with their individual drawings with pros and cons).  Next Steps: Student groups will agree on final design (labeled with materials) and complete handout for final design that will be attached to the proposal.  **Day 2**: **Brainstorm Group Designs**  Learning Targets:   * I can brainstorm initial designs. * I can draw my ideas.   Ask students to:   * get into their assigned groups * take out their individual designs from the prior day, * Review their team norms. * Each group should pick up 1 piece of butcher paper.   Teacher introduces “Participation Quiz”   * Show the participation document on the document camera * Explain to students that this quiz evaluates/assesses students and how they work together in the groups.   During group work - the teacher observes each group, looking for each group to meet the specific participation quiz criteria.  *Optional:*  *Hand each group their results.*  *Display group participation quiz on the board - in “real time.”*  Inform students that we will begin a brainstorming exercise. Outline the importance of “listening to an idea, adding to it and posing a question about it”  Students will:   1. Fold the butcher paper into fourths 2. Groups will have 5 minutes to complete their first design, each person drawing and adding to the design. 3. After 5 minutes, groups will flip the butcher paper to a new section and begin drawing an entirely new idea, each group member adding onto ideas and expanding the design. 4. Repeat for 4 designs.   Ask students to take out their phones to take a picture of their designs OR collect the butcher paper designs for students to refer to tomorrow.  Have students list the materials that they think they will need to build the prototype. This is their homework (to bring in the materials).  Next Steps: Student groups will agree on final design (labeled with materials) and complete handout for final design that will be attached to the proposal  **Day 3:Prototype & Model Build**  **Learning Targets:**   * I can build a prototype. * I can discuss solutions & listen to other’s ideas.   Warm-up/Do Now:   * Ask students to take team norms and identify a norm or character strength that your group may struggle with today. * Student should pick up 1 FINAL DESIGN SHEET (students have two days to complete it, but it does not have to exactly match the final prototype - as it evolves)   Teacher explains/describes the materials available to the class (tape, rulers, rubber bands, etc.)  Teacher outlines the criteria for success to complete ¼-1.2 of their prototype in class.  Teacher encourages student to begin building their prototypes for the remainder of the class.  Exit ticket: Each student shares with their group 1 thing their group did well today.  **Day 4:**  **Introduce Proposal Outline/Exemplar & Checklist**  Learning Targets:   * I can review/incorporate the criteria & constraints of the prototype into the proposal. * I can draft a proposal.   Warm-Up/Do now:   1. Students pick up copy of Proposal Exemplar 2. Open up computers to download Proposal Template 3. Ask students to take out the RFP   Review the Proposal for the RFP and compare it to the Proposal Exemplar. Point out the parallels between the “introductions” between the two documents (this ensures that companies applying to the RFP perhaps have a mission that aligns with the company’s mission etc). Point out that the ‘requirements’ of the RFP align to the ‘Solution’ section of the Proposal. Highlight that the design should include potential materials (i.e. concrete) which differ from materials of the prototype.  Point out the sentence stems and model how to generate responses to the RFP, using this basic proposal template.  *Optional*: *Provide actual examples of proposals used by engineering firms etc.*  Provide time for students time to work in their groups to draft their proposal AND/OR work on their final design.  Suggestions for group work:   * Through Microsoft Office 365 or Google Docs, students share the document and work on it at the same time. * Two students work on the proposal while two students work on the final design drawing   Exit card/Wrap-Up: In Science Journal or scrap paper, have student groups reflect on what they completed in class (be specific), (e.g. wrote 2 paragraphs of proposal), and write out 2 goals for tomorrow. | Students could discuss question, and take out their ideas from their research.  Students discuss answers to the question & identify that they are at the “Design Step”.  Students get into groups, agree upon norms, and create table tents. Get approval from teacher and begin individual design/sketch process.  Students read out as teacher writes a list on the board or refers to the power point of the list of criteria and constraints.  Students get up and touch and examine, explore materials.  Students turn to list of design ideas from Science Journal   * Students independently design two prototypes * Reflect on the pros and cons of the design   Students refer to handout or list of criteria and constraints.  Students take out their initial design drawings (2), and team norms. Students get out team norms and discuss with their group which norm or character strength will be a struggle today.  Students listen and observe the criteria for the participation quiz via the document camera.  Students adjust their behavior to meet the criteria of the participation quiz.  Students all have pencils and are circled around the butcher paper, reflecting on the plot of land that they have, they begin drawing 1 design. Adding images and designs to the drawing.  After 5 min. Students flip to a “clean” side of the butcher paper, and begin a new design idea. Discussing and adding ideas to larger design.  *Optional: Students will list materials needed, and make sure they are within their budget, if a budget is being used.*  Once design is approved by the teacher, students will work in groups to build their model.  Students write out a list of possible materials (or materials/budget provided) to use to build the model/prototype.  *Students get design approval from teacher before they begin the actual build. (Formative Assessment)*  Students take out the materials that they brought for their project.  Students listen for the available materials.  Students begin working in groups to build their prototype (or model) based on their final design.  Students share 1 encouraging thing they did with their group, then share out to the class.  Students collect Proposal Exemplar.  Students open up copy of electronic Proposal Template document.  Students review the highlighted and circled sections of the RFP (which need to be addressed in the prototype AND proposal).  Students refer to sentence stems for support with writing.  Students follow along with image of RFP and Proposal.  Students begin working in groups to create draft of proposal.  Students use scrap paper, to hand into teacher stating goals for tomorrow, to help with accountability. |

**Accommodations:** No special accommodations, although strategies appropriate for ELL students should be considered during the research portion (SIOP, GLAD).

Pose the question: What is the difference between a **model** and a **prototype**? Discuss in partners.

Generally:

**Model**

* Can be any scale, but usually smaller
* Used for display or visual demonstration of the product
* Often consists of only the outside of the product
* Easy and inexpensive to create

**Prototype**

* Usually fully functional, but not fault-proof
* Used for testing and performance evaluation of the product
* Often consists of both interior and exterior of the product
* Often expensive and time-consuming to create

Based on these criteria, what do you think our class will be making?

Whole group discussion. Encourage students to support arguments with evidence from the list of criteria.

Most groups will be creating a **model** rather than a prototype. However, our goal will be to eventually **test** it against a set of criteria, so it needs to function in some basic way.

So that we are all clear about what a model is, let’s look at an example. Pass out What is a Model? Handout.

Teacher leads students through the example up through the sun diagram.

Now, in partners, complete the graphic organizer for the Earth model.

Review answers to organizer to assess for understanding. (need answers)

Explain to students that they will each complete the blank graphic organizer (Model Graphic Organizer) when they are ready to begin building.

**Extensions:**

* Possibly invite a design engineer as a speaker prior to the lesson to hear about the design process?
* Consider adding budget/materials constraints. Document included.
* Students can calculate the scale of the model in relation to the map scale. They could then estimate the volume of space the model will require within the plot. They could justify the size of their model/activity as being reasonable or not for their plot.

**Assessment:**

How will you assess student learning during the problem? Will there be a final product? Will the final product criteria be clear for students from the beginning? Will there be both whole group elements and individual accountability? Attach appropriate rubrics Create rubrics for science notebooks? Attach rubric section which relates to design/build?Next lesson?

Assessment will be through the table tents (norms), science notebook records (notes/sketches/additional research), Model Graphic Organizer, and physical models built. (Formative)

Summative assessment will be the optimized model/design and the written RFP in a later lesson.

**References/Resources:**

Attach any materials students will use during the lesson; e.g., handouts, questions to answer, and worksheets.Acknowledge your sources.

Design Engineering Poster: Nasco <https://www.enasco.com/page/NascoStory_1>

Rube Goldberg:

Honda Commercial: <https://www.youtube.com/watch?v=YWk9N92-wvg>

OK GO! Video: <https://www.youtube.com/watch?v=qybUFnY7Y8w>

Instructional Plan Created by: Kathleen DuCharme, Meghan Palmer, Heather Smith and Shelley Garr