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| **Lesson Title: Battery Design Challenge** | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **4** |
| **Activity Title: The Challenge** |

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| **Estimated Lesson Duration:** | **6 class periods (80 minutes each)** |
| **Estimated Activity Duration:** | **5 class periods (80 minutes each)** |

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| **Setting:** | **Science classroom** |

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| **Activity Objectives:** |

We will… design a green high-performance battery

In order to… drive a toy car, minimize hazardous waste, and maximize battery recycling

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| **Activity Guiding Questions:** |

* How is a Galvanic cell or battery assembled?
* What happens to batteries and their components when they die?
* What factors contribute to the current or potential produced by a redox reaction?
* Do those factors affect current or potential independently, or do they work cooperatively?

| **Next Generation Science Standards (NGSS)** | |
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| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| Asking questions (for science) and defining problems (for engineering) | Patterns |
| Developing and using models | Cause and effect |
| Planning and carrying out investigations | Scale, proportion, and quantity |
| Analyzing and interpreting data | Systems and system models |
| Using mathematics and computational thinking | Energy and matter: Flows, cycles, and conservation |
| Constructing explanations (for science) and designing solutions (for engineering) | Structure and function. |
| Engaging in argument from evidence | Stability and change. |
| Obtaining, evaluating, and communicating information |  |

| **Ohio’s New Learning Standards for Science (ONLS)** |
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| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| Demonstrating Science Knowledge **(D)** |
| Interpreting and Communicating Science Concepts **(C)** |
| Recalling Accurate Science **(R)** |

| **Common Core State Standards -- Mathematics (CCSS)** | |
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| **Standards for Mathematical Practice (Check all that apply)** | |
| Make sense of problems and persevere in solving them | Useappropriate tools strategically |
| Reason abstractly and quantitatively | Attendto precision |
| Construct viable arguments and critique the reasoning of others | Look for and make use of structure |
| Model with mathematics | Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, ONLS and/or CCSS):** |

LO = Advanced Placement® Chemistry Learning Objective

SP = Advanced Placement® Science Practice

SEP = NGSS Science and Engineering Practices

LO 3.8 The student is able to identify redox reactions and justify the identification in terms of electron transfer.

SP 6.1 The student can justify claims with evidence.

SEP 7: Engaging in argument from evidence

LO 3.12 The student can make qualitative or quantitative predictions about galvanic or electrolytic reactions based on half-cell reactions and potentials and/or Faraday’s laws.

SP 2.2 The student can apply mathematical routines to quantities that describe natural phenomena.

SP 2.3 The student can estimate numerically quantities that describe natural phenomena.

SP 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.

SEP 5: Using mathematics and computational thinking

SEP 6: Constructing explanations and designing solutions

LO 3.13 The student can analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions.

SP 5.1 The student can analyze data to identify patterns or relationships.

SEP 4: Analyzing and interpreting data

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

PowerPoint Lesson

Chart Paper

Rubric for Gallery Walk(s)

Rubric for Design/Purchase Plan

Rubric for TED-Ed talk

Guidelines for uploading/posting videos to/from YouTube/Edmodo

Supplies for each team:

* an aluminum soda can (0.3 mm thick) or sheet (1.0 mm thick),
* a copper sheet (0.8 mm thick),
* other metals (zinc, 0.8 mm thick; iron, 0.8 mm thick; Ni, 0.7 mm thick),
* vinegar (5% HC2H3O2),
* table salt (NaCl),
* bleach (5− 6% NaClO, <1% NaOH),
* Drano Liquid Drain Cleaner (1− 5% NaOH, 3− 7% NaClO, 1− 5% Na2SiO3).
* beakers (150 or 250 mL),
* small butter containers (3cm Å~ 12 cm Å~ 3 cm),
* copper wire,
* alligator clip leads,
* clear silicone sealant,
* coffee stirring sticks,
* steel wool, metal cutter,
* pliers,
* small dc motors (1.2− 3.0 V, 0.2− 0.8 A)
* toy cars
* a digital multimeter,
* a ruler, and
* a laboratory balance.

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| **Teacher Advance Preparation:** |

**This activity was inspired by lessons found published on** pubs.acs.org/jchemeduc

(Smith, M. and Gray, F. (2010). “Batteries, Cradle to Grave” *Journal of Chemical Education*. Vol. 87, No. 2, pp. 162-167.)

(Furlan, P.Y., Krupa, T., Naqiv, H., and Anderson, K. (2013). “An Open-Ended Project: Building a High Performance, yet Simple, Household Battery” *Journal of Chemical Education*. Vol. 90, 1341-1345.)

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| **Activity Procedures:** |

Day Two:

1. Warm up Scenario:
   1. Have a toy car on a car rack in drive mode with a student-developed battery from the “An Open-Ended Project: Building a High Performance, yet Simple, Household Battery”
   2. Have SMART Board/PowerPoint displaying two images:
      1. Waste Processing Plant in DC
      2. Summary: “Consequence to Cell Disposal to Landfill”
   3. Introduce the challenge to the students. Do this in a strategic way, by mentioning the essential questions the class has accumulated and how as the instructor, you “pulled” these ideas together to create one essential question for the creation of the challenge. The challenge is to create a green high-performance battery that will operate a toy car.
2. Discuss the constraints of the challenge, which are:

* operating requirements for the toy car (not yet determined)
* cost of building the battery (material and disposal costs)
* materials provided
* time to work on their design (3 days)

Using a digital multimeter, show the class the outputs of the battery powering the toy car. Use this as a visual anchor to identify, explain, and clarify the constraints. Introduce and detail, with rubrics, how the group’s design/redesign will be tested, evaluated and scored.

1. Put the students in groups of three. Give each student a specific job within their groups. Jobs could include: project manager, research manager, chemical engineer. Project manager would be the student who keeps all group members focused on the task for that particular day. Research manager is in charge of getting questions answered and following the constraints of the challenge through the information gathered. The chemical engineer is responsible for what information needs to go on the final design solution and how the components of the design will work together/independently to meet the needs of the challenge. Every group member is responsible for working towards completing the task for the day.
2. Next, have students work with the “Specific Lead-Acid Battery Collection” research topic.
   1. Students will read and conduct research from targeted sources for “Specific Lead-Acid Battery Collection” in order to a create a poster that details
      1. review the structure and content of the various classes of lead-acid batteries,
      2. identify the recoverable components of cells,
      3. describe the relevant recycling processes and
      4. summarize current national or international legislation.
      5. comparisons with collection and recycling issues (7-11) as related to other consumer batteries (12-14) could also be undertaken.
3. To conclude, have students hang their posters (ideally, post-it chart paper), then engage in a gallery walk. Students will utilize a rubric to provide specific feedback to students and also obtain ideas to revise/update their findings.
4. Students will then reflect on the feedback provided and make modifications to their poster. This should begin to reinforce the redesign phase of the EDP.

Day Three:

1. Warm up: Ask students about their disposal and recycling findings from yesterday.
   1. What are the costs of primary batteries (both in materials and waste disposal)?
   2. What are the costs of secondary batteries (both in materials and waste disposal)?
   3. Which type of battery is used to operate small electronics (i.e. toy cars)?
2. Design/Purchasing Plan:
   1. Groups should determine the differences between primary and secondary batteries and determine the most appropriate option for their design.
   2. Guide the groups, using rubric for “Design/Purchasing Plan” to research/re-evaluate their learning throughout the unit to determine the materials they plan to use for their battery as well as the dimensions and arrangement of those components. All of this information should be logged (or cut/glued) into their interactive notebooks/lab journals from the previous activities in this unit. Allow students to work in their groups to begin designing and planning their solution. Encourage students to use ALL their data from the previous activities in this unit to create their solution.
   3. Before moving on, students have to post their design and purchasing plan, evaluate at two other posters and receive feedback from two other teams in a in a modified Gallery Walk.
   4. Students will summarize their findings from observing other groups and their improvement areas from the groups that evaluated their design.

Day Four:

1. Students will work in groups of 3 to implement their revised design of a high-performance, green battery to operate a toy car.
2. Students will test their batteries and collect data regarding current, voltage, run time, distance traveled, and average speed for a toy car operated with their battery.

Day Five:

Students will create, share (Edmodo and YouTube), and assess each group’s design using a TED-Talk type video.

Day Six:

Students will complete the Unit Test – Summative Assessment

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

1. Teacher should be doing check-ins on group progress every day. For example, on days 2-3 teacher should be probing students during their gallery walk to consider the implications/value of other design options as well as how they will incorporate their observations into their redesign.
2. Gallery Walk rubric: groups will be evaluating each other’s designs using a teacher created rubric. Students will have to identify if other groups stayed within the constraints given by the teacher, and pose questions for each group’s design.
3. Students will use peer-graded rubrics to self-assess their original design solutions and will then make modifications based on the feedback from other groups.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

Students will have a unit assessment that will include 30 released multiple-choice items and 4 released free response items (2 long form and 2 short form questions). This will serve as a post-test to matching test items in the diagnostic for the course offered at the beginning of the school year.

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

Students will work in cooperative learning groups (which is beneficial for all learning styles)

Students will be given jobs in their groups based on their individual strengths (for example, students with strong leadership skills could the “Project Manager” while a creative thinker might be the “Research Manager” and the student eager to test out the content/hands-on lab skills will be interested in the “Chemical Engineer” position)

Students can use technology to design their solutions if necessary instead of handwriting/drawing

Students will have the support system (organization) of their interactive notebooks/lab journals to document their progress

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson. |

This lesson was impacted by the time taken to trouble-shoot the previous lesson. As a result, students’ time was limited in making revising and developing more sound solutions to the challenge. This challenge with time also limited students’ modality to communicate solutions to others. While it was originally that students would communicate their solutions in presentation form, their solutions were tests and communicated through trial races with their batteries and toy car. In the future, the improved design and limited constraints in lesson three will allow the necessary timing for students to develop more than one iteration as well as present their product in a more formal capacity