Modeling the Piezoelectric Effect

Grade Band:Middle School and High School	**Topic:** Physical Science

Brief Lesson Description: Students create and revise models to explain how the Piezoelectric Effect works.

Performance Expectation(s):

HS-PS3-2: Develop and use models to illustrate that energy at macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative position of particles (objects). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]

MS-PS2-3: Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]

Specific Learning Outcomes:
Students will explain what piezoelectric materials are and describe their basic properties.
Students will understand and explain the concept of energy conversion, specifically how mechanical energy can be converted to electrical energy using piezoelectric materials.

Narrative / Background Information

Prior Student Knowledge:

Modeling: Students should be familiar with what a scientific model is and how to create a model. Need to refresh student memories? Show the Bozeman Science Video "Developing and Using Models"

Atomic Structure: Students should have an understanding that atoms are composed of protons, neutrons, and electrons and have a variety of structures when they combine to make molecules.

Energy: Students should understand that energy is not created but rather is transferred between objects or transformed into different forms. They should have a basic understanding of how this is applied in a simple circuit.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Developing and Using Models Modeling in 9-12 builds on K-8 and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. ● Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-PS3-2) **Asking Questions and Defining problems** Asking questions and defining problems in grades 6-8 builds from grades K-5 experiences and progresses to specifying relationships between variables and clarifying arguments and models. ● Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museum and other public facilities with	**PS3.A: Definitions of Energy** Energy is a quantitative property of a system that depends on the motion and interactions of matter and radiation within that system. That there is a single quantity called energy due to the fact that a system's total energy is conserved, even as, within the system, energy is continually transferred from one object to another and between its various possible forms. (HS-PS3-2) At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. (HS-PS3-2) These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative positions of the particles). In some cases the relative position energy can be thought of as stored in fields (which mediate interactions between particles). This last	**Energy and Matter** Energy cannot be created or destroyed–it only moves between one place and another place, between objects and/or fields, or between systems. (HS-PS3-2) **Cause and Effect** Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS2-3)

available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS-PS2-3)	concept includes radiation, a phenomenon in which energy stored in fields moves across space. (HS-PS3-2) **PS2.B: Types of Interactions** Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (MS-PS2-3)	

Possible Preconceptions/Misconceptions:

Students may have many different misconceptions about Piezoelectric materials as they work through this lesson. These include:

1. Students might think that piezoelectric materials can generate large amounts of electricity, similar to power plants. In reality, the amount of electricity produced by piezoelectric materials is relatively small and typically used for low-power applications like sensors and small electronics.
2. Students may believe that any material can exhibit the piezoelectric effect if a force is applied to it. However, only certain materials with specific atomic structures (e.g., quartz, barium titanate) have the ability to generate an electric charge in response to mechanical stress.
3. Students might confuse piezoelectric materials with regular conductive materials, thinking they function in the same way. It's important to clarify that piezoelectric materials are unique in their ability to convert mechanical energy into electrical energy and vice versa, unlike typical conductors that only carry electric current.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

Start the lesson by asking students: ***"Have you ever received a musical card to celebrate a holiday?"*** Allow students to share their own experiences. Explain to students that today's lesson will focus on HOW these types of cards work.

Show students an example of a musical card. (You may use a physical card and/or show this YouTube Video). After having all students observe the phenomenon, ask them to work with a partner to make a model of how they think the card works. It may be helpful to provide the following checklist:

1. Diagram of all components in the system with labels
2. Inputs and Outputs of the system
3. Title of system
4. Caption to explain the process.

After students create their initial models, have them share their ideas with one (or more) other groups. Then as a class come up with a consensus of how they think the card works.

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Introduce students to the idea of Piezoelectric materials by showing the TEDEd Video "How to squeeze electricity out of crystals." After showing the video, explain to students that you will be doing a demonstration of how these piezoelectric materials work.

Next, conduct the demonstration "Piezoelectric Materials" from the Ceramic and Glass Industry Foundation. (Materials for this activity can be found in the Material Science Classroom Kit or can be sourced locally). As you conduct the demonstration, students can complete the handout or you can discuss the following prompts as a class:

1. ***What is the piezoelectric effect?***
2. ***What causes the piezoelectric effect?***
3. ***Name a type of material that can have the piezoelectric effect.***
4. ***Name one current use of this material property.***
5. ***What is one potential application for this material? Where could you use the piezoelectric effect?***

(In order to meet the middle school standard associated with this lesson, make sure to ask students to generate questions related to the phenomena observed during the demonstration).

After completing the demonstration, ask students to modify/improve their model from the engage section of the lesson. Again, have them share their ideas with one (or more) other groups. Then as a class come up with a consensus of how they think the card works.

EXPLAIN:
Now that students have experienced Piezoelectric materials, they will learn how they work because of electronegativity and dipoles. Provide each student with a copy of the Piezoelectric Viewing Guide. As students watch the video, they should answer the questions. This can be done on paper or digitally.

After the video, review the correct answers found in the Answer Key. Emphasize that the mechanical energy changes the geometry of the crystal molecules and results in a dipole. This results in voltage that can then be used to control a device such as a speaker in the card.

Additional discussion questions may include:

1. ***Discuss the significance of the geometric and molecular structure of quartz in its ability to exhibit the piezoelectric effect.***
2. ***Compare and contrast the two modes of operation for a piezoelectric crystal: generating an electric current from mechanical deformation and producing mechanical vibration from an applied electric field.***

ELABORATE: Applications and Extensions:

Ask students to work with a partner to determine which ideas from their viewing guide need to be ADDED to their initial model from the engage/explore sections of the lesson. As a class, discuss what ideas they need to add and create additional items for the final model of how the card works. Add these to the original checklist from the explore section.

Allow students time to work with their partner to construct their final model of how the card works. Have them self reflect on the model using the checklist to ensure that all parts are present.

Have students present their final models to the class. At the end of each presentation, students can provide feedback on the strengths and limitations of the model.

EVALUATE:

Formative Monitoring (Questioning / Discussion):
Questions in italics throughout the process, initial and revised models.

Summative Assessment (Quiz / Project / Report):
Students can be assessed using the Assessment Prompts and graded using the Rubric/Answer Key

Elaborate Further / Reflect: Enrichment:
Students will explore the Role of Piezoelectric Materials in Modern Technology to extend their learning. Three possible activities include:

- Research Projects: Students research different applications of piezoelectric materials in various fields, such as medical ultrasound devices, accelerometers in smartphones, or vibration sensors in industrial machinery.

- Case Studies: Students prepare detailed case studies on specific applications, explaining how the piezoelectric effect is utilized and its advantages over other technologies.

- Guest Speaker: Invite an expert in the field (e.g., an engineer or scientist) to discuss real-world applications and future trends in piezoelectric technology.

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Domain Addressed: Self Regulation
Objective: Students will learn strategies to stay engaged and motivated even after the initial excitement of an activity or task has diminished.

Introduction to the lesson using the script: "Piezoelectric materials were initially discovered by Pierre and Jacque Currie in the late 1880s, but the initial excitement of the discovery failed to materialize into practical uses for many years. This often happens in our own lives–we are not excited about things after the newness wears off. Today, we're going to talk about how to stay engaged and motivated, even when the newness of something wears off. This can be helpful for school projects, hobbies, or any long-term goals."

Icebreaker Activity
- **Discussion Prompt**: Ask students to think of a time when they were really excited about starting something new but found it hard to stay interested after a while.
  - "Can anyone share an example of a time when you were super excited about something new, but after a few weeks or months, it wasn't as fun anymore?"
  - Encourage a few students to share their experiences.

Mini-Lecture: Understanding Motivation

- **Types of Motivation**: Explain the difference between intrinsic and extrinsic motivation.
  - Intrinsic motivation: Doing something because you enjoy it or find it interesting.
  - Extrinsic motivation: Doing something because of external rewards or pressures.
  - "Sometimes, our motivation can change from being excited and interested to feeling like we're just going through the motions. Understanding why this happens can help us find ways to stay engaged."

Group Activity: Strategies for Staying Engaged

- **Brainstorming**: Divide students into small groups and give each group sticky notes and pens.
  - Ask them to brainstorm and write down strategies for staying engaged in activities that have lost their initial excitement. Each strategy should be written on a separate sticky note.Examples: Setting small goals, finding a study buddy,etc.
  - **Sharing**: After 5 minutes, have each group share their top 3 strategies with the class. Stick the notes on the whiteboard.

Personal Reflection

- **Reflection Questions**:
  - "Think about a current project or activity that you're struggling to stay engaged with. Write down why you started it in the first place and three strategies from our list that you can use to stay motivated."
  - Allow students a few minutes to write their reflections.

Closing Discussion

- **Sharing and Discussion**: Invite a few students to share their reflections if they are comfortable.
  - Discuss how using the strategies can help them stay motivated and engaged.
  - "Remember, it's normal for the excitement to wear off. What's important is finding ways to keep going and stay motivated."
- **Summary**: Summarize the key points of the lesson.
  - "Today, we learned that staying engaged takes effort and planning. By using strategies like setting small goals and rewarding ourselves, we can keep our motivation high."

INTERDISCIPLINARY CONNECTIONS/IDEAS

English Language Arts: Students write essays explaining the science behind piezoelectric materials, including their structure, function, and applications. Next, Students exchange their guides and essays with peers for feedback, focusing on clarity, accuracy, and effectiveness of communication.

History: Students research the history of piezoelectric materials, focusing on key discoveries and advancements. They will then create a timeline highlighting important milestones in the development and application of piezoelectric materials and present their findings to the class, discussing how these materials have impacted technology and society over time.

Mathematics: Students use a voltmeter to measure the voltage generated by piezoelectric materials under different conditions (e.g., varying force, frequency of bending). The will then plot the collected data on graphs to visualize the relationship between the applied force and the generated voltage. Additionally they can calculate the mean, median, mode, and range of their data. They also discuss any outliers and their potential causes.

Materials Required for This Lesson/Activity

Quantity	Description
2 per class	Piezoelectric Ceramic Disks (Available in CGIF Kit)
2 per class	Piezoelectric polymer films (Available in CGIF Kit)
4 per class	LED bulbs (Available in CGIF Kit)
8 per class	Alligator clip sets (Available in CGIF Kit)
1 per class	Musical Greeting Card
1 per class	Voltmeter

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