Understanding and Experiencing Electricity:
Helping Students Understand the Process of Science through Electricity

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Overview

This unit on electricity is intended to enhance and support the School District of Philadelphia's fourth-grade Science Core Curriculum through hands-on investigations. In this unit, students will gain an understanding of how electricity works and what is needed to complete an electric circuit by developing hypotheses, gathering data, evaluating evidence, and drawing conclusions. The focus will be on the process of learning and developing inquiry skills. This unit will incorporate hands-on learning, cooperative learning, problem-based learning, and inquiry-based science instruction, which all offer means of actively engaging students in authentic scientific problem-solving. Throughout the unit students will consider these questions: What is electricity? What is a complete circuit? What is needed to complete a circuit? How do charges flow? How do different materials affect a circuit? How can a circuit be represented on paper with symbols? How can a circuit be adapted with different materials? What is needed for a valid scientific experiment? Why is it necessary to have a control?

Rationale

Elementary students develop scientific understandings of concepts such as electricity through observation and interaction, rather than through behaviorist pedagogies that are implemented by many elementary teachers. Behaviorism is primarily based on a rewards system that is used to reinforce a desired behavior. The behavior and learning are observed, but the cognitive process in learning is not focused on. A student may not completely grasp the information presented, but may be able to answer the questions correctly. Many teachers rely on readings from textbooks and presentations provided by school district curriculums some of which focus mainly on closed questions that require a specific answer. Behaviorist teaching also typically relies on positive reinforcements such as prizes, good grades, or verbal praise when students provide the correct response (Skinner, 1976).

The presentation of this abstract information with limited reference to the application of the scientific concepts will most likely result in the failure of students to grasp the concepts presented to them. Many students form misconceptions when they are not given the opportunity to make observations and make sense of what they observe through hands-on activities, specifically regarding the concept of electricity. When students are unable to apply what they read or are taught, they have difficulty mastering these concepts. The following skill base needs to be understood thoroughly by the teacher and meaningfully taught to the students in order for them to grasp electricity as a whole.

Electricity

In order to understand electricity, students need to know that everything in the universe is made of atoms. The center of an atom is called the nucleus and it is made of particles called protons and neutrons. The protons have a positive charge and electrons have a negative charge and the opposite charges are attracted to each other. Electrons are moving around the nucleus, constantly spinning to stay as far away from each other as possible. The two electrons in the shell closest to the nucleus have a strong force of attraction to the protons. The electrons in the atom's outermost shell do not have a strong force of attraction to the protons and these electrons can be pushed out of their orbits. If a force is applied to them, they can move from one atom to another and these moving electrons are electricity (Energy Information Administration, 2013).

Circuits

Electricity travels in circuits that must be a complete path before the electrons can move. If a circuit is incomplete, or open, the electrons cannot flow. When a light is switched off and on, the circuit is being opened and closed. For a bulb to light, it must be connected to the circuit at two points, the tip contact (the metal l button on the bottom of the bulb) and the base contact (the metal side of the bulb's base). When connected correctly, the charge flows from an electric wire, through the light bulb, and back out another wire (Energy Information Administration, 2013). This activity shows the transformation of energy as the chemical energy from the battery transfers into light energy when it turns the light on.

Conductors and Insulators

Electricity will only flow through a conductor. Conductors are materials that have movable electrons so they can "conduct" the electron current or flow of electrons. Most metals are considered to be good conductors of electrical current. Some include copper, silver, gold, aluminum, and iron. Copper is the most used material because it is a very good conductor of electrical current and less expensive than silver and gold.

Insulators do not allow the flow of electrical current. Insulators are materials whose electrons do not freely roam through the materials and therefore do not allow the flow of electricity. Some common insulator materials are glass, plastic, rubber, air, and wood. Insulators are used to protect us from the dangerous effects of electricity flowing through conductors. For example, the rubber coating wire on a cord is an insulator.

Common Misconceptions

There is often an assumption that student misconceptions arise mysteriously within students when they reach a certain age or higher grade, when in fact these misconceptions are often specifically taught in earlier grades. Teachers need to be aware that it is often because of misinformation in curriculum texts or prior education that influences students' concept of electricity. Most textbooks do not make it a point to encourage teachers to address misconceptions, but this can be a powerful tool because learning which concepts are wrong helps students avoid these deterrents to learning (Sefton, 2002).

One misconception is that electricity flows from the battery to the light bulb to light it up. Many students are unaware that the charge continues to flow around the circuit in a circular motion (in a series circuit) over and over through the battery, through the wires, and through the light bulb. There is a path provided by flowing electrons or charged ions. Electric currents in copper wires are a flow of electrons, but these electrons are not supplied by the batteries but already exist in the wire. The electrons in a circuit are already there before a battery is even connected. Instead of thinking that batteries or generators create the electricity, the correct statement is that batteries and generators *cause* electric charge to flow.

Another misconception is when conductors are defined as something through which electricity can flow, instead of something that contains movable electrons or electricity. Insulators should be defined as something that does not contain moveable electrons or electricity. There is also a misconception that charge flows at different rates throughout the circuit. However, the charge flows at the same rate where it enters the light bulb as where it exits the light bulb. The charge is not stronger where it exits the battery or flows through the battery again. In fact, even when no current is flowing, the free electrons in the wire move randomly. The current flow in a series circuit occurs simultaneously at all points in the circuit. When an electron leaves the negative terminal of the battery, an electron enters the positive end of the battery at the same time and when one electron enters the light bulb at one end of the circuit, another electron exits the light bulb at the same time at the other end of the light bulb (Aydeniz, 2010).

Overcoming Misconceptions

Students are going to come into the classroom with prior knowledge, which will guide their understanding of new information. It's crucial for teachers to pay attention to the incomplete understandings, false beliefs, and misconceptions that are brought with students to science class. In order for students to develop understanding in an area of inquiry such as electricity, students must have accurate knowledge, understand the facts and ideas in the unit area, and organize the information and knowledge in a way where it can be applied in other situations. Each of these misconceptions will be addressed in the unit and teachers should make a point to help students overcome them (Aydeniz, 2010).

Objectives

This unit will help students to develop an understanding of how electricity works and what is needed to complete an electric circuit through various investigations. Students will be challenged to light a bulb with just one wire and a battery. They will discover how the filament of the bulb works to light the bulb. Build and compare simple circuits with a focus on how connections are made

- Student will begin an inquiry into the science of electricity. They will discuss what they already know about electricity and what they want to know.

- Identify the essential components of an electric circuit and understand their functions.

- Students will be able to use their knowledge of circuits to make a motor run and discover how to get electricity from a battery to this receiver. They will also understand what a switch does in a circuit and how it controls the flow of electricity.

- Using their knowledge of circuits, students will propose hypotheses about what materials are good conductors and which are insulators. They will then test them in a circuit.

- Students will use their knowledge of circuits to ask a question, develop a hypothesis, and evaluate evidence about the number of batteries and bulbs used in a circuit. Students will test the size of the wires, the number of batteries used, and the number of bulbs in a circuit and evaluate the evidence.

- Each pair of students will use two wires to connect their battery to a light bulb.

- Students will use their knowledge of circuits to ask a question, develop a hypothesis, and evaluate evidence about the number of batteries and bulbs used in a circuit.

- Students will increase their understanding of and ability to carry out the scientific method.

Standards

The lessons and ideas presented in this unit are appropriate for fourth grade students studying the concept of electricity. The lessons provide a basic understanding of circuits and terms associated with electricity like complete circuit, incomplete circuit, filament, conductors, insulators, and inquiry. This unit will provide a framework for further investigation of electricity including real world applications and physics courses in years to come. This unit will help students fulfill the Pennsylvania Academic Standards for: Science, Reading, Writing, Speaking and Listening. The Standards are listed in the Appendix.

Strategies

Activating prior knowledge through inquiry-based learning:

Students come to formal education with a range of prior knowledge, skills, beliefs, and concepts that greatly influence how they view and interpret the environment around them. This affects their abilities to remember, reason, solve problems, and acquire new information. Therefore, teachers must pay attention to this prior knowledge and address the false concepts that the students bring with them (Polman, 2000).

In this unit, students are encouraged to ask questions, make predictions, test their hypotheses, and discuss results. In this way, students will be able to witness for themselves evidence of scientific concepts that either support or refute their beliefs. Each lesson is designed to build on the foundation of the previous lesson. The proceeding lesson is intended to require information learned earlier and combine it with new inquiries and investigations in order to establish more knowledge about electricity. This scaffolding will help students develop an accurate and organized understanding of electricity and associated concepts (Polman, 2000).

Problem-Based Learning:

The best way for students to learn science is to experience the problems and try to solve them. To do this, real-world problems are presented for students to investigate what they need to know and want to know. In a problem-based learning environment, students take responsibility for what is learned and how it is learned. The teacher guides the investigations through challenging questions and well-planned lesson structure, but the students use collaboration and inquiry to problem-find, problem-solve, and evaluate results.

Cooperative Learning:

This unit will incorporate cooperative learning where students need each other to complete a task and are expected to participate in tasks that are necessary for the group's success. The teacher circulates around the room as a facilitator, but the students carry out their tasks without constant instruction by the teacher. In cooperative learning, all members have the opportunity to make their own contributions, develop respect for all members, problem-solve constructively, and learn from one another.

When students participate in engaging learning activities in well-planned, structured, and supportive cooperative groups, their anxiety levels are reduced and they are able to receive information. Cooperative groups tend to generate more participation and stimulate multiple brain regions. The amygdala is the small part of the brain in the temporal lobes that is linked to emotions and aggression. When the amygdala is hyperactive, the pathways block information from entering the memory. When the amygdala is relaxed, more information can enter the memory banks and be stored for later retrieval because there is nothing blocking the flow of information (Willis, 2007).

The students are able to benefit from each other's strengths and communicate ideas to one another. Each group will need all students to participate in order to complete the task. Students are responsible for accomplishing their tasks in the way that they think best, which will be seen throughout the unit. If the group work is successfully planned, it will help build a supportive classroom community, which will increase self-esteem and academic performance.

In cooperative learning, there is often more than one answer or more than one way to solve the problem or create the project. This leaves the options open for students exploring electricity and asking further questions. Following the cooperative learning that will be observed for assessment, students will complete individual responses to the activity in order to ensure individual student involvement and understanding (Willis, 2007).

Hands-On Learning:

Students will be given materials to observe, explore, and learn from hands-on throughout this unit rather than the behaviorist method of teaching and learning. While learning facts and definitions is important in any subject of science, children need to be able to physically apply the information that was taught, specifically in an electricity unit. They need to understand the relationship between the structure and function of the circuit and its components in order to understand electricity. Hands-on interaction will help to accomplish this (Polman, 2000).

Vocabulary Four Square:

The vocabulary four-square method of instruction is used in this unit because it allows students to learn new vocabulary words using their individual prior knowledge to make a personal connection to the word. There are different templates that can be used for the four-square graphic organizer, but in each template students are required to think about the word in different ways. Some of the templates require synonyms and antonyms, definitions in the students' own words, a description of what it is, using the word in a sentence, (Cockrum, 2007). See Appendices A and B.

Science Notebooks:

Science notebooks can be used in the science classroom to help students develop, practice, and refine their science understanding. They can respond to experiments and investigations by organizing their thoughts regarding the new information. Science notebooks also help students enhance their reading, writing, mathematics, and communications skills. They offer many opportunities to develop and enhance students' communication skills, written, visual, and oral. Even students who may have poor writing skills can use observational drawings and graphs to show their learning misconceptions and their correct conceptions. Teachers can use these notebooks to guide their teaching and take note of misconceptions and mastery of skills. They can formatively assess concept development at the students' ability level (Gilbert, 2005).

Classroom Activities

Unit Instruction Plan/Lesson Sequence
Unit: 4th Grade Science: Electricity Focus for Learning: Students will gain an understanding of how electricity works and what is needed to complete an electric circuit by developing hypotheses, gathering data, evaluating evidence, and drawing conclusions.
Lesson 1: Introduction to Electricity **Objectives**: Student will begin an inquiry into the science of electricity. They will discuss what they already know about electricity and what they want to know.

Materials: chart paper, students' science notebooks, pencils

Procedure:
The teacher will begin by distributing the students' Science notebooks and asking the students to set up a KWL (Know, Want to know, Learned) chart. Individually, they will record what they already know about electricity in the first column and what they would like to know about electricity in the second column. Students will then quietly discuss what they recorded with the 4 -5 other students at their table. Each table will provide 2-3 things they know about electricity and 2 things they want to know. This information will be recorded on a class KWL chart. The "learned" column will be filled in as each lesson progresses.

Students will then be asked to respond to the following question in their notebooks:
How do you think you can get the light bulb to light up using 2 copper wires, a battery, and a small light bulb? Draw a picture of how you think it will work.

Volunteers will draw their predictions on an additional chart in front of the classroom.

Duration: 30 minutes

Lesson 2:
Part 1: Lighting a Bulb: Can you light a light bulb using two wires and a battery?
Objective: Each pair of students will use two wires to connect their battery to a light bulb and make it light up.

Materials: two wires, battery, light bulb, vocabulary four-square hand-outs, pencils

Procedure:
Each pair of students will collect their materials and use them to create a complete circuit that will light a bulb. At the end, they will add what they learned in the lesson to the L portion of their KWL charts in their notebooks.

Questions: As groups find a way to light the bulb using two wires, the teacher will circulate around the classroom and ask each group:
Where did you connect the wires to the battery?
Where did you connect the wires to the light bulb?
What happens when you touch the wire to the glass part of the bulb?

Duration: 45 minutes

Assessment: Observation, Science notebooks

Part 2: Can you light a light bulb with just one wire and a battery?

Objective: Students will use only one wire, light bulb, and battery to make a complete circuit.

Materials: one wire, battery, light bulb

Procedure:
Each pair of students will use only a wire, a light bulb, and battery to make a complete circuit.
Questions: As groups find a way to light the bulb using only one wire, ask:
How do you know when electricity is flowing in a bulb circuit?
How did you get the bulb to light with only one wire?
What is important to remember about making a complete circuit?
How many places on the battery did you have to connect? Where were they? [two, the top of the battery
and the bottom]
How many places on the bulb did you have to connect? Where were they? [two, the side of the
metal band on the bulb and the very bottom tip of the bulb]

Assessment: After each pair has had an opportunity to create a complete circuit, students will read the following definitions with their partner and determine which part of the circuit matches each definition. Next, they will be given a paper that can be folded into four sections to create a Vocabulary Four-Square template. A Vocabulary Four-Square includes four of the following sections: what the word means in the students' own words, a picture of the word, a sentence with the word, characteristics (what is it like?), and examples and non-examples. See Appendices A and B.

Filament: The thin wire in the light bulb that glows when an electric charge goes through it. The filament is connected at the bottom tip of the light bulb and on the metal side so that the current can flow through the bulb from one side to the other side.

Electricity Receiver: The part of the circuit that uses the energy to make something happen.

Electricity Source: The part of the circuit that provides the electric current to make something happen.

Circuit: the pathway through which the charge flows from the D-cell to the light and back to the cell is a circuit. The circuit must form a complete circle from one end of the D-cell back to the other end of the D-cell for the charge to flow.

Duration: 45 minutes

Lesson 3:
Making a Motor Run
Objective: Students will be able to use their knowledge of circuits to make a motor run. Students will include a switch to open and close their circuit.

Materials: electric motor, D-cell, 1 switch, 1 circuit base, 1 short wire, 1 light bulb holder, 2 additional wires

Procedure: Review the work with light bulbs.
Students will "turn and talk" with their partner and discuss the following questions:
What was needed to make the light bulb turn on?
Show students how the circuit base is used to hold the components in place.
The captain of each table of 4 will retrieve the supplies for the group.

Questions: As students are using their materials to create a complete circuit, ask them to consider the following questions:
How can you get charges to flow from a battery (electricity source) to this motor (electricity receiver)?
What does a switch do in a circuit?
How is the motor circuit like the bulb circuit? How is it different?

Summarize: The switch controls the flow of electricity. When the switch handle is touching the clip, you have a closed circuit. In a closed circuit, the electricity flows and the motor runs. When the handle is not touching the clip, you have an open circuit. The electricity cannot flow, and the motor does not run.
The chemical energy from the battery is transformed into light energy in the bulb circuit and transformed into motion energy in the motor circuit.

Assessment: Observation and individual response in science notebooks to the following question. Where are switches found around the classroom, in homes, and in cars? What is their purpose? How do they work? Students will add what they learned in the lesson to the "L" portion of their KWL charts in their science notebooks.

Duration: 45 minutes

Lesson 4:
Using Schematic Diagrams to represent a circuit on paper. See Appendix D.

Objective: Students will be able to use symbols to create a schematic diagram to represent a circuit on paper.
Students will recognize the importance of symbols in representing diagrams.

Materials: poster with symbols for each circuit component, science notebooks, circuit materials

Procedure: The teacher will introduce schematic diagrams, which are used to represent a circuit on paper. Electricians often use schematic diagrams to show their work. The symbol for each component will be shown on the board and students will practice these symbols in their science notebooks. A sample circuit will then be demonstrated using the symbols. Students will be given the materials used to build circuits in the previous lesson. In groups of 4, they will build a complete circuit and then use schematic diagrams to represent their circuits on paper. Each student will draw it in his or her notebook and each group will present a larger diagram to the class. Students in each group will be given a different colored marker and will be required to contribute to the diagram using their marker and recording their name with their marker.

Assessment: Observation, science notebooks, group diagram with individual colored markers represented

Duration: 45 minutes

Lesson 5:
Finding Conductors and Insulators

Objective:
Students will be able to sort conductors and insulators after testing them in the circuit.

Materials: circuit materials from previous lesson, plastic, wood, glass, aluminum foil, paper clips, yarn, pennies, plastic straws, rubber bands, metal washers, and a circuit base (optional for convenience).

Procedure:
The teacher will review with the students how a switch worked in a circuit to make it complete. The students will discuss what they needed to make a complete circuit (i.e.: all components must be touching, the wires must be touching the ends of the battery, the wires must be touching the metal side of the bulb and the bottom metal part of the bulb).
Students will then be given a bag of testable objects. In their science notebooks, students will make a t-chart and predict which objects will be conductors and allow the charge to flow through the circuit and which will be insulators and not allow the charge to flow. See Appendix E.

After predicting, students will test each object by attaching the item to a wire by wrapping the stripped wire end around the object or placing the object between the wire and the battery. If the motor turns on, the object is a conductor. If it does not turn on, the object tested is an insulator. Students will then compare their predictions to their results. They will draw conclusions about conductors and insulators based on their results and create a group poster showing the results.

Discussion Question: What do all conductors have in common?

Real life application: In conclusion, the teacher will discuss how insulation prevents fires and contributes to electrical safety in homes.

Assessment:
Observation, science notebook predictions, results, and conclusions. Each group will also be given an 11x 17 paper which will be folded into two sections. Each student will be given a different colored marker and the group will make a list of the insulators and conductors that they tested. The teacher will be able to see each student's predictions and results as well as their individual contribution to the group poster.

Duration: 45 minutes

Lesson 6:
Developing Hypotheses about Conductors and Insulators

Materials: materials needed to complete circuit, various classroom objects

Objective: Students will use their previous knowledge of circuits, conductors, and insulators to develop a hypothesis about what other objects or materials in the classroom would make a good conductor. They will test their hypothesis by testing various objects in the classroom for conductivity.
Students will understand that they need a variety of different materials to make a valid scientific experiment.

Assessment: Observation, science notebook hypothesis and response to results, KWL chart.

Duration: 30 minutes

Lesson 7:
Will the one light bulb (out of two) closest to the battery shine first when the circuit is complete?

Objective: Students will recognize that energy flows through a circuit simultaneously at all points in the circuit.
Students will recognize the importance of developing a hypothesis based on prior knowledge then testing the hypothesis and making new hypotheses based on the results throughout the experiment.

Materials: 2 light bulbs, 1 D-cell, 4 copper wires, 1 switch

Procedure:
Students will make a prediction about which light bulb will shine first or if both light bulbs will turn on simultaneously when the circuit is complete. They will complete the circuit by closing the switch and investigating when each light bulb turns on. They will discover that both light bulbs turn on simultaneously. They will then make a hypothesis about why this works. Students will be given an opportunity to add more light bulbs, batteries, and wires to test their results further and draw conclusions about what they discover. Each student will draw a schematic diagram of their tested circuit, noting when the light bulbs turned on once the circuit was complete.

Assessment:
Observation and schematic diagrams

Duration: 45 minutes
Lesson 8:
Will the brightness of a light bulb be affected by the number of batteries in a circuit?

Objectives: Students will demonstrate understanding of the need to have a comparison

circuit in order to test a hypothesis by describing the problems involved with interpreting the results of an experiment without a control.
Students will evaluate the differences between a control circuit (simple circuit with 2 wires, 1 battery, and a light bulb) and a different circuit.

Materials: various types of batteries, various light bulbs, and various sizes of wires, Creating Circuits Hypothesis Worksheet See Appendix F

Procedure:
The teacher will ask students "Will the brightness of a light bulb be affected by the number of batteries in a circuit?" and begin a class discussion. Students will provide one or two hypotheses to test. Each group of 4 will use the materials provided to test these hypotheses and will need to present a brief report to the class on their conclusions.

As they are working on their experiment, they will be filling out the Creating Circuits Hypothesis Worksheet.

The teacher will be focusing on if each group included a control circuit in their experiment or not. Groups that did not include a control circuit will be focused on to show how difficult it is to make valid interpretations when there is no control.

Questions: What brightness are you comparing your created circuit to? Why is it important to have a control in an experiment?

Assessment: Creating Circuits Hypothesis Worksheet, Observation, Class discussion

Duration: 30 minutes

Lesson 9:
Evaluating Evidence
Objectives: Students will use what they have learned about circuits and electricity to ask a question, develop a hypothesis, and evaluate evidence about the number of batteries, bulbs, wires, and materials in a circuit.
Students will create a circuit that will be compared to the control circuit in the previous lesson.
Students will understand the importance of having a control in an experiment.

Materials: various types of batteries, various light bulbs, conductors, insulators, and various sizes of wires, Creating Circuits Hypothesis Worksheet

Procedure:
Students will be asked to construct a question regarding the number of batteries, bulbs, and other materials in a circuit (e.g. Will the brightness of a light bulb be affected by the number of batteries in a circuit?). They will be reminded of the importance of a control in a valid scientific experiment. They will then develop a hypothesis based on their knowledge of circuits and electricity (The bulb will shine brighter when only one bulb is used compared to a circuit where two bulbs are used). The students will then gather the needed

materials and test their hypothesis. They will record the results and present their conclusion to the class. This will show their ability to apply rules and compare their circuit to the control circuit.

Assessment: Observation and Creating Circuits Hypothesis Worksheet, Group presentation

Duration: 45 minutes

Annotated Bibliography/Resources

Teacher Bibliography

Aydeniz, Mehmet. Measuring the Impact of Electric Circuits KitBook on Elementary School Children's Understanding of Simple Electric Circuits. *Electronic Journal of Science Education, 14(1),*
This article provides information on common misconceptions that children have about electricity.

Beaty, William J (1995). Why is Electricity Impossible to Understand? Retrieved March 20, 2013, from http://www.electricalcontractor.net/ESF/Why%20Electricity%20is%20Impossible%20to%20Understand.htm.
This website provides common misconceptions that children have about electricity.

Bransford, John D., Ann L. Brown, and Rodney R. Cocking. How People Learn: Brain, Mind, Experience, and School. Committee on Developments in the Science of Learning. National Research Council: Washington, D.C. 2000
This resource provides information on how students learn in different environment with various types of instruction. It also shows student misconceptions and the benefits of hands-on activities to disprove misconceptions.

Cockrum, W. A., & Markel, S. L. (2007). The four square vocabulary instruction strategy. *The Journal of the International Association of Special Education*, 8, 98-100.
This article describes the benefits of the vocabulary four-square instruction strategy.

Energy Information Administration (n.d). Science of Electricity. Retrieved March 11, 2013, from http://www.eia.gov/kids/energy.cfm?page=electricity_science-basics.
This website is useful for electricity background and circuit descriptions.

Gilbert, Joan and Marleen Kotelman. (November/December, 2005). Five Good Reasons to Use Science Notebooks. *NSTA Science and Children, 28-32.*
This article provides reasons why science notebooks are beneficial to students.

Polman, Joseph and Roy D. Pea. "Transformative Communication as a Cultural Tool for Guiding Inquiry Science." School of Education, Technology & Learning Center. St. Louis, MO: John Wiley & Sons, Inc. 2000.
This resource provides information about teaching science through inquiry and the benefits of communication.

Sefton, Ian M. "Understanding Electricity and Circuits: What the Text Books Don't Tell You." School of Physics, The University of Sydney, 2002. http://staff.science.uva.nl/~eberg/Antwerpen/MisconceptieArtikelen/Electricity%20Misconceptions%20Sefton.pdf

This article presents misconceptions about electricity and the importance of addressing them in the classroom.

Sippel, Sarah. Effective Explicit Methods of Vocabulary Instruction. Concordia University Portland. 2010.
This article describes the benefits of the vocabulary four-square instruction strategy.

Skinner, B.F. (1976). About Behaviorism. New York: Vintage Books.
This book describes behaviorist teaching and learning methods.

Willis, Judy (March 2007). Cooperative Learning Is a Brain Turn-on. *Middle School Journal*, 38 (4): 4-13.
This article highlights the benefits of cooperative learning.

Student Bibliography

Energy Information Administration (n.d). Science of Electricity. Retrieved March 11, 2013, from http://www.eia.gov/kids/energy.cfm?page=electricity_science-basics.
This website is useful for electricity background and circuit descriptions.

Florida Power and Light Company (n.d.). Kid's Korner: Energy Education is Fun! Retrieved March 13, 2013, from http://www.fplsafetyworld.com/?ver=kkblue&utilid=fplforkids&id=16185.
This website is useful for electricity background, fun facts, and interactive games.

Appendices/Standards

Pennsylvania State Standards

Science:

- S4.C.1.1.1: Identify materials that are conductors and insulators
- S4.A.2.1.4: Use scientific thinking processes to conduct investigations and build explanations by observation, communication, comparing and organizing
- 3.1B: Know models as useful simplifications of objects or processes.
- 3.2C: Recognize and use the elements of scientific inquiry to solve problems
- 3.7A: Explore the use of basic tools, simple materials and techniques to safely solve problems.

Reading:

- E04.B-C.3.1: Demonstrate understanding of connections within, between, and/or among informational texts.
- E04.B-C.3.1.3: Integrate information from two texts on the same topic in order to demonstrate subject knowledge.

Writing:

- E04.C.1.2: Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
- E04E.1.1.2: Develop the topic with facts, definitions, concrete details, quotations, or other information and examples related to the topic.
- E04.E.1.1.5: Link ideas within categories of information using words and phrases (e.g., another, for example, also, because)
- E04.E.1.1.4: Use precise language and domain-specific vocabulary to inform about or explain the topic.

Speaking and Listening:

- 1.6.4.A: Listen critically and respond to others in small and large group situations. Respond with grade level appropriate questions, ideas, information, or opinions.
- 1.6.4.B: Demonstrate awareness of audience using appropriate volume and clarity in formal speaking presentations.

Appendix A

Name: ______________________　　　　**Date: _______________________**

Four-Square Vocabulary Word: ___________________

What is it? (write a definition in your own words)	Draw a picture of the word.
Use the word in a sentence.	Examples: Non-examples:

Appendix B

Name: ______________________ **Date: _______________________**

Vocabulary Word: ____________________

What is it? (write a definition in your own words)	Draw a picture of the word.
Characteristics (What is it like?)	Use the word in a sentence.

Appendix C

My Predictions: Which testable objects are conductors and insulators?

Conductors	Insulators

Appendix D

Schematic Diagram Symbols

Battery: ------- | | --------

Light bulb: ____L_____

Wire: ___________

Motor: ______M _______

Appendix E

Experiment: Conductors & Insulators

Directions: Place an "X" in the correct column to indicate if each item is a conductor or an insulator.

Object Name	Conductor	Insulator
Rubber Band		
Piece of Screen		
Piece of Cardboard		
Piece of Copper		
Piece of Aluminum Foil		
Shiny Nail		
Silver Metal Washer		
Piece of Yarn		
Piece of Paper		
Brass Ring		
Plastic Straw		
Wooden Stick		
Eraser		
Yellow Bingo Chip		
Brass Fastener		
Paper Clip		
Styrofoam Square		
Silver Screw		
Dull Nail		
Black Rock		
River Pebble		

Appendix F

Creating a New Circuit

Read the following scenario and answer the question in complete sentences.

Ms. Mastrobuoni's class was doing an experiment about the needs of a plant and their growth. One student had two plants and wanted to prove that two of the needs of plants are water and sunlight. She put one plant in a dark closet, but still watered it. She put another plant in the sunlight, but did not water it. On the 5^{th} day of the experiment, she observed her plants to make a conclusion about her discovery. She noticed that neither plant survived. What is the problem with her experiment? How would you have changed the experiment?

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Describe each section of your experiment testing the control circuit to your new circuit.

Question:

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Hypothesis:

Materials Needed:

Procedure:

Results:

Conclusion: