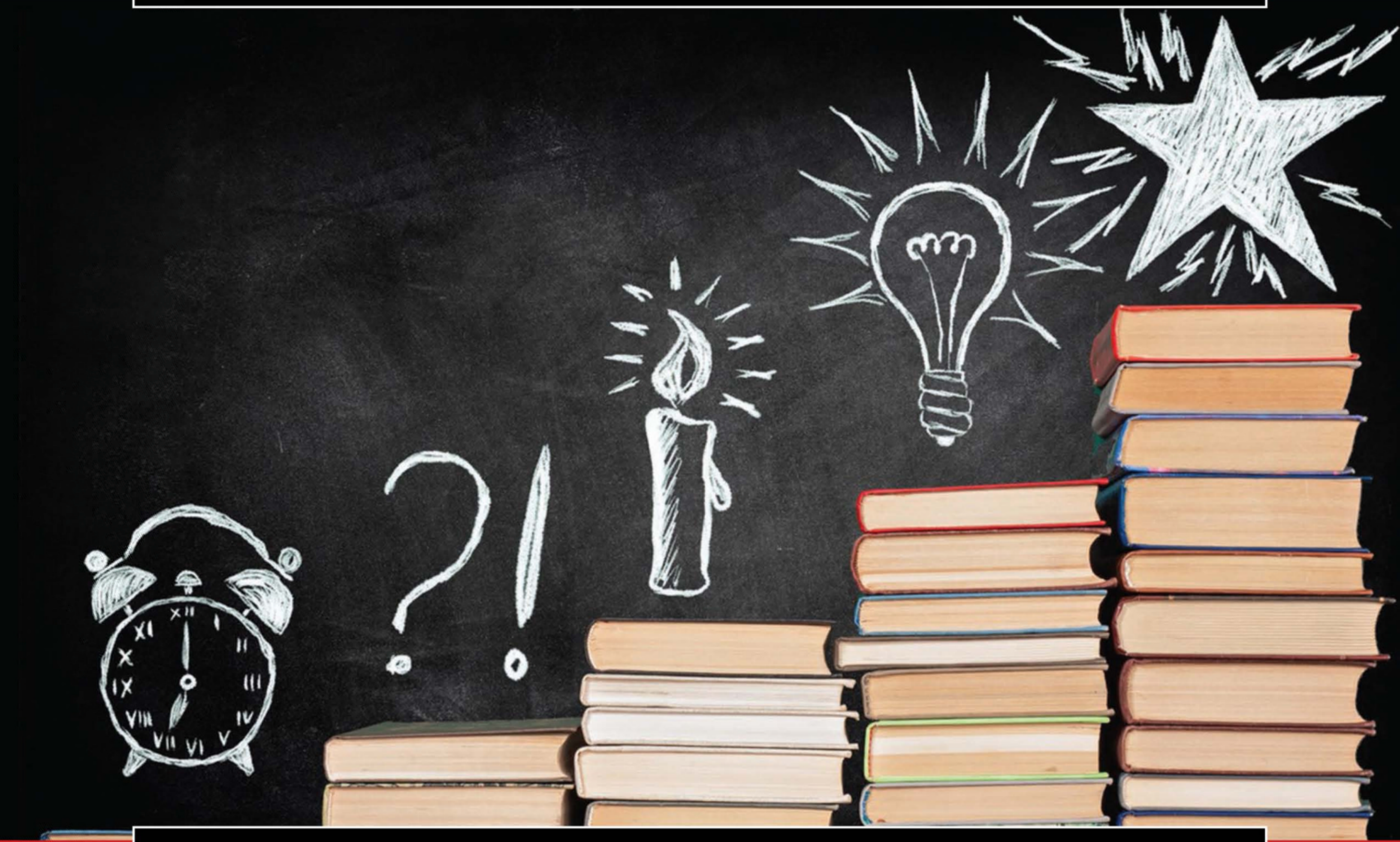
STEPS to STEM

A Science Curriculum Supplement for Upper Elementary and Middle School Grades – Teacher's Edition

Aaron D. Isabelle and Gilbert A. Zinn

Aligned with the Next Generation Science Standards (NGSS)



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PREFACE

A science program that ignores process skills development is like a reading program that ignores the basics of reading and writing.

– Colvill & Pattie

Welcome to *STEPS (Science Tasks Enhance Process Skills) to STEM (Science, Technology, Engineering, Mathematics)*, an inquiry-based science curriculum supplement focused on the development of students' science process skills and problem-solving skills. This program has been created in response to the high-stakes testing environment in schools across the United States in which there has been a departure and de-emphasis on science instruction. We specifically designed this science program to allow your students to learn key science concepts while gaining experience with the basic science process skills through "structured inquiry" STEP activities. Furthermore, with the increased emphasis on STEM (Science, Technology, Engineering, Mathematics) experiences as illustrated in the *Next Generation Science Standards (NGSS)* (Lead States, 2013), students not only need to have a strong foundational understanding of the "big ideas" in science, but also need to be expert critical thinkers and problem solvers prior to the high school years. *STEPS to STEM* will provide your students with these valuable and essential experiences in science.

The vast majority of inquiry-based science curricula used in Elementary and Middle Schools are referred to as "skills-based" curricula. Science process skills or abilities reflective of the behavior of scientists and engineers (e.g. observing, inferring, predicting, measuring, etc.) are used while students are engaged in the active exploration of science concepts. The use of science process skills and the learning of science concepts become inseparable when a skills-based curriculum is implemented. Colvill & Pattie (2002) state that a "skills-based" science program is necessary if teachers base their lessons on problem-solving or inquiry-based learning experiences; "nothing can be more frustrating in a problem-solving program if the work is held up by a lack of skill in the basic processes" (pp. 20–21). Problem-solving activities require scientific reasoning and critical thinking abilities which, in-turn, require proper use of the basic science process skills. Therefore, teachers must not take for granted that students have adequately developed these skills; rather, "we must be deliberate in how we instruct students and encourage their development of these skills" (Froschauer, 2010, p. 6). Providing students with a wide range of meaningful, hands-on science experiences to develop their process skills should be a primary objective for all science teachers. Accordingly, *STEPS to STEM* has been specifically designed to nurture the use of the science process skills while students actively participate in meaningful and engaging science activities. Throughout the program, students *Investigate* everyday materials, develop *Hypotheses*, and then *Test* their ideas related to a particular science concept; this occurs in STEP 1 (Investigate–Hypothesize-Test). In STEP 2, students extend their learning from STEP 1 when they *Observe* a new but related set of materials, *Record* ideas, and then make a *Prediction* (Observe-Record-Predict). In STEP 3 students *Gather* additional everyday materials to *Make* an experimental set-up which will allow them to *Try* out their ideas (Gather-Make-Try) (Note: meaningful connections to *Mathematics* are commonly made during the STEPS either using measurement or mathematical calculations). Lastly, students are ready to engage in a *STEM Center* where they will be more fully focused on problem-solving and/or engineering practices; students extend what they learned in the previous STEPS by focusing on a problem to solve (i.e. a team challenge). Students first conduct *Research* using *Technology* to gain more background information and facts about the problem (as well as information about scientists/inventors who worked on a similar problem); work together to devise a *Plan* to solve the problem (Note: this will include discussion, preliminary designs, sketches, or building models); and then try to *Solve* the problem by testing their design/solution. This sequence can certainly be followed by re-design and re-testing if necessary. This three-phase format of the program will help your students develop a genuine understanding of each science concept while nurturing their process skills and problem-solving abilities. Students will learn to think and act not only like scientists, but also like engineers.

STEPS to STEM combines both "structured" and "guided" experiences for your students. After a set of "structured" STEP activities is completed (which will help students learn prerequisite content knowledge and skills), your students will be engaged in *STEM Centers* which are "guided" problem-solving experiences. These center-based experiences focused on a problem will allow your students to not only practice and refine their problem-solving skills, but also explore their own ideas while thinking/acting like engineers. Using a STEM Center approach, you will be able to actively support and assess students' understanding and use of science and engineering skills, while nurturing students' problem-solving abilities. This, in-turn, will help to inform you about your students' readiness to advance to the next science concept in your curriculum.

Lastly, students are asked to identify which *NGSS* Science & Engineering Practices were utilized during the problem-solving process. This type of self-reflection will further emphasize that the students are using key practices that reflect the behavior of both scientists and engineers.

We firmly believe that quality science instruction, characterized by building process skills in the context of learning big ideas in science, is critical for students' academic development. On the one hand, the use of process skills is not limited to science; rather they will assist students in all academic areas. On the other hand, we live in a highly technological, democratic society which demands that individuals be independent, critical thinkers who are able to make good decisions while working collaboratively with others. As stated by White & Harrison (2012), these skills are not confined to the science classroom, but can be learned and used in other disciplines, as well as transferred to real-world situations; they serve as the foundation for helping students to become effective and responsible citizens capable of making informed decisions on a variety of important issues. Therefore, teachers need to make it a top priority to nurture the development of these practices—not just in the science classroom, but across the curriculum. *STEPS to STEM* will help you to prepare your students for the real-world by first stimulating their interest and curiosity about the world around them. Once students realize that science (and engineering) is all around them, you will have taken the first step to help them develop into life-long learners, a fundamental disposition for success in our global and highly technology society.

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INTRODUCTION

Teacher's Guide for STEPS to STEM

The learning experiences in *STEPS to STEM* are specifically designed to stimulate the interest of your students and enable them to explore specific areas of science at their own pace. Each activity provides opportunities for the students to develop the skills of observation and an understanding of the basic science process skills characteristic of how scientists think and act. Through these activities, students gain experience in manipulating materials, observing changes, measuring objects, recording results, predicting effects, inferring causes, and communicating ideas.

Once students have completed a set of three (3) STEPS focused on a "big idea" in science, students are ready to collaborate using an STEM Center Approach. STEM Centers provide students with the opportunity for extended investigations focused on a single problem. They not only practice their science process skills, but also move beyond these skills as they use critical thinking and problem-solving skills. Although each STEM Center is guided by a particular problem or task, students should be allowed to develop their own questions and problems which derive from their curiosity and interest in the topic.

The program is flexible and therefore adaptable as an individualized or whole-class program that will fit easily into any science curriculum. Only simple, readily available materials are needed for most of the activities.

FEATURES OF THE PROGRAM

STEP Activities

Each chapter includes STEP activities focused on one of seven (7) "big ideas" in science at the elementary and middle school grade levels: Electricity and Magnetism; Air and Flight; Water and Weather; Plants and Animals; Earth and Space; Matter and Motion; Light and Sound. Each activity is correlated with the *Next Generation Science Standards (NGSS)*. Once students successfully complete three (3) STEP activities, they are ready for a STEM Center which makes use of the knowledge and skills learned in the previous STEPS. Each STEP activity and STEM Center utilizes a different set of skills and processes in the development of science concepts. The structure of the individual steps for each area is as follows:

STEP 1	Investigate – Hypothesis – Test
STEP 2	Observe – Record – Predict
STEP 3	Gather – Make – Try
STEM Center	Research – Plan – Solve

The content of the activities has been chosen to satisfy a wide range of interests among your students, in correlation with content of the *NGSS*. In general, the activities are independent of one another and may be performed in any sequence that fits the objectives of your district's science program.

STEM Centers

After each set of STEP activities is completed, students work in small, cooperative groups or teams to complete a STEM Center. STEM Centers are guided centers in which students are able to make decisions, problem-solve, and use critical thinking skills. Each STEM Center is guided by a task or problem; however, as students advance in this program and gain proficiency with the science and engineering skills, students should be encouraged to develop and solve their own problems/tasks.

While using STEM Centers, the teacher should serve as a facilitator of the learning experience, monitor and assess students' progress, and offer assistance as needed. Using STEM Centers, students are given the opportunity to think/act as scientists and engineers. It is also essential for students to share their work and their thinking with their classmates after a STEM Center has been completed. (Note: based upon the readiness of the students, as well as the complexity of the task, a STEM Center may take 2–3 class periods.) In doing so, a sense of classroom community focused on STEM will be nurtured.

Practices versus Process Skills

As stated in the National Research Council (NRC) Framework (2012), the term “practices” are used in the *NGSS*, rather than “science processes” or “inquiry” skills for a specific reason: “We use the term ‘practices’ instead of a term such as ‘skills’ to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice” (NRC Framework, 2012, p. 30).

The following eight (8) Science & Engineering Practices are utilized throughout the *NGSS* and are an integral part of the problem-solving process:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

To encourage self-reflection and emphasis of these practices, after each STEM Center is complete, students are asked to identify which Science & Engineering Practices they feel that they used to solve the STEM Center team challenge. Teachers are encouraged to engage students in discussion about their thinking both during and after the STEM Center has been completed, and to help make them aware that certain key practices were utilized. Students are also encouraged to reflect along with their team members.

STEM Center Tips:

1. Give each team of 3-4 students ample space to spread out the materials. You may consider placing a large piece of chart paper on the table/desks not only to serve as a focal point, but also to make the clean-up process easier. Access to a computer or laptop is essential since students need to conduct background research on the topic.
2. Review safety procedures and the importance of using all materials appropriately.
3. After research has been conducted, instruct each team to develop a plan to solve the problem (Note: you should review each team’s plan before they begin. Also, because students may need to bring in additional materials the next day to complete their design, it is suggested to devote one full class period to “solve the problem.”)
4. Emphasize that although each team will be working cooperatively, each student is responsible for completing his/her own Sci-Book (see next section).
5. Allow students to work for 30-40 minutes at a time, but always leave time for each group to briefly share their findings with the whole class to promote a community of scientists/engineers.
6. After completing each STEM Center, ask the students to share questions or anything new that they wonder about. Keep track of students’ questions and problems on a “question/problem” or “wonder” wall and allow the students to revisit these ideas whenever possible.
7. Once students share what they learned and what questions they have, be sure to infuse and re-emphasize the key science ideas which you want them to learn from the previous STEP activities, as well as the STEM Center experience.

Sci-Book

A science notebook or Sci-Book serves as a companion to this program. Using the Sci-Book, students maintain a record of their completed activities which can serve as a form of authentic or performance-based assessment. Recording ideas, plans, sketches, and questions are especially critical during STEM Center experiences so that students can look back on their work, view their progress, and share their thinking with classmates and with the teacher. This will also help to instill a sense of purpose and pride in using and maintaining the Sci-Book.

Teacher Notes

Each STEP activity contains a copy of the student activity sheet, along with notes and background information for the teacher. This material will help you anticipate and answer any questions that may arise in the course of the activity. You may also elect to transmit some of the background information to the students if you feel it is appropriate; however, each activity should be thought of as a supplementary experience, not specifically intended to teach a concept in depth.

Sci-Terms

Key science terms (language demands) or Sci-Terms are listed after each STEP activity. In the spirit of inquiry-based science, it is suggested that these terms be formally introduced to students in the context of their experiences rather than at the beginning of a particular STEP activity. In doing so, the academic language will be more meaningful to the students because they will be based upon their personal investigations. Students can be given the definitions or they can look up the terms on their own using a science dictionary. In addition, students should be encouraged to add additional ideas from their own experiences to create a working definition for each term.

About Metric Units of Measurement

The use of metric units is steadily increasing in the United States and is the common system of measurement used within the scientific community. It is therefore important to familiarize students with the metric system and to make them as much at ease with it as with the customary English system.

It is generally agreed that this goal is best achieved by avoiding "conversions" about different units and simply using metric units naturally and independently. For this reason, we have adopted a policy in these activities of sometimes using metric units and sometimes using English units. In any given activity, only one system or the other is used throughout. In this way, the students will learn through experience the magnitudes of lengths, volumes, and weights expressed either way. They will learn, for example, about how long 10 centimeters is, just as they have already learned about how long 1 foot or 12 inches is.

CONCLUSION

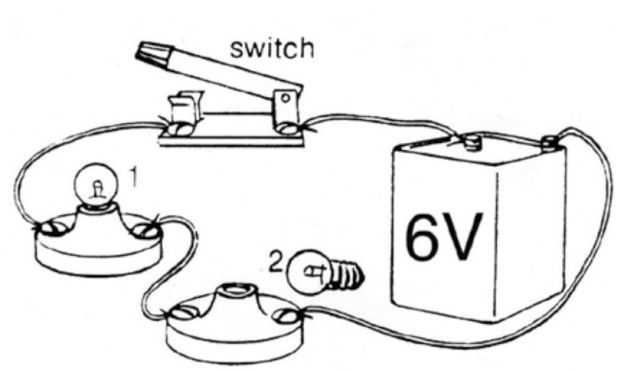
STEPS to STEM is a science curriculum supplement and resource designed to help your students find enjoyment in science and in the process of problem-solving. There are things to do, discoveries to be made, and problems to solve for each individual student in your class. Your students will enjoy the success of finishing each set of STEPS and the accompanying STEM Center, and in many cases, will be left with something tangible to show for their efforts. These rewarding experiences will help to keep students' interest high. Ideally, they will lead to more explorations, curiosity, and observations of the world around them.

ELECTRICITY & MAGNETISM

Step 1: Series Circuits

A. Investigate

1. Set up the electric circuit as shown in diagram. This is a series circuit.



2. Close the switch by pulling the blade down. What happens?

With the blade of the switch pulled down, the circuit is complete. Both bulbs will light.

3. Take out bulb #1. What happens?

When one bulb is removed, the other bulb does not light.

4. Replace bulb #1. What happens?

____

____

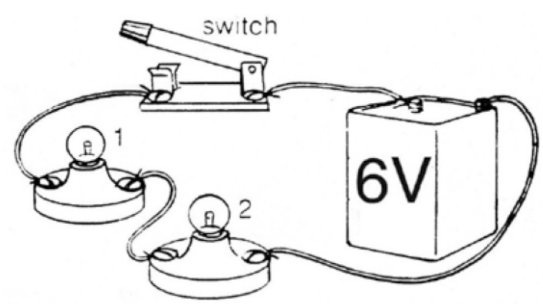
B. Hypothesis

1. In a series circuit, there is:

   __***a***__ a) only one path for the current.
   ______ b) more than one path for the current.

2. When any part of a series of a circuit is disconnected:

   __***a***__ a) the current stops flowing.
   ______ b) the current flows through the other parts.



C. Test

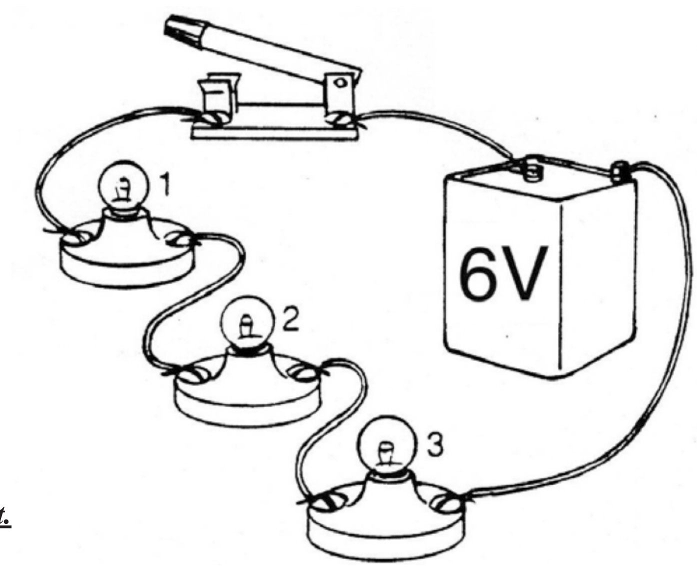
1. Add bulb #3 to the series circuit.

2. Close the switch.
   What happens?

____

____

____



3. Remove one of the bulbs. What happens?

When one bulb is removed the other two will not light.

4. Replace the bulb and remove another. What happens?

As bulbs are added in a series circuit, the brightness of each is decreased.

Teacher Notes:

A. Use any miniature bulb rated at 1.5 volts.

Background Information:

An electric current is a flow of electrons. Electrons are particles with a negative electric charge that are present in all atoms. In metals, some of the electrons move easily from one atom to the next.

The "push" that causes electrons to move through a metal wire is called voltage. A dry cell produces voltage by chemical reactions. The positive terminal of the dry cell attracts electrons. The negative terminal repels electrons. When a metal wire is connected to the terminals of a dry cell, electrons flow into the wire from the negative terminal and flow out of the wire into the positive terminal. Electrons are pushed along the wire from the negative end toward the positive end. This is an electric current.
An electric current cannot flow unless it has a continuous conducting path. If a series circuit is broken at any point, the entire current stops flowing.

An electric current carries energy. This energy is turned into heat and light when the current flows through the metal filament of the light bulb. When more bulbs are added in the series, their total resistance to the flow of current increases. Less current flows and the bulbs shine less brightly. If dry cells are added in series, their total voltage is increased. This causes more current to flow in a circuit.

Sci-Terms:

Series circuit
Electric current
Electricity
Resistance
Electrons
Dry cell
Voltage
Switch

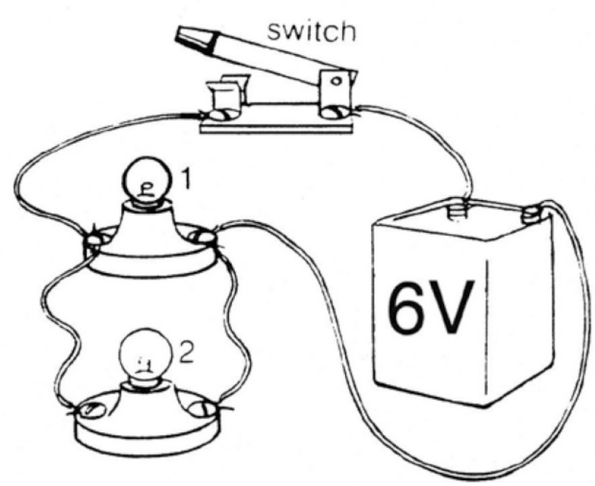
Connections to the *Next Generation Science Standards* (NGSS):

Standard: 4.PS3 Energy (p. 35)
Performance Expectation: 4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electrical currents. (p. 35)
Disciplinary Core Ideas:

- PS3.A: Definitions of Energy. Energy can be moved from place to place by moving objects or through sound, light, or electrical currents (p. 35)
- PS3.B: Conservation of Energy and Energy Transfer: Energy can also be transferred from place to place by electrical currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (p. 35)

Step 2: Parallel Circuits

A. Observe



1. Set up the circuit as shown in the diagram. The two bulbs are connected in parallel.

2. Close the switch. What happens?

In a parallel circuit, each bulb is connected independently to the source of energy--the dry cell. When the circuit is complete, after the blade of the switch is pulled down, both bulbs will light.

3. Remove bulb #1. What happens to bulb #2?

When either bulb is removed, electricity can still flow through the other lamp and return to the dry cell.

4. Replace bulb #1. Remove bulb #2. What happens to bulb #1?

____

____

B. Record

1. Connect 1 bulb, a switch, and a battery in a series circuit.

2. Close the switch. Observe how bright the bulb is. Call this brightness NORMAL.

3. Observe the brightness of the bulbs in each of the following circuits:

   a) 2 bulbs in series with a battery
   b) 2 bulbs in parallel with a battery

4. In the chart, record whether the bulbs are NORMAL, DIMMER, or BRIGHTER.

Kind of Circuit	Brightness
1 bulb in series	NORMAL
2 bulbs in series	***DIMMER***
2 bulbs in parallel	***NORMAL***

C. Predict

1. With two bulbs in parallel, open the switch.

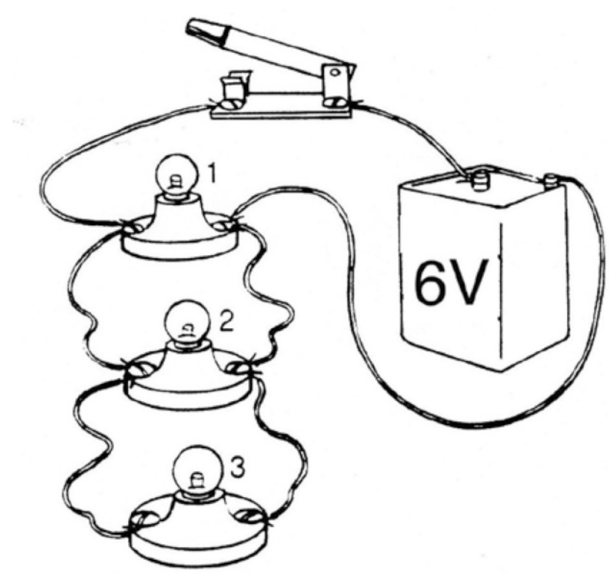
2. Add a third bulb in parallel with the other two.

3. Predict whether the bulbs will be NORMAL, DIMMER, or BRIGHTER when you close the switch.

____

4. Test your prediction. Was your prediction correct? Explain your thinking.

The brightness remains the same-normal--when additional bulbs are added to a parallel circuit.



Background Information:

In a parallel circuit, each branch receives the full voltage of the source of current, making a complete circuit by itself. Therefore, one branch is not affected by opening or closing the circuit of any other branch. Also, the amount of current in each branch remains the same, no matter how many other branches are connected in parallel. Therefore, the brightness of the bulbs remains the same.

However, the source of current must supply a separate current for each branch. If there are many branches, the current drain on a dry cell becomes greater and the cell becomes used up faster. This can be offset by connecting several dry cells together in parallel--positive to positive and negative to negative. This forms a battery. A battery of cells in parallel has the same voltage as a single cell, but it can supply current for a longer time before it wears out. Dry cells in parallel will not make a bulb brighter, because the voltage remains the same.

Sci-Terms:

Parallel circuit
Branch
Electric current
Resistance
Dry cell
Battery
Voltage

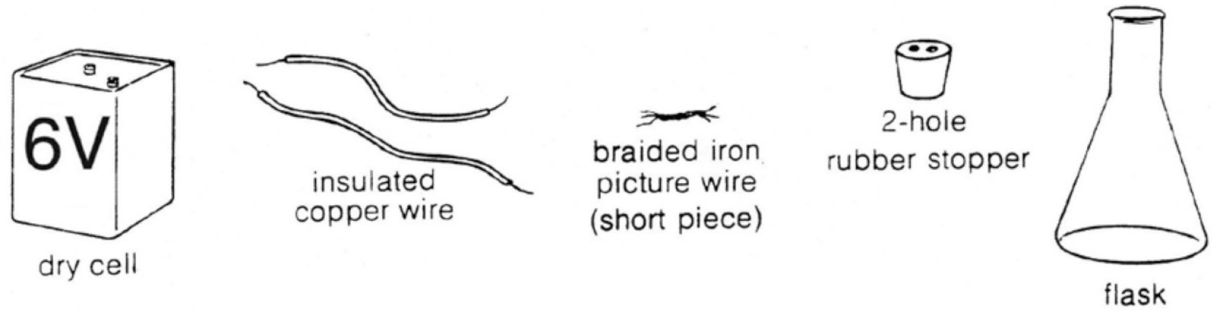
Connections to the *Next Generation Science Standards* (NGSS):

Standard: 4.PS3 Energy (p. 35)
Performance Expectation: 4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electrical currents. (p. 35)
Disciplinary Core Ideas:

- PS3.A: Definitions of Energy. Energy can be moved from place to place by moving objects or through sound, light, or electrical currents (p. 35)
- PS3.B: Conservation of Energy and Energy Transfer: Energy can also be transferred from place to place by electrical currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy. (p. 35)

Step 3: Electricity and Heat

A. Gather



1. Strip ½ inch of the insulation from each end of the copper wires.

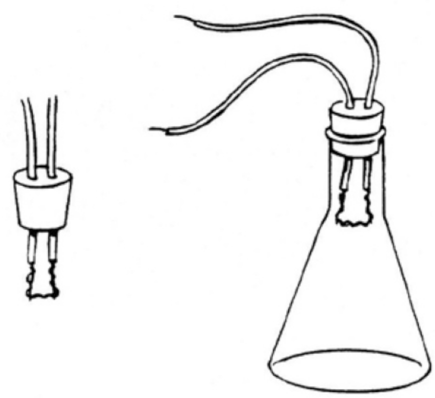
2. Unravel the iron picture wire (this will be the light bulb filament).

B. Make

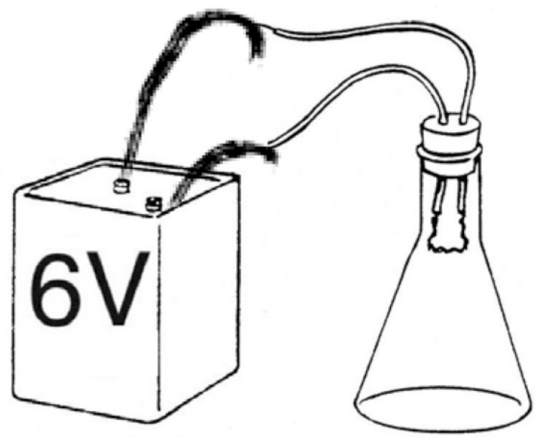
1. Put a copper wire through each of the holes in the stopper.

2. Attach one strand of the iron picture wire to the two bare ends of the copper wire.

3. Put the stopper into the flask.



C. Try



1. Connect the outside ends of the copper wire to the dry cell.

2. What happens to the iron wire (filament)?

The iron wire begins to glow.

3. How does the flask feel?

The flask may soon feel warm due to the heat produced.

4. Darken the classroom. What do you observe?

Light is also produced by the glowing wire.

5. Use 2 batteries in series instead of 1. What happens to the wire?

With more voltage, there will be more current; the wire will get red hot and may melt.

6. Where else can you find electricity being used in this way?

Hot plates, toasters, and electric blankets turn electricity into heat energy.

Teacher Notes:

A. A cork or a piece of clay, with a bottle, can be used instead of the 2-hole stopper and the flask.

B. Be sure to twist the bare ends of the copper wire and the iron wire together.

Background Information:

Iron wire does not conduct electricity as well as copper wire. This "resistance" to the flow of electrons in the iron wire will cause it to get hot and glow. The same thing happens in a light bulb.

Electric light bulbs use tungsten wire or alloys which include tungsten to produce the desired amount of light. Tungsten has a very high melting point and a good resistance to electrical current. Light bulbs do not contain ordinary air. If they did, the tungsten wire (filament) would quickly burn up because of the oxygen in the air. Light bulbs are filled with a mixture of nitrogen and argon gases. Light bulbs eventually burn out because the great heat of the filament causes it to slowly evaporate. The dark area inside the glass of an old bulb is formed by tungsten atoms that evaporated from the wire and condensed on the glass.

During the STEM Center experience, students can use wires (filaments) with different thicknesses, then try different kinds of metal. In addition to using iron, copper, or other metals, students might also try using different thicknesses of graphite used in mechanical pencils to achieve the brightest glow.

Sci-Terms:

Incandescent light bulb
Filament
Current
Resistance
Heat energy
Light energy

Connections to the *Next Generation Science Standards* (NGSS):

<u>Standard</u>: 4.PS3 Energy (p. 35)
<u>Performance Expectation</u>: 4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electrical currents. (p. 35)
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STEM Center 1.1

Team Challenge: *How can your team make a light bulb filament glow the longest and the brightest?* [NGSS 4-PS3-3. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.]

A. Team Research

Using the computer as a research tool, find at least three (3) new facts on light bulbs and filaments that will help you solve the problem [e.g. what makes a light bulb filament glow? What kinds of materials were used for filaments in early light bulbs? What materials are used for filaments in modern day incandescent light bulbs?].

Fact 1:

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____

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Fact 2:

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Fact 3:

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Find two scientists who were involved in the development of light bulbs through the years and identify at least one way that the use of light bulbs has impacted our everyday lives.

____

____

____

____

B. Team Plan

Where do we go from here to solve the problem? Discuss your ideas with your group members and devise a plan. Use the space below for notes and/or sketches of your design:

C. Team Results – Solve

What did you do to help find the solution to the problem? Describe what you did, what you observed, and explain your thinking. (Note: you can use both pictures and words in the space below.)

Write down any questions that you have and anything that you are curious about.

Science & Engineering Practices

During your work in the STEM Center, you used certain key "practices" similar to how scientists and engineers think and act. Identify which Science & Engineering Practices you feel that you were engaged in during the STEM Center problem-solving process. You are encouraged to talk with your team members about this and reflect upon your thinking process. Place a check in the right hand column next to each practice that you made use of:

1. Asking questions and defining problems	
2. Developing and using models	
3. Planning and carrying out investigations	
4. Analyzing and interpreting data	
5. Using mathematics and computational thinking	
6. Constructing explanations and designing solutions	
7. Engaging in argument from evidence	
8. Obtaining, evaluating, and communicating information	