STEM EDA is designed as a three course progression through STEM (science, technology, engineering, and mathematics) topics. Students begin by exploring STEM concepts (STEM Explore, 6th grade), then transition to discovering fundamental concepts (STEM Discover, 7th grade), followed by the application of the concepts (STEM Apply, 8th grade). Throughout each course in the sequence, the engineering design process guides the students through the design and implementation of the projects and concepts.

Welcome to STEM EDA!

STEM Explore, Discover, Apply (STEM EDA) is designed to engage middle school students through a series of hands-on projects that help improve their problem-solving and critical-thinking skills. All projects seamlessly integrate the engineering design process which allows students to creatively explore STEM through design.

This multi-grade level curricula utilizes liberal arts disciplines to provide meaning and depth to the content. Through STEM EDA, students develop invaluable skills focusing on leadership, team-building, creativity, and communication.

STEM EDA’s modular nature provides ultimate flexibility to schools. Teachers can implement the curricula as a standalone elective course, insert specific modules into an existing class, or provide the modules as an after school program.

Grade Progression

<table>
<thead>
<tr>
<th>Grade Progression</th>
<th>6th</th>
<th>7th</th>
<th>8th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explore</td>
<td>STEM</td>
<td>Discover</td>
<td>Apply</td>
</tr>
</tbody>
</table>

What is STEM EDA?

STEM EDA engages middle school students through a series of hands-on projects that help improve their problem-solving and critical-thinking skills. All projects seamlessly integrate the engineering design process which allows students to creatively explore STEM through design.

This multi-grade level curricula utilizes liberal arts disciplines to provide meaning and depth to the content. Through STEM EDA, students develop invaluable skills focusing on leadership, team-building, creativity, and communication.

Goals of Course

- Foster excitement for STEM
- Develop a level of exploration in middle school students through STEM projects
- Provide a context for the engineering design process through “classic” STEM projects
- Drive towards fundamental concepts (at the grade appropriate level) through STEM experiences
There is an energy here that is very contagious!
My students are motivated and excited to come to school and work on this module.
Students who were unmotivated and uninvolved are now key players in their small groups and have found an interest in academics they didn’t think they had.

-Middle School Teacher

A Few Things You Will Notice

The stop sign indicates the end of a section and is a good/suggested stopping place. This symbol is visible in both the student edition and the teacher manual.

Cyber Pop Outs connect the STEM topic to the cyber world.

GREEN BOX
Definitions and notes will be pointed out to the students within this area.

CALCULATION BOX
Space for students to work problems.

This material is based upon work supported by the U.S. Department of Homeland Security under Grant Award Number, 2013-PD-127-000001, Modification #2. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Department of Homeland Security.
The process contains overarching themes as well as defined steps. Use the process as a quick reference throughout the module.

- **Iteration** – Revisiting steps provides the opportunity to improve upon designs.
- **Communication** – Within a design team, communication is essential to reach an agreement on a solution.
- **Teamwork** – Group cooperation provides diverse perspectives and help in accomplishing goals.
- **Creativity** – STEM and liberal arts disciplines are integrated to encourage unique solutions.
- **Imagination** – Opportunity to apply creative thoughts during development offers unlimited options.
Electricity

This is a sample module with extracted pages
STEP 1: IDENTIFYING THE PROBLEM

The United States has been hit by a cyber attack! The attackers shut down the country’s entire electrical grid. The damage is so severe it is not known when power will be restored. You and a group of friends decide to make flashlights to help provide light during the blackout.

You must have a good understanding of electricity in order to make the flashlights, and this will require a lot of research on the topic. Following the research stage, you will use an assortment of materials to design and build your own flashlight.

As you begin, it is important to clearly state the problem that has been presented to you. Identifying the problem will help as you move through the solution by keeping you on task.

In your own words, write a few sentences that identify the problem. 

______________________________

______________________________

______________________________

______________________________

______________________________

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______________________________
STEP 2: RESEARCHING THE PROBLEM

It is important to understand the problem and research areas that will help your team design a solution to the problem.

What are some areas you should research? Why?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
In your own words, describe an electron. 

______________________________

______________________________

Atoms are the basic units of matter. This means that everything is made up of atoms. Atoms consist of a nucleus and negatively charged electrons in a cloud around the nucleus. The nucleus consists of protons and neutrons, but for this lesson we will focus on the electrons that are floating around the nucleus. Electrons are negatively charged particles that provide us with electricity.

Some atoms easily give up or share their electrons with other atoms. Atoms that can easily share their electrons with neighboring atoms are called conductors. Atoms that hold on tightly to their electrons and do not share them are called insulators.

Now let’s go online and research the types of materials that are conductors and insulators. In the space below, list three examples of each from your home or classroom. After you have created your list, trade with a classmate to see if you both agree on conductors and insulators.

**Conductors**

1. ____________________________
2. ____________________________
3. ____________________________

**Insulators**

1. ____________________________
2. ____________________________
3. ____________________________
Use your current knowledge to decide if each object listed below is a conductor or an insulator. Write your answer as either C to indicate conductor or I to indicate insulator. If you do not know the answer to any of the materials listed below, you may need to do additional research on conductors and insulators.

1. Gold Necklace  
2. Silverware  
3. Wood  
4. Keys  
5. Aluminum Foil  
6. Paper Airplane  
7. Window Pane  
8. T-Shirt  
9. Ocean Water  
10. Human Body

**Batteries**

Electricity is provided through a number of different means like power plants and lightning. These are power sources, which is any source that makes electricity. Batteries are also a very common power source and are used to power many devices. For the flashlights you will design, we will focus on batteries.

Why do you think batteries are a more practical power source than power plants and lightning? 

Batteries were first introduced by the Italian physicist Alessandro Volta in 1800. He referred to the battery as a voltaic pile because it used a series of specific materials stacked in a pile which allowed for electricity to be produced. The battery he invented is much like batteries used today because of the electrochemical cells used to convert chemical energy into electrical energy. (Do you see how the term electrochemical cell came about?) We will discuss electrochemical cells in more detail later, but first, let's look at batteries. You use batteries almost everyday in the devices around you. List six devices that require batteries.

1.  
2.  
3.  
4.  
5.  
6.
Depending on the multimeter, the section labeled V may have many different options. In the spaces below, list the dial options on your multimeter and circle the dial setting you will use to test your 9V battery.

Dial options: _______  _______  _______  _______  _______  _______  _______

Let’s test your 9V battery. Connect the red test lead to the red wire coming from the battery and the black test lead to the black wire. Turn the dial to the appropriate setting, and then turn on the multimeter.

What is the voltage value for your battery?

Your teacher will now provide each team with different types of batteries to test with your multimeter. To test batteries that do not have wires, press the metal portion of the black lead to the negative end and the metal portion of the red lead to positive end of the battery. Locate the voltage listed on the battery, set the dial, and test each battery. Record your results in the table below.

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Dial Setting</th>
<th>Voltage Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Circuits

Now that you have tested different batteries for their actual voltage values, let’s build a circuit. A circuit is the connection of electrical components that sends electrons from the negative to the positive end. You will use a 9V battery, alligator clips, and incandescent light bulbs to build your circuits. This is the same configuration from earlier but without the various conductor materials. You will test different circuit configurations and record what happens to the voltage across the light bulbs for each configuration.

We will start with a very simple circuit that uses the 9V battery, two alligator clips, and one incandescent bulb. The drawing on the next page illustrates the configuration of the circuit that you will build. The components are represented as follows:

\[
\text{Battery} \quad \text{Light Bulb} \quad \text{Alligator Clips}
\]
Review

You have learned about the different components you will need to include in your flashlight, and you have worked with electricity in different circuit configurations. Before you start developing ideas for your flashlight, let’s review key concepts that have been discussed.

What is the component in an atom that allows for electricity? ________________

**True or False:** Electrons in an insulator are shared freely, allowing electricity to flow easily. ________________

List two conductors and two insulators. ________________

 Who invented the modern day battery? ________________

How do batteries help create electricity? ________________

The anode refers to the ________________ end of the battery.

The cathode refers to the ________________ end of the battery.

What are electrochemical cells? ________________

Identify the following components in the electrochemical cell diagram.

*Anode, Cathode, Salt Bridge, Half cell 1, Half cell 2, and Flow of Electrons (e⁻ →*)*
How does the salt bridge help the battery function? (Hint: anion and cations.)  

Anions have a ___________ charge. Cations have a ___________ charge.

**True or False**: Anions are negative and give electrons, and cations are positive and accept electrons. ____________________________________________________________________________

Which component is the anode, the cathode, and the salt bridge in a battery built with pennies, zinc washers, and salt water soaked paper? ____________________________________________________________________________

What instrument is used to measure voltage? ____________________________________________________________________________

What are the units that provided the push in a battery? ____________________________________________________________________________

What is Kirchhoff’s Voltage Law? ____________________________________________________________________________

Identify the circuits below as series or parallel.

[Diagram of two circuits, one series and one parallel.]
How does the voltage across the light bulbs in a series circuit relate to the voltage supplied by the battery?

How does the voltage across the light bulbs in a parallel circuit relate to the voltage supplied by the battery?

Explain how switches work.

Identify each circuit diagram component.

BONUS: Determine the voltage for A (light bulb one in Loop 1) and for B (light bulbs in Loop 2) from the information provided in the diagram. Note that the power source is 9V, the total voltage across the two light bulbs in Loop 1 is 9V, and the second light bulb in the Loop 1 has a voltage across it of 4.5V.
STEP 3: BRAINSTORMING SOLUTIONS

Now that you have researched concepts related to the problem and explored the various factors that affect the design of your flashlight, it is time to brainstorm some solutions to the problem.

Remember what you are designing. Refer to your problem statement from Section 1.

You are creating a flashlight in preparation for many days without power due to a cyber attack that shut down the country’s electrical grid. You have a 9V battery with battery clip, multiple incandescent bulbs (at least six), a switch, and alligator clips. You will design the circuitry and the housing for your flashlight. Be creative with the layout of the bulbs, and pattern a design that uses all six bulbs (e.g., a smiley face). You might also want to add your creative touch to the housing with a decorative symbol or name for your design.

Let’s begin with brainstorming ideas for your flashlight design.

Should you use a conductor or an insulator for the housing of your flashlight? Explain.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Think about different flashlights you have used. What are most of the flashlights made of?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

All flashlights have a few things in common. Write down at least three parts that are common to flashlights you have used. Share these with your classmates and try to determine the other important parts of a flashlight.

1. __________________  2. __________________  3. __________________

4. __________________  5. __________________  6. __________________

http://energy.gov/articles/top-9-things-you-didnt-know-about-americas-power-grid
STEP 4: CHOOSING A SOLUTION

Each team should have developed at least three flashlight design ideas. It is now time to choose your final design solution. Keep in mind as you are analyzing the design ideas, you may want to combine ideas to form a new design all together.

How do you begin to choose the final design solution for this challenge?

Three important factors influencing your design decision are: **Brightness** - amount of illumination; **Size** - convenience and ease of transporting; and **Repair** - ease of replacement and repair.

Decide as a class on three other factors that are also important to the flashlight design. Three additional factors are:

1. 
2. 
3. 

A chart is included on the next page listing the three initial factors. Spaces are provided for you to include the three additional factors your class chooses. Notice the second row is labeled as **Weight**. This row will help you assess the importance of each factor and will in turn, help you decide on your overall design. You will use the **Brightness** factor as your basis for comparison. If **Brightness** has a **Weight** of 10, as a class, decide how important each of the remaining factors is compared to flashlight **Brightness**.

For example, your class might decide that **Size** is half as important as **Brightness** because if the light is not bright enough to use, then it does not matter how easy it is to carry. In this case **Size** would receive a 5 in the **Weight** row (blue row). Perhaps your class feels **Size** is more important than **Brightness**, specifically that it is two times more important. In this instance, 20 would be listed in the **Weight** row for **Size**.

Discuss and weigh each factor as a class, and then input the **Weight** on the chart for each factor. The remaining sections of the chart will be described later.
<table>
<thead>
<tr>
<th>Total Points</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>Brightness</td>
<td>10</td>
</tr>
<tr>
<td>Description</td>
<td>N/A</td>
</tr>
<tr>
<td>Design Idea</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td></td>
</tr>
</tbody>
</table>
STEP 5: CREATING & DEVELOPING A Prototype

It is time to start creating your prototype! As you are building your prototype over the next few days, you might want to revisit some of the earlier steps in the design process. That is okay. The next few pages in this manual are left open for you to sketch, make notes, and document the process of creating and developing your prototype. Additional materials, such as scissors and tape, may be needed as you develop and assemble the housing and head of your flashlight.

Thinking Space
Let's take a break from the flashlight prototypes and do some creative writing.

Your team is building a flashlight to provide light while the electrical grid is down. One day while the power is still out, you and your friends stumble upon the cyber attackers’ lair. Their hideout is filled with computers running off of a generator. You have to move stealthily through the maze of equipment to try and shut down the attack. Luckily, you have your homemade flashlight with you.

Together with your teammate, write a story about this experience that provides an answer to each of the questions listed below. You may use the following pages to write your story, use your own paper, or type your story in a Word® document. Teams will present their stories along with their working flashlights in Section 6: Testing and Evaluating the Prototype.

• Where is the lair?
• Who are the individuals behind this attack?
• What is the cyber attackers’ ultimate plan?
• What or who do you encounter in their hideout?
• How do you stop the attackers from carrying out their plan?
• What happens after you stop the attack?
STEP 6: TESTING & EVALUATING THE PROTOTYPE

Let’s test your prototype. Teams will take turns reading their stories and presenting their designs to the class. As you read your story, be expressive and have fun as you demonstrate your working flashlight.

While you are presenting, be sure to note the performance of your flashlight and then answer the following questions. Use the additional spaces to record how your classmates’ flashlights perform.

Does the switch work properly? __________________________

Do the lights turn on? __________________________________

Were there any lights that did not turn on? If so, which ones? __________________________

Briefly describe the team’s story. ___________________________________________________

Flashlight Presentations

Team ___________________________________________

Does the switch work properly? ____________ Do the lights turn on? ____________

Were there any lights that did not turn on? __________________________________________

Briefly describe the team’s story. ___________________________________________________
STEP 7: IMPROVING & REDESIGNING

It is important to take some time to reflect on the project. Looking at what happened during the testing and evaluation phase will help in improving and redesigning.

How closely does your final design match the design you chose in Step 4? Rate your final design on a scale of 1 to 5, where 1 does not match at all and 5 matches exactly. ________________________________

If you answered with a number lower than 5, how did your design change during the construction of the prototype? _____________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

Did the switch work properly? __________________________________________________

Did all of the lights turn on? ___________________________________________________

If all of the lights did not turn on, what problem caused the lighting failure? __________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

If all of the lights did not turn on, how could you correct the problem in order to make the lights work properly? _____________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________