SAFE Chips Project

Engineering, Grades 9-12

DRAFT

SCALE K-12
SCalable Asymmetric Lifecycle Engagement
Precollege Microelectronics Workforce Development

INSPIRE
Research Institute for Pre-College Engineering

PURDUE UNIVERSITY

Cover Information

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Unit Title: SAFE Chips Project
Grade Level Range: 9^{th}-12^{th} Grade

Acknowledgments

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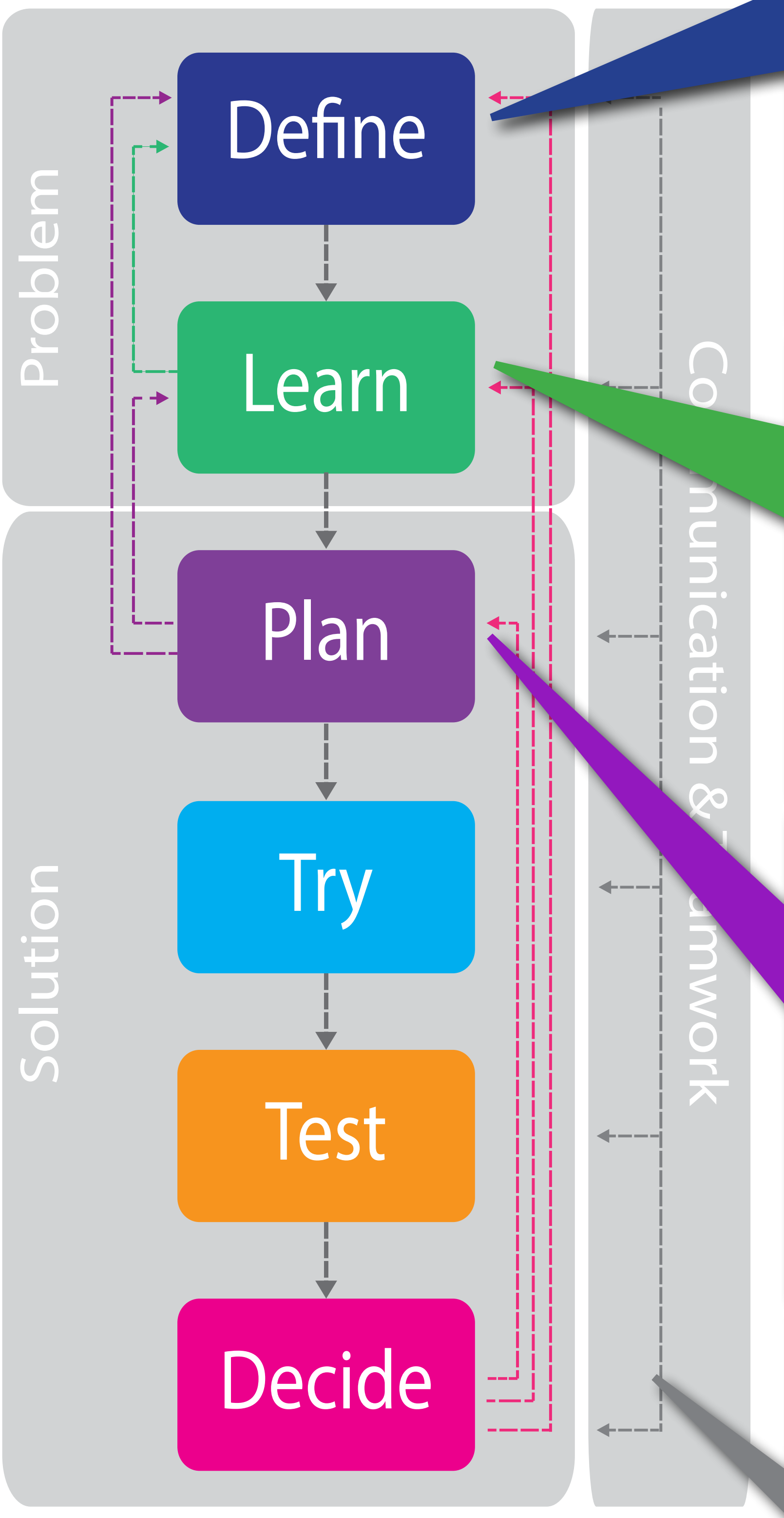
Mentors
Mentor 1
Mentor 2

Overview: Engineering Design Process

Engineering Design Process
A way to improve



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DEFINE THE PROBLEM

- Who is the **client**?
- What does the client need?
- Why does the client need it?
- Who is the **end user**?
- Why might the end user want it?
- What are the **criteria** (requirements)and **constraints** (limits) of the solution?

Problem Scoping:
WHO needs **WHAT** because **WHY**

LEARN ABOUT THE PROBLEM

- What kind of background knowledge is needed?
  - What science/math knowledge will be needed?
  - What materials will be needed?
- What has already been done to solve the problem?
- What products fill a similar need?
- How should we measure success and improvement?

PLAN A SOLUTION

- Continue to specify the criteria/ constraints
- Generate ideas of possible solutions
- Develop multiple solution paths
- Consider **constraints, criteria**, and **trade-offs** (criteria that compete with one another)
- Choose a solution to try
- Develop plans (blueprints, schematics, cost sheets, storyboards, notebook pages, etc.)

COMMUNICATION

- Communicate the solution clearly and make sure it is easily understandable
- Use **evidence** to support why the client should use your solution

TRY A SOLUTION

- Put the plan into action
- Consider risks and how to optimize work
- Use criteria/constraints and consider trade-offs from the problem/plan to build a **prototype** (a testable representation of a solution), **model**, or **product**

TEST A SOLUTION

- Consider testable questions or hypotheses
- Develop experiments or rubrics to determine if the solution is meeting the stated criteria, constraints, and needs
- Collect and analyze data

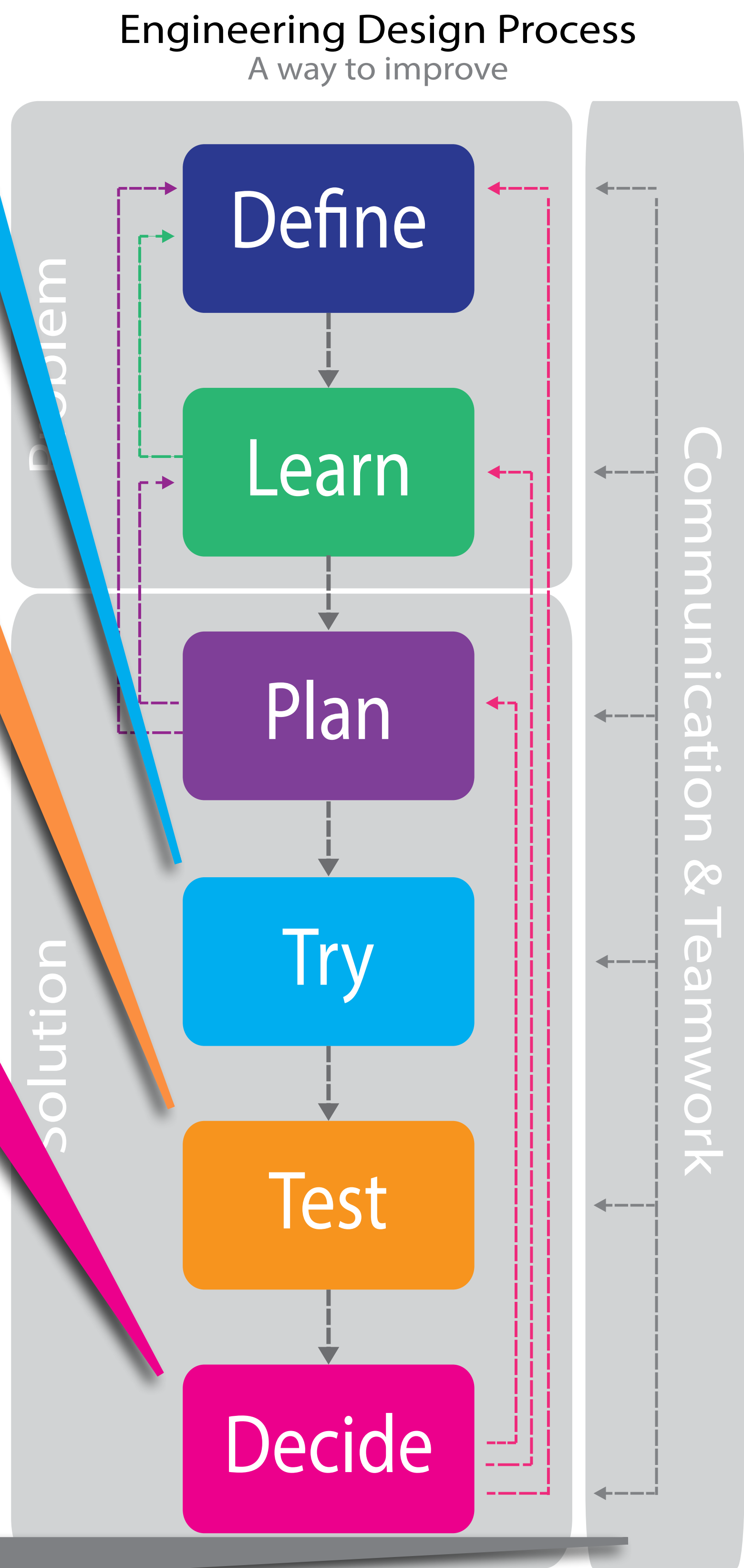
DECIDE IF THE SOLUTION IS GOOD ENOUGH

- Are users able to use the design to help with the problem?
- Does the design meet the criteria and constraints?
- How could the design be improved based on test results and feedback from the client/user?

Iterative nature of design: Always consider which step should be next!

TEAMWORK

- Discuss in teams how the solution meets the criteria and needs of the client
- Consider different viewpoints from each teammate



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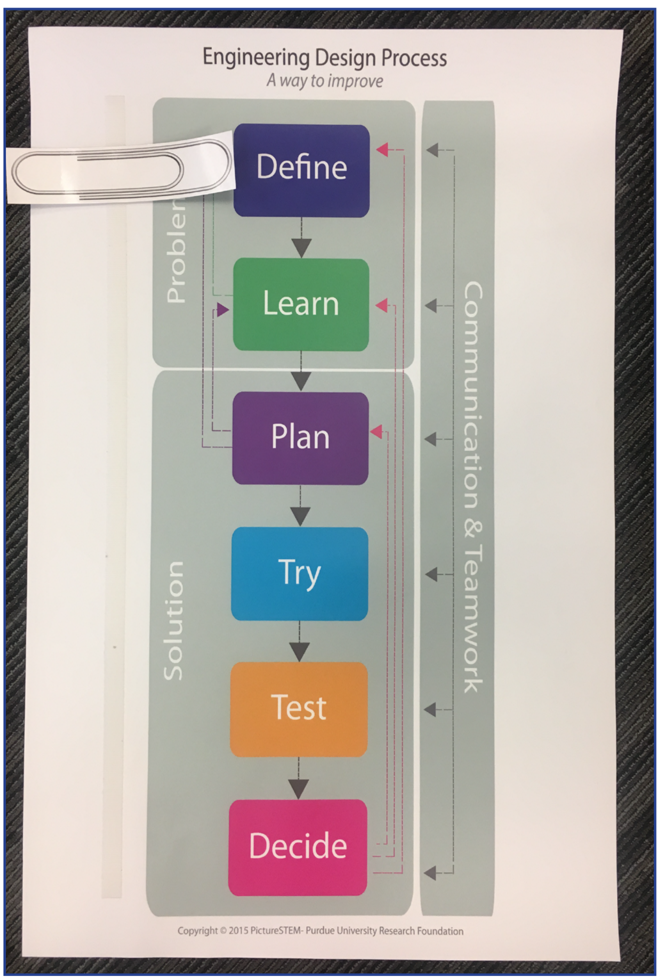
Overview: How to make EDP sliders

How to create the poster

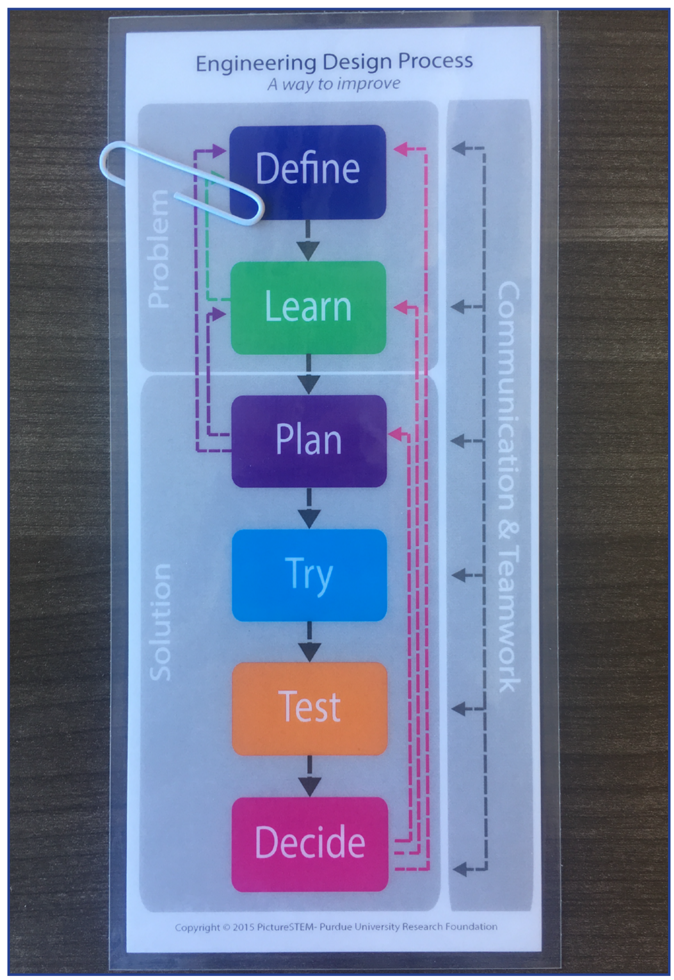
1. Download the high-quality PictureSTEM Slider Poster and the paper clip images from PictureSTEM.org.
2. Print the poster and the paper clip on poster-sized paper and cut to size. High-gloss or semi-gloss paper is the best choice.
3. Use self-sticking Velcro on the back of the paper clip and down the side of the poster so that the paper clip can be placed to point at all 6 sections of the slider.

How to create individual sliders

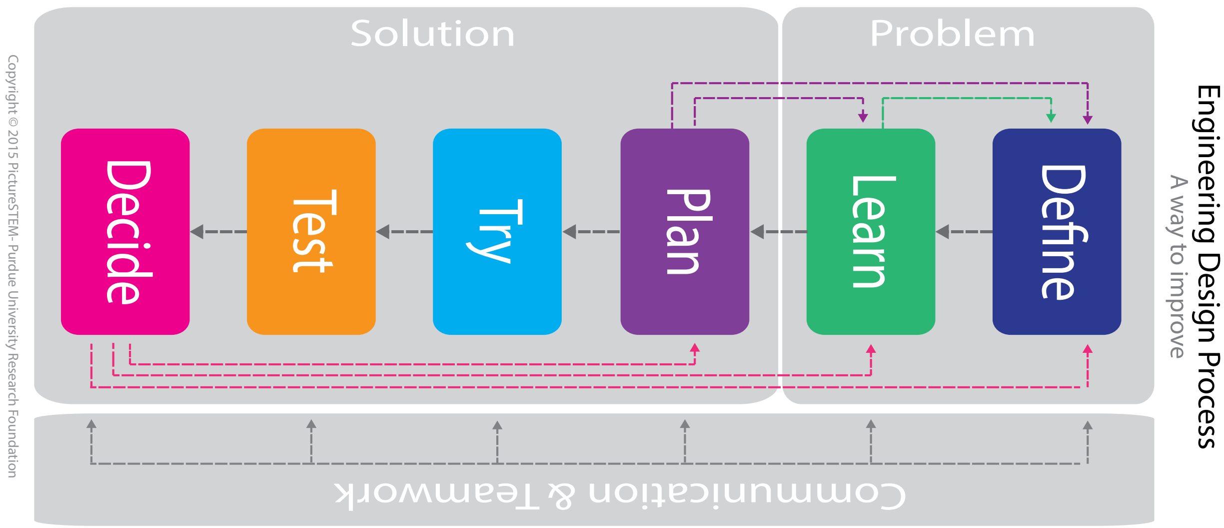
1. Print the sliders on the opposite page - enough for one slider per student in your class.
2. Cut the sliders apart.
3. Laminate the sliders individually.
4. Use a jumbo paper clip as the pointer for each slider.



Poster



Individual slider


Engineering Design Process
A way to improve
Problem
Solution
Define
Learn
Plan
Try
Test
Decide
Communication & Teamwork
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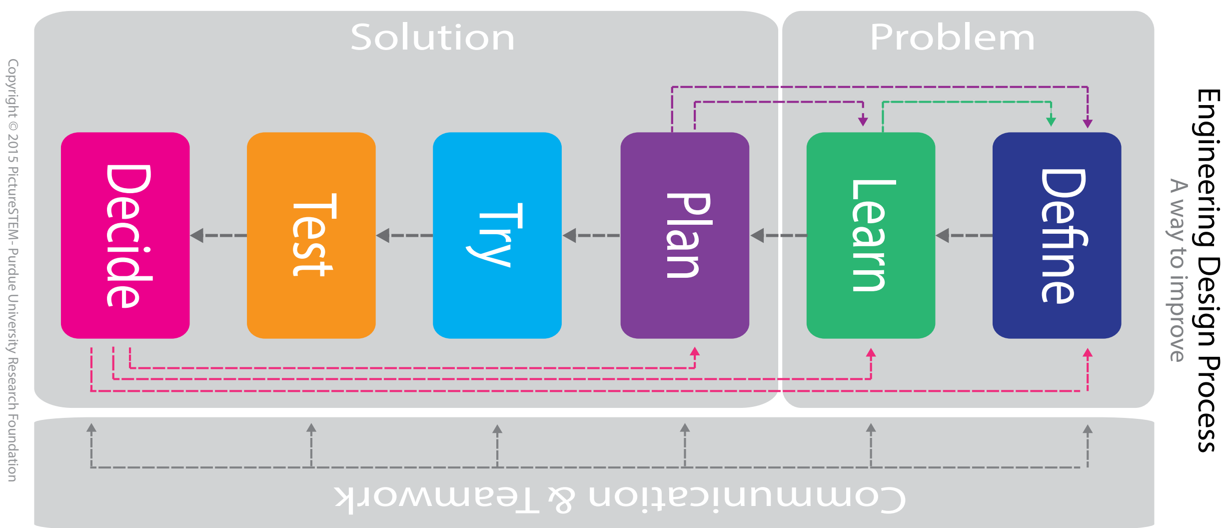
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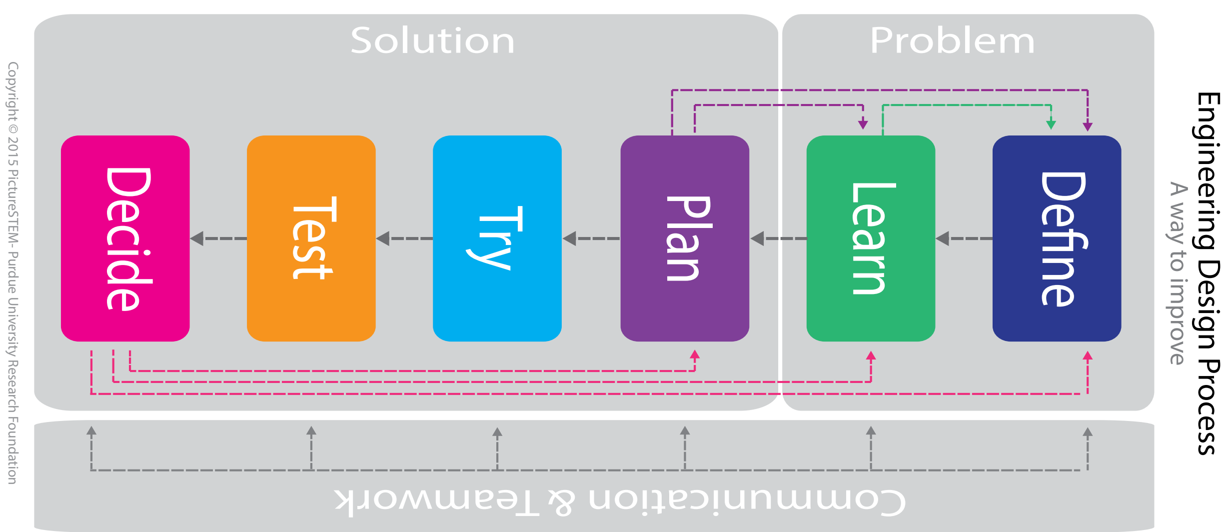
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Unit Overview

Grade Levels: 9th-12th

Approximate Time Needed to Complete Unit: 10-12 Class periods ~ 2 Weeks

Unit Summary:

This unit will detail the chip shortage and the effects that the pandemic and other factors had on the supply chain. This will also set up the need to produce chips locally rather than rely exclusively on chips from overseas. There are cybersecurity connections, buisness connections, and engineering design project connections.

Subject Connections:

Science Connections	Technology and Engineering Connections	Mathematics Connections
Brief mentions of electricity, insulators and conductors	Microelectronics, cybersecurity, microchips, digital electronics	Cost Comparisons

Lesson Summaries

Lesson 1: History of Chips

Go over microelectronics vocabulary, history of development and what they have enabled us to do. Microelectronics are all around us, whether you knew it or not you use hundreds every day. The chips are in all of our smart devices, our cars, our phones, our gaming consoles and computers. The manufacturing that microelectronics enable give us the chairs we sit in, the tools and products that we use in daily life.

Lesson 2: Supply Chain

Examine the chip supply chain, potentials for disruptions, environmental, security, price, and time concerns

Microchips, like any other product are subject to the laws of supply and demand. Disruptions like natural disasters, trade disagreements, or wars are just a few of the examples that can tip a delicate balance and send prices and wait times skyrocketing. Even when the system works as intended, where these chips come from and who is in charge of making them can cause concerns in security, safety, and environmental sustainability.

Lesson 3: Before and After Covid – The Chip Shortage

Specifically examine the effect that Covid had on the supply chain, and why the chip shortage brought many industries to a halt. Why are we so dependent on them? And What can be Done?

The pandemic really forced industries to reckon with their dependence on international chip supply, and the lack of an industry within the US to be able to compensate. We will be examining the manufacturing process of these chips, ways that we could create a national system to support this process, and pros and cons of the United States doing so.

Lesson 4: Manual vs. Electric Locks/Plan & Implement Your Solution

Design a solution for SAFE by either creating an electric lock that reduces dependency on foreign made chips, or creating a poster advocating for the reasons the US needs to step up chip production.

Lesson 5: Communicate Your Solution

Present posters/Demonstrate their solutions

Students will present the results of their research and creative solutions.

Unit Overview

Unit Planner

Lesson	Time Needed	Objectives	Materials	Duplication Master
1. History of Chips	2 Days	Students will be able to: • Define Microelectronics • Outline the History of Microelectronics Development • Identify an industry affected by the chip shortage		
2. Supply Chain	2 Days	Students will be able to: • Outline the manufacturing process of a chip • Identify where parts of the manufacturing process could compromise the integrity/quality of a chip (Business) • Describe the mechanics of international trade • Explain why businesses expand into international markets and how governments assist in this expansion • Identify the basic economic problem and how it influences marketing strategies		
3. Before and After	2 Days	Students will be able to: • Describe how Covid affected the manufacturing process (and cost/time to produce) of the items identified in lesson 2 • Explain the basic functions of some common chips, and what was used before that chip was developed • Apply the concept of supply and demand to explain how covid affected the industry		

Lesson	Time Needed	Objectives	Materials	Duplication Master
4a. Manual vs. Electric Locks	3 Days	Students will be able to: • Describe how a manual lock works • Describe advantages and disadvantages of manual locks • Describe how an electric lock works • Describe the advantages and disadvantages of electric locks		
4b. Plan and Implement your Solution	2 Days	Students will be able to: • Conduct research about a supply chain • Construct and argument for why the US should scale up chip production		
5. Communicate your Solution	1-2 Days	Students will be able to: • Demonstrate their working electronic locks • Explain their development process and why their lock has an advantage over locks with components from foreign sources Business • Present their posters • Suggestions for redesign/ evaluation of the unit		

Unit Overview

Master Material List

	Unit Materials	Lessons Where Material is Used
Per Classroom		
Per Group		
Per Student		

LESSON ONE:

Lesson Objectives
Students will be able to:
- Identify the problem from a client.
- Identify background knowledge needed to develop a solution.
- Explain the criteria and constraints.

Time Required
One 50-minute lesson

Standards Addressed
NGSS HS ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Key Terms
Client, engineering design process, criteria, constraints, microelectronics

Lesson Materials
Per classroom
- EDP Poster
- Chart paper

Per student
- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook

Lesson Summary
Students will learn about engineering, the engineering design process, and criteria and constraints. The students will read and interpret a letter from the client that asks them to participate in an engineering design challenge. Microchips are all around us in cars, phones, computers, gaming consoles, and even electronic toothbrushes. Students will engage with this context and prepare questions for how to move forward in the engineering design process.

Teacher Background

Teamwork
Students should be teamed strategically and may or may not be assigned jobs within their team. When forming student teams, consider academic, language, and social needs. In place of strategic teaming, a random teaming can be substituted. Students will work in these teams of 3 or 4 throughout the unit. Effective teamwork is essential in this unit as well as in engineering in general. The teams will operate as consulting engineers with each team specializing in a specific measuring device eventually working together as a class to address the client's problem.

Engineering Design Process
NOTE: If students are familiar with the engineering design process (EDP) before beginning the unit, the teacher can skip this (EDP) introduction.

The engineering design process (EDP) is an iterative, systematic process used to guide the development of solutions to engineering problems. There is no single engineering design process, just like there is no one scientific method. However, the various engineering design processes have similar components. The engineering design process (EDP) involves understanding the problem, learning background information necessary to solve the problem, planning, trying, testing the solution, making changes based on the tests, and communicating their ideas. Students will use an engineering design process slider throughout the unit to help them understand where they are in the design process. For more information about the steps of the engineering design process presented in this unit, see the front matter section about it.

Some common misconceptions about engineering

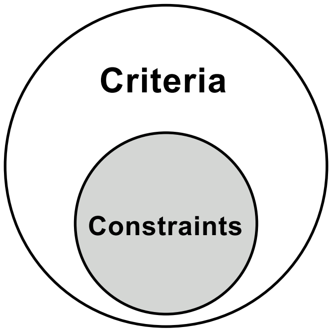
- Engineers do not have to learn anything new when they are working on a project. **In reality:** Engineers need to continually learn throughout their lives.
- Engineers come up with solutions that are just “good enough” and do not take risks. **In reality:** Engineers strive to create the best solution possible through optimization. It is normal to experience failure when solving engineering problems.
- Engineers work alone to solve a design problem. **In reality:** Engineers collaborate with people in different disciplines and fields to best solve a problem. Engineering problems often require a wide range of content knowledge.

Some common misconceptions about the EDP

- The engineering design process is linear, and you never need to go back to previous phases. **In reality:** The EDP is a cyclical process that requires many iterations.
- Once the project is done, it is considered complete and not revisited. **In reality:** The engineering design process is never really “done” and it is revisited so engineers can improve projects and make changes.

Criteria and Constraints:

One difficulty that students might experience is distinguishing between criteria and constraints. Criteria are the things required for a successful design, or goals of the designed solutions. They help engineers decide whether the solution has solved the problem. Another way of thinking about criteria are that they are anything that the client and the engineers will use to judge the quality of a solution. Constraints are a specific type of criteria; they are those criteria that limit design possibilities, or the ways that that problem can be solved. If constraints are not met, the design solution is by default not a viable solution to the problem. The relationship between criteria and constraints is represented in the figure. It may be helpful to post the definitions with the figure somewhere in the classroom for future reference.



Duplication Masters
1.A Content Pre-Assessment
1.B Problem Scoping Prompts
1.C Client Letter
- 1.C1 for business classes
- 1.C2 for engineering classes

Educator Resources
1.D Problem Scoping Section 3 Key
- 1.D1 for business classes
- 1.D2 for engineering classes

LESSON ONE:

Assessment

Pre-Activity Assessment

Assess students' prior knowledge by listening to their responses to 1.B Problem Scoping Prompts. Use students' answers to 1.A Content Pre-Assessment as baseline data about the students' current level of understanding and background knowledge.

Activity Embedded Assessment

Observe students' discussions and written responses to 1.B Problem Scoping Prompts. Check students' brainstorming lists to see if they can identify the content they will be expected to master by the end of the unit.

Post-Activity Assessment

Use the 1.E Problem Scoping Section 3 Key to evaluate students' answers to the notebook prompts.

Problem Scoping

In this lesson, students will be in the Problem Scoping section of the engineering design process, specifically on the define the problem step. Define the problem and learn about the problem combine to make Problem Scoping. In this stage, students will be first introduced to the engineering problem through a client letter and then be given a chance to ask questions to the client to receive more information about the problem. The problem statements given in the client memos purposefully do not provide all the information necessary to solve the problem. Students are tasked with generating questions about the problem to try to fill in this missing information. Based on all information from the client, students will then define the problem in terms of: what the problem is and why it is important, who are the client and end users, what are the criteria and constraints, and what other information they may need to learn about in order to solve the problem. This process of generating ideas and questions for the client is an important skill on its own both in engineering and in other fields, but it also helps to ensure that the students fully understand the problem and their task in the engineering design challenge.

Solution Generation

The Solution Generation section of the engineering design process includes plan the solution, try out the plan of the solution, test the solution, and decide whether the solution is good enough. When engineers are generating solutions, they will use iteration as a means to continually improve their solution, reflect back on the problem definition and what they have learned about the problem, and consider criteria, constraints, and trade-offs. Trade-offs involve having to make compromises about which criteria to emphasize because they compete with one another in terms of making the solution effective. For example, cost could be a trade-off for durability.

Engineering Notebook

Throughout the unit students will be recording information in an engineering notebook, and they will need the notebook immediately in Lesson 1. The engineering notebook is a digital set of documents which includes writing prompts, black space to take notes or upload pictures of work, and digital copies of the duplication masters that are listed in each lesson. The engineering notebook is offered as a google doc but can be adapted to your classroom needs. Students' engineering notebooks will support their communication of ideas and should be used consistently throughout the unit.

Vocabulary

Students will be introduced to many new science and engineering vocabulary terms throughout the unit. It may be helpful to create a vocabulary section in their notebook with term definition and memory clue. Additionally, the class could maintain a word wall.

Before the Activity

- Assemble the Engineering Design Process Sliders and post the EDP poster in the classroom (see the front matter for how to assemble them). If your students do not want to use the sliders, simply hanging the poster achieves the same result. Make sure you and your students can refer to the EDP sliders and/or poster throughout the unit.
- Determine student teams of three or four. These teams should be their teams throughout the rest of the unit.
- Print and make copies of the following worksheets in the labeled amounts:
    - (1 per student) 1.A Content Pre-Assessment, 1.D Client Letter

Classroom Instruction

Introduction

1. **Complete the pre-assessment activity.** The students will participate in a more formal pre-assessment to assess their current level of knowledge and understanding regarding the topics of supply chain, microelectronics, and the engineering design process. Using the questions on the 1.A Content Pre-Assessment, distribute hard copies of the survey. Make sure to tell students that this is just to assess any prior knowledge, so it is okay to not know the answers.
2. **Review prior knowledge.** Lead a discussion with the class in which students are able to share their prior knowledge on the topics of engineering, supply chain, microchips. *Prompts may include the following: What do engineers do? What kinds of industries do engineers work in? What is a microchip? What might be some reasons why there is a microchip shortage?*
3. **Set up engineering notebooks. Say:** *Engineers use notebooks to document their design process and keep notes. We will also be using Engineering Notebooks throughout our engineering challenge. Each day, you'll use the digital notebooks to take notes and record what you are learning. In addition, there are*

questions that you'll be asked to answer. NOTE: You can have your students type in their notebooks in two different colors – one for thoughts and prompts that are individual and one for thoughts and prompts that they discuss in their teams. This will help both you assess, and the students recognize, where ideas came from. You also may want to have students start a Table of Contents page.

4. **Complete problem scoping section 1.** Direct students to the 1.B Problem Scoping Prompts in their engineering notebooks. Have students individually answer the prompts from section 1. Make sure to let them know that it is okay if they do not know very much about engineers or engineering – just have them answer these questions to the best of their ability.
5. **Form teams.** After students have finished the prompts, explain that for the rest of the unit they will start the day with a review of the engineering design process, and then look at a specific problem that will require the use of that process. Explain that students will be working in small teams to solve a problem being brought to them by the client. Divide students into teams of 3 or 4.

Activity

6. **Discuss engineers and engineering.** Allow students to share their answers from 1.B Problem Scoping Prompts section 1. Define engineers and engineering and take some notes for students to type in their notebooks. As a class create a list of the different types of engineering and have students brainstorm careers that may fall within each type of engineering in their notebooks. Explain that the problem they will be solving falls under the category of environmental engineering and draws on biology and electronics to understand the context and generate a solution.
7. **Introduce the Engineering Design Process.** Display the Engineering Design Process poster and pass out individual EDP Sliders and a paper clip to each student. **Say:** *Engineers use an engineering design process, along with mathematics, science, and creativity, to understand a problem and come up with a solution. Since we are working as engineers during this unit, we will be using this engineering design process as a guide while we come up with a solution for our engineering problem.* Go through the EDP Slider and ask the students what they think each stage involves. Be sure to clarify any misconceptions and elaborate where needed. There is a detailed description of the EDP Slider in the front matter of the unit. **Ask:** *Based on what*

we have discussed so far, where do you think we are in the engineering design process? **(Define).**

8. Introduce the problem. Discuss with students about the chip shortage. Watch https://youtu.be/IUfobGJVszs?si=q7TMonZcbKY4P5j7 (about 5 mins) OR https://youtu.be/sfAyXjRFUJk?si=3Pwaa6DqI5w-rj51 (about 10 mins) depending on the time allotted. Allow students time to read copies of the 1.D Client Letter. Encourage them to type in their notebooks as they read to keep track of important information. Give students time to discuss in small teams what information they read in the letter. **Ask:** *What is the challenge? What are some possible constraints and criteria?*
9. **Identify the problem from the client.** Have the students reread the letter, if necessary, to identify the problem and type it in their notebooks.
10. **Identify required information.** Have students work together to brainstorm a list of "required information" in order to help the client with their request. Encourage them to highlight/underline the things on their list they already know.
11. **Complete problem scoping section 2.** After reading the letter, direct students to respond to section 2 of the 1.B Problem Scoping Prompts in their notebooks. They can do this individually or in teams.
12. **Complete problem scoping section 3.** After students have completed the section 2 prompt, direct students to section 3 of 1.B Problem Scoping Prompts. They can do this individually or in teams.

Closure

13. **Revisit the problem.** Give the students a chance to revise their list of questions or required information they composed for the engineering challenge.
14. **Discuss the engineering design process. Ask:** *Which phase of the engineering design process did we focus on related to our challenge today? Why is this important?* Ex: Students need to understand the root problem from the perspective of the client and other stakeholders before attempting a solution.

Name____ Date________________ Period ___________

1.A Content Pre-Assessment

Name______________________________________ Date______________ Period __________

1.A Content Pre-Assessment

Name______________________________________ Date______________ Period __________

1.B Problem Scoping Prompts

Section 1:

Directions: Please answer the following questions.

1. What do engineers do?

2. How do engineers solve problems?

Section 2:

Directions: Please answer the question after hearing about the engineering design challenge.

3. What questions do you want to ask the client?

Section 3:

Directions: Please answer these questions after you have been able to ask questions about the challenge. First, complete each prompt on your own. Then write your revised answer (if different) to the prompt, based on the discussion with your team. You may use a different color writing utensil to distinguish your answer and how it changed after talking with teammates.

4. The client is:

5. The client's problem is:

6. The problem is important to solve because:

7. The end-users are:

8. An effective solution for the client will meet the following criteria:

Name____ Date_______________ Period __________

1.B Problem Scoping Prompts

9. The constraints (or the limits) of the solution are:

10. Think about the problem of carbon emissions. In terms of designing a method to combat this issue, what are at least 2 things you need to learn in order to make an evidence-based recommendation? Make sure to consider all important aspects of the problem. Be specific.

1.C1 Client Letter – Business Class

Dear Engineers,

The world is currently facing a shortage of microchips that has impacted essentially every industry. Microchips are used in agriculture, science, medicine, engineering, and even throughout your own classroom. The microchip shortage that began in 2020 led to an increase in prices and requires the reuse of products. As global use of in technology continues to increase, so does the need for increased production of microchips.

My company, SAFE Chips, works to increase US participation in the microelectronics industry. This work is important so that the country remains competitive among the global push to engage with this industry. I would like you to examine the business side of the microchip shortage and determine how the United States can increase microchip production and remain competitive in this industry. Your ideas need to be possible to implement within the next calendar year.

Please use the engineering design process, science and mathematics knowledge, and your ingenuity to make an evidence-based recommendation for us. Please include this recommendation in your final report so we know why you have come to your conclusion. Note that this recommendation must be reliable, cost-effective, ethical, and demonstrate the use of scientific reasoning. We look forward to reading your report and implementing your result.

Sincerely,

Charlie “Chip” Campbell
Engineer
SAFE Chips

1.C2 Client Letter – Engineering Class

Dear Engineers,

The world is currently facing a shortage of microchips that has impacted essentially every industry. These microchips are used in agriculture, science, medicine, engineering, and even throughout your own classroom. The chip shortage that began in 2020 led to an increase in prices and requires reuse of products. As global participation in technology continues to increase, so does the need for increased production of microchips.

My company, SAFE Chips, works to increase US participation in the microelectronics industry. This is important so that we remain competitive among the global push to engage with this industry, and address national security concerns that can happen when microchips are supplied from foreign sources. My company has many physical files that must remain classified and protected. I would like you to create an electronic lock to protect our information that utilizes microelectronic technology. The lock needs to be controlled by a microcontroller, have some features that make it user friendly, and help provide justification for the US production of microchips.

Please use the engineering design process, science and mathematics knowledge, and your ingenuity to make an evidence-based recommendation for us. Please include this recommendation in your final report so we know why you have come to your conclusion. Note that this recommendation must be reliable, cost-effective, ethical, and demonstrate the use of scientific reasoning. We look forward to reading your report and implementing your result.

Sincerely,

Charlie “Chip” Campbell
Engineer
SAFE Chips

1.D1 Problem Scoping Section 3 Key – Business Class

Section 3:

4. The client is:

   Charlie "Chip" Campbell at SAFE Chips.

5. The client's problem is:

   There is a global microchip shortage.

6. The problem is important to solve because:

   Microchips are used in essentially every industry.

7. The end-users are:

   Everyone that uses microchips.

8. An effective solution for the client will meet the following criteria:

   The recommendation should be reliable, cost effective, ethical, and demonstrate the use of scientific reasoning.

9. The constraints (or the limits) of the solution are:

   The solution needs to be implemented within the next calendar year.

10. Think about the problem of carbon emissions. In terms of designing a method to combat this issue, what are at least 2 things you need to learn in order to make an evidence-based recommendation? Make sure to consider all important aspects of the problem. Be specific.

    Answers will vary. Potential ideas include learning what a microchip is, how to make a microchip, what type of facility makes microchips, how quickly they can be produced, what facilities currently exist in the US, etc.

1.D2 Problem Scoping Section 3 Key – Engineering Class

Section 3:

4. The client is:

   Charlie "Chip" Campbell at SAFE Chips.

5. The client's problem is:

   They need to protect classified physical files.

6. The problem is important to solve because:

   The files must be protected to prevent competitors from finding their information.

7. The end-users are:

   SAFE Chips employees.

8. An effective solution for the client will meet the following criteria:

   The recommendation should be reliable, cost effective, ethical, and demonstrate the use of scientific reasoning.

9. The constraints (or the limits) of the solution are:

   Must use a microcontroller, must be user-friendly, must help justify US chip manufacturing

10. Think about the problem of carbon emissions. In terms of designing a method to combat this issue, what are at least 2 things you need to learn in order to make an evidence-based recommendation? Make sure to consider all important aspects of the problem. Be specific.

    Answers will vary. Potential ideas include what the filing system looks like, components of electronic locks, the available budget, etc.

LESSON TWO:

Lesson Objectives
Students will be able to:
- Explain the key phases of the supply chain within the microchip industry
- Identify the relationship between the supply chain, consumers, pricing, and product availability
- Describe influential factors that impact the supply chain when given a specific phase of the supply chain to examine.

Time Required
One 50-minute lesson

Standards Addressed
PMK 1.6 Explain the Nature of Global Trade

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Key Terms
Supply chain, consumers, demand, production

Lesson Summary

Examine the microchip supply chain, potentials for disruptions, environmental, security, price, and time concerns

Microchips, like any other product are subject to the laws of supply and demand. Disruptions like natural disasters, trade disagreements, or wars are just a few of the examples that can tip a delicate balance and send prices and wait times skyrocketing. Even when the supply chain system works as intended, where these chips come from and who is in charge of making them can cause concerns in security, safety, and environmental sustainability.

Objective: By the end of this lesson, students will be able to explain the intricacies of the microchip supply chain, recognize potentials for disruptions, and discuss the environmental, security, price, and time concerns associated with the microchip industry.

Teacher Background

Background Information on Lesson Content

Teachers may find watching the video and reading the article provided to the students as a helpful introduction to the microelectronics supply chain.

Before the Activity

Make sure students have access to the article and/or the YouTube video(s) on their individual devices, otherwise it might have to be accessed by the instructor and reviewed as a class.

Classroom Instruction

Introduction (10 minutes)

1. **Identify where students are in the Engineering Design Process. Say** *So we have been introduced to a problem by the client, and now we get to learn more about it.*
2. **Introduction to Supply Chain: Say** *Who here has heard of the term 'supply chain'? And who thinks they have a definition for it?* Have students share their definitions. Encourage them to write these in their engineering notebooks. **Say** *A supply chain is the entire process of making and selling commercial goods. It starts with raw materials and ends with the final product in the hands of consumers. Each step in this chain, from design and manufacturing to distribution and sales, is interconnected and essential. In the microelectronics industry, the supply chain is especially complex and fascinating, impacting everything from*

smartphones to satellites. Today, we are going to learn all about it

Main Activity (30 minutes)

3. **Create the Chain** Assign a small group of students to each phase of the supply chain: The YouTube videos below can be provided to students as a place to start.

   (1) Research, design, and development. This phase involves research to understand market demands and designing electronic components or devices. Engineers and designers work on creating product prototypes and specifications for all kinds of products that have chips in them. https://youtu.be/Bu52CE55BN0?si=GW-I7aypvXV5CdUy

   (2) Material Procurement and Manufacturing. Raw materials are procured from the earth, and then the multiple components of the semiconductors are manufactured by companies all over the world. https://youtu.be/Bu52CE55BN0?si=xPSjQAZtabYNUL_o

   (3) Testing, Quality Control, and Packaging. After each of the components are manufactured, they must be tested to ensure they are working up to standard. Components are often tested in final assembly as well to see how well they work together. https://youtu.be/7gg2eVVayA4?si=fKHtwh48VTqsK4uI

   (4) Distribution and Market Integration. Companies that produce semiconductors and microchips often are not the final distributors of the chips, they are shipped off to other technology companies that use the chips in their products. https://youtu.be/VJwnAaZw7Ac?si=TApN-sbbPxinB5-r

   (5) Recycling and Sustainability. https://youtu.be/VJwnAaZw7Ac?si=Py4lJ8VvnqNoUB8c

   Have Students put together a few slides of a PowerPoint presentation, to combine at the end of class into a discussion of the supply chain. See Duplication Masters 2.A for an optional worksheet to help students find what information is important to the supply chain. To start learning about the semiconductor (microelectronics) supply chain, students can

   A) Read this Article: https://www.investopedia.com/semiconductors-supply-chain-7367716

   or

   B) Watch this Video https://youtu.be/z9RDXd2xeks?si=oKQWa10YfDUGkfB1

Lesson Materials

Per classroom

- EDP Poster

Per student

- EDP slider and paperclip
- Laptop/Chromebook/Tablet
- Engineering notebook

Duplication Masters

2.A Microchip Supply Chain Worksheet

Conclusion (10 minutes)

4. **Group Sharing:** Have students share their slides in order that a microchip would go through to get from the beginning of the chain to a consumer product of instructor choice.

The Supply Chain

Name____ Date_______________ Period __________

2.A Microchip Supply Chain Worksheet

Microchip Supply Chain Worksheet

Objective: By completing this worksheet, you will gain an understanding of your assigned phase in the microchip supply chain, recognize potential disruptions, and explore environmental, security, price, and time concerns associated with the industry.

Your Name: ______________________________

Assigned Phase: ______________________________

Instructions:

1. Review the introductory information (i.e., article and videos) provided by your teacher.

2. Define the term “supply chain” in your own words:

____

____

Main Activity (30 minutes):

Phase Overview:

- Briefly describe your assigned phase in the microchip supply chain. What is its primary purpose and role within the supply chain?

____

____

Disruptions:

- Identify and describe disruptions that can affect your assigned phase within the supply chain.

____

____

Name____ Date_______________ Period __________

2.A Microchip Supply Chain Worksheet

Real-World Experience:
- Reflect on any personal or observed experiences related to supply chain disruptions, especially during the COVID-19 pandemic. How did disruptions affect the availability of products?

____

____

Concerns:
- Discuss any environmental, security, price, or time concerns associated with your assigned phase. How do these concerns impact the overall supply chain?

____

____

LESSON THREE:

Lesson Objectives

Students will be able to:

- Explain the problems with the current supply chain
- Identify ways that electronic locks made in the US would outline how to solve these problems
- Organize these thoughts into a clear outline

Time Required

One 50-minute class

Standards Addressed

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Key Terms

Brainstorming, supply chain

Teacher Background

If students don't have a lot of experience with brainstorming, this video may be helpful to them https://youtu.be/mtn31hh6kU4?si=RgLKzHSRYMAokp88

Before the Activity

Instructors should have an understanding of Evidence-Based Reasoning and how that is involved in the Plan stage. Evidence-based reasoning is a critical thinking approach that emphasizes using concrete, reliable data and information to support conclusions and decision-making. In the context of the engineering design process, evidence-based reasoning plays a vital role during the planning stage.

During the planning stage of engineering design, engineers gather and evaluate existing data, research, and empirical evidence related to the problem they are trying to solve or the product they want to create. This evidence serves as a foundation for making informed decisions and setting design objectives. Engineers must consider scientific principles, historical data, industry standards, and any relevant research findings to ensure their design is grounded in solid evidence.

By incorporating evidence-based reasoning into the planning stage, engineers can avoid making assumptions or relying on guesswork, leading to more robust and successful designs. It also helps in identifying potential challenges, mitigating risks, and ensuring that the final product meets the intended goals and requirements. In essence, evidence-based reasoning is the cornerstone of sound engineering design, enabling engineers to make informed choices based on empirical support rather than intuition or speculation.

Classroom Instruction

Students will plan and justify a solution for an electronic lock using a microcontroller, focusing on functionality, coding steps, and the broader implications of microelectronics production in the U.S.

Introduction (10 minutes)

1. **Briefing: Identify where students are in the Engineering Design Process. Say:** *Now we know a little about the problems our supply chain is vulnerable to, well today we are going to plan our solutions.*

- Introduce the project and its constraints (using a microcontroller with one interface).
- Outline the key functionalities desired, like error messages and backspace options.

2. **Outline Evidence Based Reasoning –** *Discuss what EBR is and have students fill out Duplication Masters 3C.*
3. **Q&A Session (5 minutes):** Address questions to clarify the project's requirements and constraints. Instructor may want to add on other constraints as well, such as time, cost, or deliverables like code printouts, pseudocode, flowchart processes and other things and the teacher deems necessary.
4. **Brainstorming Session.** Use Duplication Masters 3.B
   - Group Formation: Divide the class into small groups (3-4 students per group).
   - Idea Generation: Groups brainstorm potential features and functionalities for the lock

Activity

5. **Feature Selection (5 minutes):**
   - Groups select essential features for their lock design. These could include process flow diagrams for if a code is inputted correctly, incorrectly, how to "reset" the system, etc.
6. **Designing the Code Structure (10 minutes):**
   - Outline basic steps for coding the chosen features, focusing on logic and error handling.
7. **Justification for U.S. Production (5 minutes):**
   - Discuss why it would be beneficial to bring the production of such locks and other microelectronics-driven devices back to the U.S.
   - Consider factors like economic impact, quality control, innovation, and national security
8. **Engineering Notebook Reflection (5 minutes)**
   - Reflection Questions (5 minutes): Fill Out Duplication Masters 3.D
     Have students individually respond to questions in their engineering notebooks:
     What are the key features of your lock design, and why did you choose them? Why is it important to consider bringing microelectronics production back to the U.S.? What benefits and challenges do you foresee?

Lesson Materials

Per classroom

- EDP Poster

Per student

- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook

Duplication Masters

3.A, 3.B, 3.C, 3.D

Conclusion (5 minutes)

9. Group Discussion and Wrap Up

- Briefly discuss common themes or interesting points raised in the reflections
- Summarize the key learning points and the value of thoughtful engineering solutions.

Plan a Solution

3.A

SAFE Chips, Inc.

Dear Engineers,

Subject: Request for Electronic Lock Design to Support U.S. Chip Manufacturing Initiative

We hope this letter finds you well. At SAFE Chips, Inc., we are embarking on an ambitious project to revitalize and strengthen the microelectronics industry in the United States. A critical component of this endeavor is the development of an advanced electronic lock system that aligns with our vision of innovation, security, and domestic production.

Project Overview:
The electronic lock we envision is not just a product; it's a statement of our commitment to cutting-edge technology and U.S. manufacturing excellence. This lock will serve as a keystone in our larger effort to bring chip production back to American soil, addressing key concerns around national security, economic growth, and technological leadership.

Design Specifications:

1. **Microprocessor-Based: The lock should be powered by a microprocessor, symbolizing our dedication to microelectronics. This component is essential for ensuring advanced functionality and future scalability.**

2. **User-Friendly Interface: Despite its technological sophistication, the lock must be easy to use, catering to a wide range of users. We emphasize simplicity in operation without compromising on security or features.**

3. **Constraints:**
    - **Single Interface Control: Given the use of a microcontroller with only one interface, the design should optimize functionality within this limitation.**
    - **Feature Focused: Key features we are looking for include error messages for incorrect code entries and a backspace or clear option for user convenience.**
    - **Justification for U.S. Production: Your design proposal should include a rationale for why such technology should be manufactured domestically. Consider aspects like quality control, economic benefits, and fostering innovation.**

Next Steps:
We are eager to see your innovative approaches and solutions. Please submit your initial design proposal and justification by the date your teacher will give you. We will review your submission and schedule a meeting to discuss the next stages of development.

Thank you for partnering with us in this groundbreaking venture. Together, we can make significant strides in bringing high-tech manufacturing and innovation back to the U.S. shores.

Warm regards,
Safe Chips Inc.

3.B Generate Ideas/Plan Lessons

Teacher Directions:

Once students have generated a few solution ideas that they think could be potentially effective solutions, ask to students to individually complete Section 1- Pros and Cons. Then have them present their graphic from Section 1 to their team. The team needs to select ideas or integrate ideas from among their teams to get 2 ideas to flesh out. Have them complete Section 2 - Evidence-Based Reasoning (EBR) Idea Graphic for each of the ideas. You may want to divide this task among team members. In Section 3, students answer questions about these EBR graphics to make a decision about which idea(s) they should move forward with. Note: Curricula vary in terms of how many ideas students are expected to generate and how many ideas are tested. Use the EBR graphic and questions according to what your expectation is of students in terms of how many ideas they generate and how many prototypes are tested.

Section 1:
Analyzing Your Brainstormed Ideas

This question goes after individual brainstorming but before TEAM EBR Graphic.

Solution Ideas	Pros of idea	Cons of idea	Address Criteria?	Meet Constraints?	Rank ideas
Idea 1:			yes / no	yes / no	
Idea 2:			yes / no	yes / no	

Make changes based on analysis

Section 2: Evidence-Based Reasoning Graphic

Problem including Criteria & Constraints • Explain the client’s problem that needs a solution and why it is important to solve. • List criteria and constraints you will use to decide if your solution is working.
Problem: **Criteria:** **Constraints:**
Simplifying Assumptions (if any) • List things that might be important but you have decided not to worry about in order to focus the solution or simplify the analysis of the solution

Design Idea #1 • Plan including drawing, labels of materials used, and labels of what each part does.	**Data/Evidence** • List science/mathematics learned and/or results of tests that support your design idea.
Justification - Why do you think this design idea will work? • Explain how your data and evidence support your design idea in order to meet criteria/constraints.	

Design Idea #2 • Plan including drawing, labels of materials used, and labels of what each part does.	**Data/Evidence** • List science/mathematics learned and/or results of tests that support your design idea.
Justification - Why do you think this design idea will work? • Explain how your data and evidence support your design idea in order to meet criteria/constraints.	

3.D Generate Ideas/Plan Lessons

Evidence-Based Reasoning Graphic Instructions:

<table>
<tr><th colspan="2">Problem including Constraints & Criteria</th></tr>
<tr><td colspan="2">Problem: the engineering problem the client asked you to solve
Criteria: the requirements, or goals, of the designed solutions
Constraints: things that limit design possibilities</td></tr>
<tr><th colspan="2">Simplifying Assumptions (if any)</th></tr>
<tr><td colspan="2">Ways to make a complex problem simpler -
Things we ignore to focus the design or simplify analysis</td></tr>
<tr><th>Idea #_____</th><th>Data/Evidence</th></tr>
<tr><td>• Description of the design
• Drawings of the design, different views better
• Dimensions (sizes)
• Label materials in design (show where they are used)
• Interesting features</td><td>Observations and data that show why you think your design will work

Examples:
• Data from science or mathematics lessons/labs/experiments
• Total cost of design</td></tr>
<tr><th colspan="2">Explanation, Justification, Reasoning</th></tr>
<tr><td colspan="2">Complete sentences that state why you think your design will be successful. These sentences should refer to the problem, criteria, constraints, idea, and data/evidence.</td></tr>
</table>

Section 3:
Analyzing Your Team Ideas

This question goes after TEAM EBR Graphic.

Directions: Analyze your team solutions and answer the final question. You may work as a team, but your answers for the table and the question are not required to be the same.

Solution Ideas	Pros of idea	Cons of idea	Address Criteria?	Meet Constraints?	Rank ideas
Idea 1			yes / no	yes / no	
Idea 2			yes / no	yes / no	

1. **Which solution did your team choose and why?**

2. **What changes do you need to make before you try to implement your solution?**

LESSON FOUR:

Lesson Objectives
Students will be able to:
- Identify where examples of microchips are in the real world
- Interact with microelectronics to understand components
- Use the engineering design process to solve a problem

Time Required
Three 50-minute lessons

Standards Addressed
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Key Terms
Microcontroller

Classroom Instruction

Day 1: Introduction to Micro:bit and Basic Assembly
Total Time: 50 Minutes

Introduction (10 minutes)

1. **Identify Where they are in the Engineering Design Process.** **Say** *We have defined the problem, learned about it, and done some planning of ideas on how we can help. Now we are going to try and come up with a solution*
2. **Introduction to Micro:bit and its role in the project.** Pass out micro:bit(s) **Say** *These are microcontrollers, and only through research in microelectronics have we been able to make something so powerful so small.*

Activity: Starting the Assembly (30 minutes)

3. **Distribute materials (Micro:bit, keypad, wires, etc.).** Reference Duplication Masters 4.A for assembly instructions.
   - Demonstrate how to connect the 4x4 keypad to the Micro:bit.
   - Guide students through the process of connecting their keypads.
   - Initial setup of Micro:bit on computers using MakeCode editor.

Conclusion (10 minutes)

4. **Recap what was learned about Micro:bit and its applications.**
5. **Discuss the next steps and what to expect in the following class.**

Day 2: Advanced Assembly and Introductory Programming
Total Time: 50 Minutes

Introduction (10 minutes)

1. **Review of previous day's work and introduction to the day's objectives:** Overview of programming concepts relevant to the project. These include variables, loops, conditional statements, functions, and Object-Oriented Programming. OOP is a way of organizing code using objects, which are like blueprints for creating things. It helps engineers like us model real-world systems and relationships more effectively.

Activity: Basic Programming (30 minutes)

2. **Complete the assembly of the circuit.**
3. **Demonstrate a simple code to test the door lock/unlock feature.**
    1. Initialize the Micro:bit and keypad
    2. Initialize a variable "enteredCode" to an empty string
    3. Initialize a variable "passcode" with the predefined passcode
    4. Display a welcome message on the Micro:bit screen
    5. Repeat until the lock is successfully opened:
        a. Listen for keypad input
        b. When a keypad button is pressed:
            i. Add the pressed button's value to "enteredCode"
            ii. Display "*" on the Micro:bit screen for each button pressed
            iii. Wait for a short delay (e.g., 500 milliseconds) to allow the user to enter the next button
        c. If the length of "enteredCode" is equal to the length of the "passcode":
            i. Check if "enteredCode" matches the "passcode"
            ii. If it matches:
                - Display a success message on the Micro:bit screen
                - Unlock the system (e.g., turn on an LED, play a sound)
                - Exit the loop
            iii. Else:
                - Display an error message on the Micro:bit screen
                - Clear "enteredCode" to start over

Lesson Materials

Per classroom

- EDP Poster
- Chart paper

Per Student

- EDP slider and paperclip
- Laptop/Chromebook/Tablet
- Engineering notebook

- Wait for a brief moment (e.g., 2 seconds) before allowing new input

d. If the user wants to reset the input (e.g., press a clear button):

i. Clear “enteredCode”

ii. Clear the display on the Micro:bit screen

iii. Wait for a brief moment (e.g., 1 second) before allowing new input

6. End the program once the lock is successfully opened

5. **Assist students in writing and uploading their first code.** A) If time allows, introduce additional features like lockdown counter or button control.

Conclusion (10 minutes)

6. **Discuss challenges faced during assembly and programming.** Give students a preview of finalizing and testing the project in the next class.

Day 3: Project Finalization and Testing
Total Time: 50 Minutes

Introduction (10 minutes)

1. **Recap of the progress made in the first two classes.**
2. **Explanation of testing and troubleshooting processes.**

Testing:

- Testing is the process of checking if a system or product functions as intended.
- Engineers use testing to verify that their creations perform correctly and meet specific criteria.
- It involves evaluating the system’s behavior under different conditions to ensure it works reliably.
- Testing helps identify defects, inconsistencies, or areas for improvement.
- It is an essential quality assurance step in engineering and product development.

Troubleshooting:

- Troubleshooting is the process of diagnosing and resolving issues or problems in a system.
- Engineers use troubleshooting when they encounter unexpected behavior, errors, or malfunctions in their

creations.

- It involves systematic problem-solving to identify the root cause of the issue.
- Troubleshooting is crucial for maintaining and repairing systems to ensure they operate correctly.
- Engineers use their knowledge and problem-solving skills to address problems and find solutions.

Activity: Testing and Troubleshooting (30 minutes)

3. **Instruct students to run a series of tests on their security systems.** Have them test things like what happens when an incorrect password is entered, if they mistype a number what would they need to do to reset the system, and if they can enter a correct password and re-lock the system multiple times.
4. **Guide them through troubleshooting common issues.** Offer troubleshooting strategies, such as checking code logic, reviewing connections, and using debugging tools.
5. **Allow time for students to refine and adjust their projects.** Encourage students who might be frustrated if their designs aren't working out exactly as they hoped. Emphasize that troubleshooting is an essential part of the engineering design process, and professional engineers virtually never only make one prototype.

Conclusion (10 minutes)

Reflect on the learning experience and key takeaways from this exercise. Discuss the importance of problem-solving and creativity in engineering.

Micro:bit Lock Project Assembly Instructions

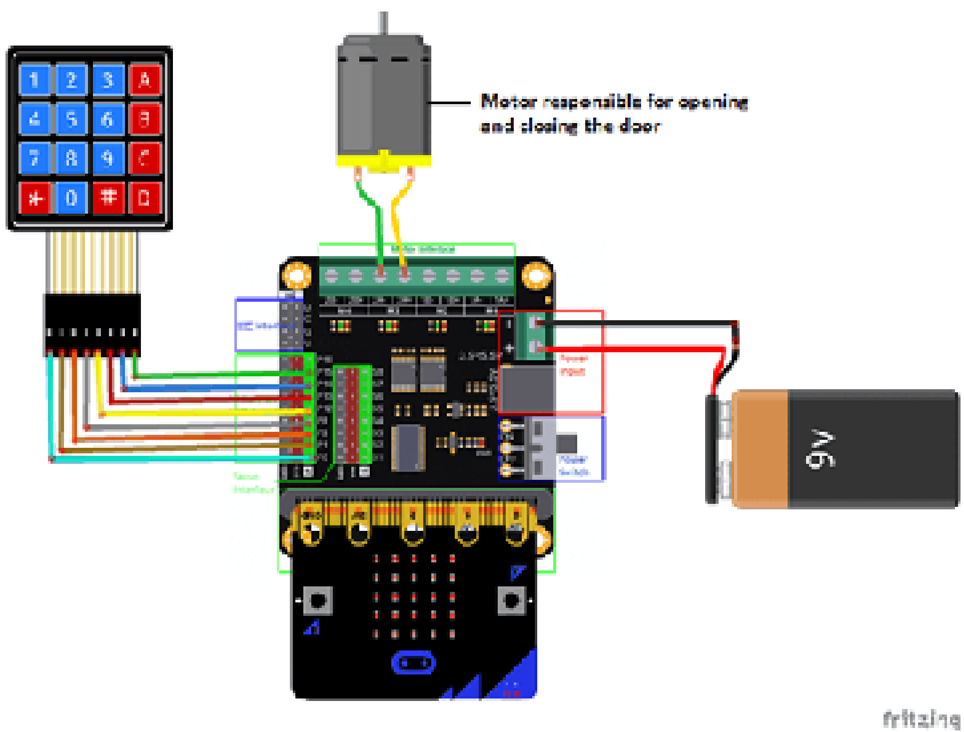
The assembly instructions for the Micro:bit Lock Project are as follows:

Micro:bit Lock Project Assembly Instructions

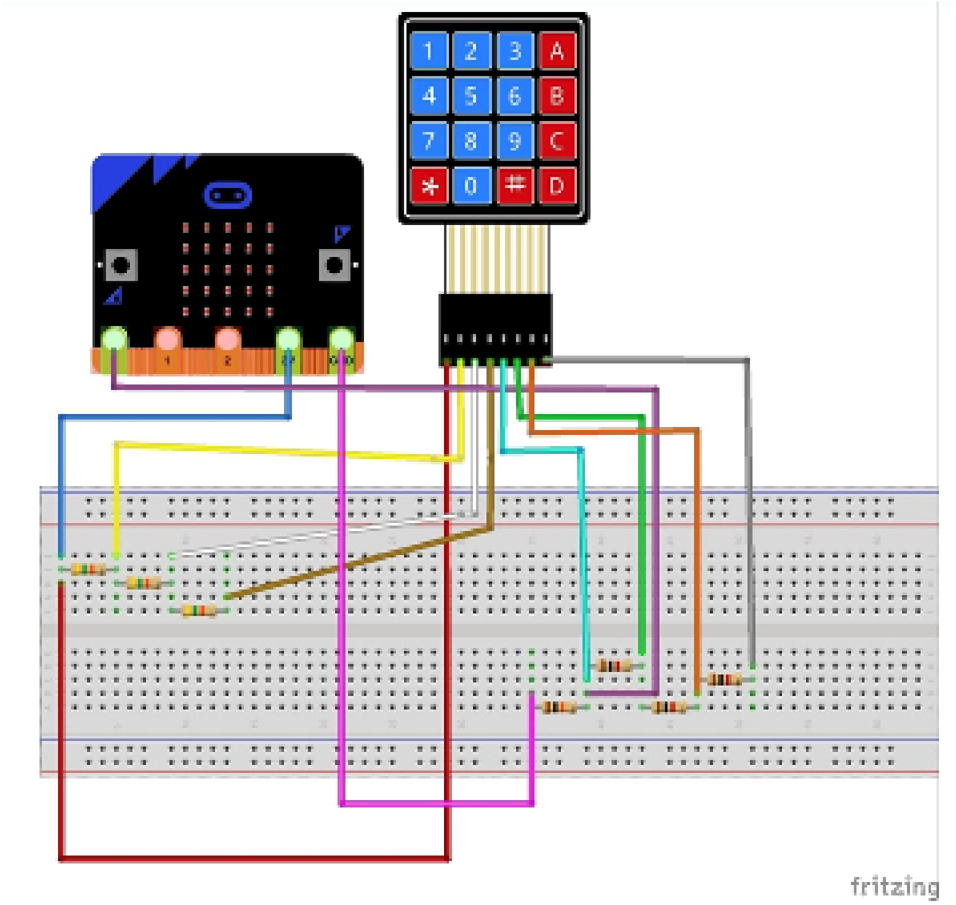
Hardware Step 1 – Interfacing the Keypad
1. Membrane Keypad Interface: Understand that the membrane keypad has 16 different switches with 16 different characters. These switches are grouped by row and column.
2. Driver Circuit: Create a driver circuit for the 4x4 keypad to interface with the Micro:bit.

Step 2 – Wire it Up
1. Servo Motor: Attach the 3 pins of the Servo motor to P2 of the breakout board.
2. Micro:bit Connections:
    - Attach Ground (Black pin) of the Micro:bit to the 10k Ohm resistor.
    - Attach the 3V (Red pin) to the 5k Ohm resistor.
    - Attach A0 (Yellow pin) to the point between the 10k Ohm Resistor and 1k Ohm resistor.
3. OLED Display: Connect GND, VCC, SCL, and SDA of the breakout board to GND, VCC, SCL, and SDA of the OLED, respectively.

[NEED TO CHANGE FOR COPYWRITE]



Alternative Wiring:

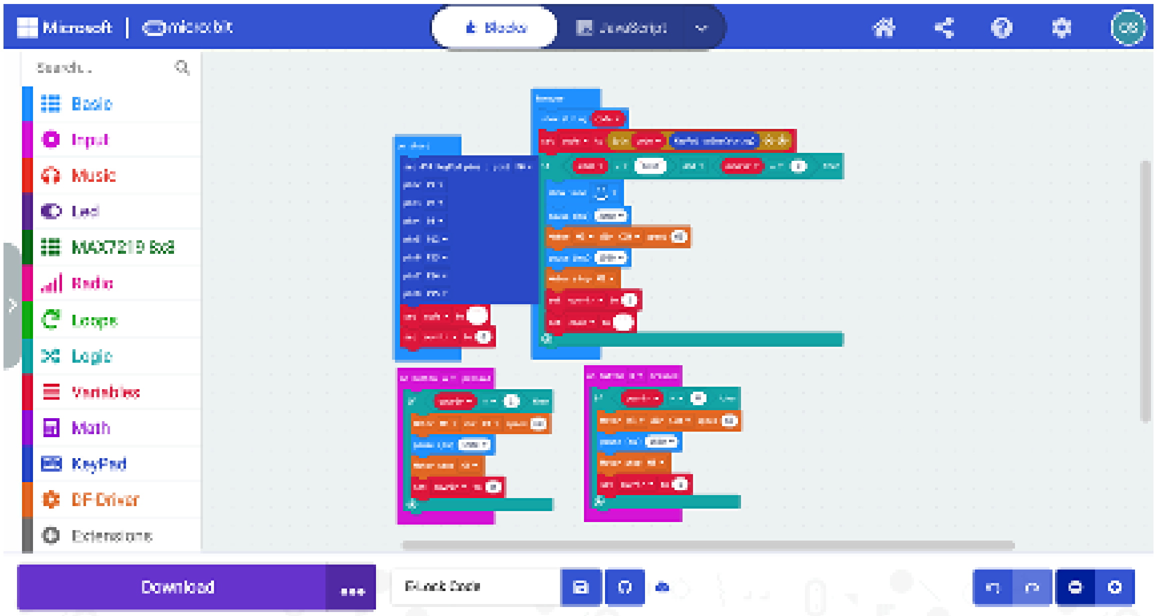


Step 3 – Coding the micro:bit

1. Initialization
    - Initialize the OLED display.
    - Initialize a 4x1 array.
    - Initialize the lockdown counter.
2. Key Press Handling:
    - Button A acts as the enter character button.
    - Press Button A after each key on the 4x4 keypad to key in a 4-digit number.

Step 5 – Demo Time!

1. Operation:
   - Each key press on the keypad will display the corresponding character on the OLED.
   - To unlock the door, key in “3Button A6Button A9Button A#”.
   - Press button B to unlock.
   - To reset, press A+B.
   - Entering the wrong password three times triggers a lockdown timer displayed on the OLED. You can enter the password again after 60 seconds have passed.



LESSON FIVE:

Lesson Objectives
Students will be able to:
- Explain why chip manufacturing
- Test their Designs
- Reflect on what they would change about their designs

Time Required
One-Two 50-minute lesson(s)

Standards Addressed
HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Key Terms
Evaluation, Testing, Redesign

Teacher Background

If students don't have a lot of experience with brainstorming, this video may be helpful to them https://youtu.be/mtn31hh6kU4?si=RgLKzHSRYMAokp88

Classroom Instruction

Introduction (5 minutes)

1. **Identify where students are in the Engineering Design Process. Say:** *These last few day(s) of the project will be the testing and deciding phases. We will test your locks, evaluate them and recommend the changes to be made and the features that work to the client.*
   - Introduce the rubric and explain each category.
   - Emphasize that in the real world, engineering products virtually never go through only one iteration of testing, it is perfectly normal to get things wrong and have things to fix.
2. **Testing Phase Use Duplication Masters 5.B** Students test their electronic locks based on the assembled designs.
   - Focus on testing functionality, checking connections, and ensuring the software operates as intended.
   - Teachers circulate to offer guidance and observe the testing process.
3. **Troubleshooting Use Duplication Masters 5.C**
   - Students identify and resolve any issues encountered during testing.
   - Encourage peer collaboration for problem-solving.
   - Emphasize creativity and resourcefulness in troubleshooting.

Activity

4. **Preparation for Presentation**
   - Students prepare a brief presentation of their project.
   - Ensure they are ready to demonstrate functionality and articulate their design and coding choices.
   - Have students also present what they answered for Duplication Masters 5.C (Their redesign reccomendations)
   - Offer tips for effective communication and presentation skills.
5. **Presentation and Evaluation**
   - Groups or individuals present their electronic locks and justifications. Use Duplication Masters 5.A to evaluate each presentation. Provide constructive feedback to each student or group. Encourage students to reflect on what they learned and how they can apply these skills in future projects.

Conclusion

- Summarize key learnings from the project.
- Discuss the importance of testing and presenting in the engineering design process.
- Give Post-Assessment. Have students take the assessment individually, this is to evaluate what they learned during this unit.

Post-Lesson Activity

- Students write a reflection on their experience, focusing on what they learned, challenges they faced, and how they overcame them, and how they would improve their designs in the future.

Lesson Materials

Per Classroom

- EDP Poster

Per Student

- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook
- Electronic lock prototypes (assembled in previous lessons)
- Computers with programming software
- Testing tools (e.g., batteries, wires)
- Rubric handouts (Duplication Masters 5.A)
- Presentation tools (projector, whiteboard)

Duplication Masters

5.A

5.A

Rubric for “Try Some Safe Chips Out” Project

1. **Understanding of Concepts** (20 Points)
Demonstrates a clear understanding of microchips and their real-world applications. (0-5 Points)
Shows comprehension of the engineering design process. (0-5 Points)
Accurately identifies and explains the role of microcontrollers. (0-5 Points)
Understands programming concepts relevant to the project. (0-5 Points)

2. **Assembly Skills** (20 Points)
Follows instructions for assembly accurately. (0-5 Points)
Connects components (keypad, Micro:bit, wires, etc.) correctly. (0-5 Points)
Demonstrates proper setup of Micro:bit and other hardware. (0-5 Points)
Completes assembly with attention to detail and neatness. (0-5 Points)

3. **Programming Skills** (20 Points)
Successfully writes and uploads code to the Micro:bit. (0-5 Points)
Code functions as intended for the door lock/unlock feature. (0-5 Points)
Implements additional features (if applicable). (0-5 Points)
Code is well-organized and clearly commented. (0-5 Points)

4. **Problem-Solving and Troubleshooting** (20 Points)
Effectively troubleshoots and resolves issues during testing. (0-5 Points)
Demonstrates ability to refine and adjust the project as needed. (0-5 Points)
Shows creativity and resourcefulness in solving problems. (0-5 Points)
Works collaboratively to solve problems (if in a group). (0-5 Points)

5. **Presentation and Demonstration** (20 Points)
Clearly explains the project and its components. (0-5 Points)
Demonstrates the project’s functionality effectively. (0-5 Points)
Answers questions confidently and accurately. (0-5 Points)
Presentation is well-organized and engaging. (0-5 Points)

Teacher Directions:

This table is a decision matrix to help students organize their thoughts about what what they have learned about the problem, the background, and the test results. Scaffold the filling out of this table to help students think critically about their solutions and how they might try to make modifications for improvement.

Analyze your solution based on:	The results from your tests	The expected results based on what you learned before planning	whether or not your solution addressed the criteria and met the constraints
What went well?			
What needs improvement?			

1. **Based on your analysis of your test results, the expected results, and the criteria and constraints, what improvements to your solution do you want to make and why?**

Decide/Final Solution Lesson(s)

Teacher Directions:

In Section 1, students use evidence-based reasoning in reporting their final solution to the client. This can happen through use of the EBR graphic as part of their memo or presentation, or you can have the students include the aspects of the EBR graphic (without the graphic itself) in the memo or the presentation. In Section 2, these questions should be completed after presenting the solution to the client and the entire design challenge is complete. See Page 12 for information about how to fill in the EBR graphic.

Section 1:
Evidence-Based Reasoning Graphic

Directions: Complete this Evidence-Based Reasoning Graphic to report what your final chosen solution is and the evidence to support your decision.

<table>
<tr><td colspan="2">Problem including Criteria & Constraints
• Explain the client's problem that needs a solution and why it is important to solve.
• List criteria and constraints you will use to decide if your solution is working.</td></tr>
<tr><td colspan="2">Problem:

Criteria:
Constraints:</td></tr>
<tr><td colspan="2">Simplifying Assumptions (if any)
List things that might be important but you have decided not to worry about in order to focus the solution or simplify the analysis of the solution</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Design Idea
• Plan including drawing, labels of materials used, and labels of what each part does.</td><td>Data/Evidence
• List science/mathematics learned and/or results of tests that support your design idea.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Justification - Why do you think this design idea will work?
• Explain how your data and evidence support your design idea in order to meet criteria/constraints.</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Teacher Directions:

This table is a quality matrix to help students organize their thoughts about what they have learned about the problem, the background, the first design, and the redesign tests. Scaffold the filling out of this table to help students think critically about their solutions and how they might discuss further modifications for improvement to the client.

Directions: Fill in the table regarding the overall quality of your solution.

Analyze your redesign based on:	The results from your redesign tests	The expected results based on what you learned before redesigning	whether or not your solution addressed the criteria and met the constraints
What went well?			
What needs improvement?			

1. **Did your redesign improve your solution? Why or why not?**

2. **If you could do another redesign, how would you try to improve your solution?**