Engineering Design Unit

Lesson 1. Color: Black is Hot!
(90 minutes)

Learning Objective
Design an experiment to investigate the impact of surface color on surface temperature.

*Suggested Materials**
infrared thermometer, glue, foam board 1x1 squares (five pieces), construction paper 1x1 squares (four in total – one each of red, blue, yellow, and black), color pencils, and the "Conduct your Color Investigation" pages from the *Engineering Notebook*
** These suggested materials are for each small team. We recommend small teams of 2-3 learners.*

Engage (10 minutes)
Facilitate small team discussions to elicit learners' prior knowledge of temperature and color.

- Encourage each team to respond to the following prompts:
  - ✓ Have you noticed how differently colored clothing feels in the sun?
  - ✓ Which colors feel the most warm? Most cool?
- Inform learners they will conduct an experiment to answer the following question:
  - ✓ What is the best color for the outside of a house in an Urban Heat Island environment?

Explore (35 minutes)

- Distribute the "Conduct your Color Investigation" pages from the *Engineering Notebook*, glue, infrared thermometer, foam board squares (five pieces), and construction paper squares (four in total – one each of red, blue, yellow, and black) to each team.
- Provide teams the opportunity to explore the relationship between color and surface temperature by designing and conducting an experiment. Begin the experience by asking each team to affix the construction paper squares to one side of the foam board squares (the fifth foam board square will be left white). Supervise while each team uses the "Conduct your Color Investigation" pages from the *Engineering Notebook* to design and conduct a surface temperature/color experiment.
- The "Conduct your Color Investigation" pages from the *Engineering Notebook* are divided into five sections: (1) identify independent and dependent variables, (2) create a step-by-step explanation of the experiment, (3) make a prediction, (4) conduct the experiment, and (5) analyze your data through investigative prompts.

Explain (25 minutes)

- Utilize the round-robin method for each team to share their experimental design and results. Investigate shared differences in designs or results through large group discussion.
- As a group answer the following prompts:
  - ✓ Which color recorded the highest temperature?
  - ✓ Which color recorded the lowest temperature?
  - ✓ Was the difference between highest and lowest significant?
  - ✓ What do you think would happen with other colors?

Expand (15 minutes)

- Encourage learners to reflect in their engineering notebook by drawing a picture related to the following prompts:
  - ✓ If you are a homebuilder and you wanted to paint a home with the intent of keeping the outside walls as cool as possible, what color(s) would you choose?
  - ✓ What types of natural and built objects would make your home attractive/functional and still be as cool as possible?

Evaluate (5 minutes)

- Informal questioning:
  - ✓ If a pink, a light blue, and a dark green box (of equal size and material) were left in the sun, which box would have the highest inside temperature? Explain.
  - ✓ If the same three boxes were left outside at night, which box would have the highest inside temperature?
  - ✓ Now that you have conducted your experiment, of the colors that you tested, what is the best color for the outside of a house in an Urban Heat Island environment? Why?

Engineering Design Unit

Lesson 2. Material: Is Cotton Just for Shirts?

(90 minutes)

Learning Objective
Design an experiment to investigate the impact of different insulation materials on surface temperature.

Suggested Materials*
infrared thermometer, foam board 1x1 squares (six pieces), tape, and insulation materials (bubble wrap, cotton batting, fabric, paper, cardboard, Easter grass, Styrofoam, etc.), and the "Conduct your Heat Transfer Investigation" pages from the *Engineering Notebook*
** These suggested materials are for each small team. We recommend small teams of 2-3 learners.*

Engage (10 minutes)
Facilitate a large group discussion to elicit learners' prior knowledge of temperature and insulation materials. While learners are participating in the discussion record their suggestions on the board or any public surface.

- Encourage the group to respond to the following prompts:
  - ✓ What are some different types of insulation materials? (Things learners might relate to: jackets, hats, gloves, shoes, etc.)
  - ✓ Are there differences in how heat from the sun moves through these different insulation materials?
  - ✓ Do you think these materials would be good to insulate your house?
- Inform learners they will conduct an experiment to answer the following question:
  - ✓ What is the best insulation material for a house in an Urban Heat Island environment?

Explore (40 minutes)

- Distribute the "Conduct your Heat Transfer Investigation" pages from the *Engineering Notebook*, infrared thermometer, foam board 1x1 squares (six pieces), and insulation materials.
- Provide teams the opportunity to explore the relationship between insulation material and by surface temperature by designing and conducting an experiment. Begin the experience by asking each team to choose three insulation materials they would like to test. Each team will create three "insulation foam board sandwiches" using their foam board squares, insulation material, and tape provided. Each "sandwich" should be of equal thickness (we recommend 0.5 inches, 1.0 inch, 1.5 inches, or 2.0 inches) and the tape should not cover either the top or the bottom surface (the tape can overlap onto the top and bottom surfaces, but keep it to the edges). Learners will take surface temperature measurements for both the "top" and the "bottom" of the insulation foam board sandwich. The "top" is the surface that faces the sun and the "bottom" is the surface that is not.
- Supervise while each team designs and conducts a surface temperature/insulation material experiment.
- The "Conduct your Heat Transfer Investigation" is divided into five sections: (1) identify independent and dependent variables, (2) create a step-by-step explanation of the

experiment, (3) make a prediction, (4) conduct the experiment, and (5) analyze your data through investigative prompts.

Explain (25 minutes)

- Utilize the round-robin method for each team to share their experimental design and results. Investigate shared differences in designs or results through large group discussion.
- As a group answer the following prompts:
  - ✓ How can you determine which insulation material allowed the least amount of heat to pass through?
  - ✓ Which material was the best insulator?
  - ✓ What makes some insulation materials better than others?

Expand (10 minutes)

- Using their engineering notebooks, encourage learners to reflect on the following prompts:
  - ✓ Could an insulation material used to insulate against heat be used to insulate against the cold? Explain your reasoning.
  - ✓ Can you think of any animals that use insulation to help them survive? How does the insulation help them to survive?

Evaluate (5 minutes)

- Informal questioning:
  - ✓ If an insulated and a non-insulated box were left in the sun, which box would have the most cool inside temperature? Why?
  - ✓ If the same two boxes were left in a cold room, which box would have the highest inside temperature? Why?
  - ✓ Now that you have conducted your experiment, of the insulation materials that you tested, what is the best insulation material for a house in an Urban Heat Island environment? Why?

Engineering Design Unit

Challenge: ***Design and construct a model house using the Engineering Design Process so the inside temperature is at least 8-10ºF lower than the outside temperature on a sunny day in an Urban Heat Island environment.***
(six 90-minute sessions)

Suggested Materials*
Materials for each model house: two foam boards, infrared thermometer, glue, duct tape, construction paper (various colors), heavy-duty scissors for cutting foam boards
Insulation materials: bubble wrap, cotton balls, fabric, shredded paper, fiber fill, etc.
** These suggested materials are for each small team. We recommend small teams of 2-3 learners.*

The learning activities in units 1 and 2 of the Urban Heat Island phenomenon were designed to prepare learners to attempt this project-based challenge. Knowledge gained from conducting investigations in units 1 and 2 will inform the design process inherent in this challenge. Encourage learners to refer to their *Engineering Notebook* as needed with attention to their data-based analysis and conclusions from their investigations.

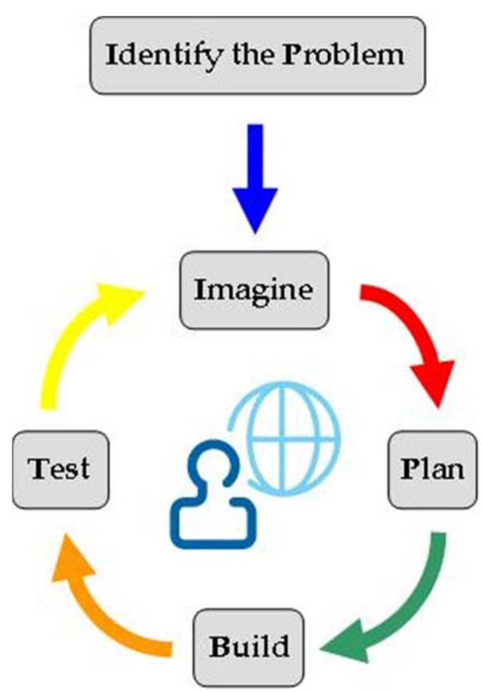
Provide teams the opportunity to design, build, and test their own model house using the Engineering Design Process. We suggest that you engage learners in at least three iterations of the design, build, and test phases. At the end of each iteration, teams should save their model house so they can demonstrate the progress they made in creatively meeting the challenge.

As learners iterate through the three design, build, and test phases, they should be encouraged to carefully document each iteration. As teams test their designs, they will need to defend their design decisions. Learner teams will discover through the use of the Engineering Design Process that the design decisions they make will impact the successful outcome of their effort.

The Engineering Design Process

You may not know it, but you are a problem solver. Everyday you encounter problems that require action. Whether the problem is simple or complex, you always seem to find a solution. Sometimes your solutions work great and other times your solutions don't seem to help at all.

Like you engineers are problem solvers and just like you not all of their solutions work perfectly. To help engineers find the best solution(s), they try many different ideas (good and bad), learn from their mistakes, and modify their ideas based on what the have learned. This series of steps is called the **design process**.



Identify the Problem
Before you begin to gather solution ideas, it is important that you understand the problem. Identify what needs the problem addresses.

Imagine
Imagining a solution begins with brainstorming as many new ideas or improvements on old ideas as you can. Always remember that brainstorming is a technique used to generate all types of ideas, judgment and criticism is not allowed.

Plan
Select a one or more of the most appropriate new ideas (or improved old ideas) created during the *imagine* stage and create a plan of action for each idea. Each plan should include drawings and descriptions for the overall look, size, parts, material, functions, etc. Each plan should be specific enough for you to use them in the next stage.

Build
Follow your plan(s) to build your design.

Test
At this stage you want to evaluate how your built design(s) solve the needs of the problem. Consider the following questions:
- ✓ Does your design meet the needs of the problem?
- ✓ Can your design be improved and still meet the needs of the problem?

Identify and Understand the Problem

Why do we build houses?
Facilitate a large group discussion to elicit learners' knowledge of why we design, build, and live in houses. If you live in an Urban Heat Island environment, you would want to live in a home that is designed to provide you with reduced indoor temperature than the outside environment. For instance in the summer, especially in an Urban Heat Island like Phoenix, it is a challenge to maintain a comfortable indoor temperature without heavy usage of air-conditioning. Houses can be designed and constructed with materials that will naturally enhance the living environment by providing reduced temperatures without using additional energy. Therefore, this challenge is designed to engage learners in thinking about this challenge and creatively designing solutions with found objects. Consider the following questions for group discussion:
- ✓ When is your home the most warm during the year?
- ✓ What time of day is your home the most warm?
- ✓ If you did not have air-conditioning in your home, could you live in that home during the warmest months?
- ✓ If you did not have electricity to run a fan or to run your air-conditioning unit in your home, and had to live in that home what would you do?
- ✓ What ideas do you have for building a home that will have lower indoor temperatures than the outside environment?

Present learners with the following "Engineering Constraints":

Design constraint

- Repeat the design, build, and test phases for your model house three times. [Note: This repetition is known as iterations. This is frequently referred to as "design iterations" which is a part of the Engineering Design Process.]
- Use information from each successive design-build-test phase to inform the next.

Construction materials

- You will be provided with two foam boards for each design effort.
- Maximize your usage of the foam board (make as large a model house as possible with these materials).
- Use these materials to construct outside and inside walls, floor, and the roof.
- Construct a shelf at mid-height on the inside of your model house.

Insulation material

- Choose an insulation material first. Use that insulation material ONLY for that particular design.
- This means that you cannot mix insulation materials within one design.
- However, you can use a different insulation material for your next design.

Insulation thickness

- For each design keep your insulation thickness the same for all walls. Thickness cannot exceed 2 inches.

Inside temperature

- Use the inside mid-height shelf surface to measure the inside temperature of your model house.

Outside temperature

- Use the outside wall surface of your model house that faces the sun to measure the outside temperature.
- Take your measurement at mid-height of this outside wall surface.

Measurement device

- Use the same infrared thermometer to measure the inside and outside temperature for each of your three designs.

What do we already know? Synthesize your Knowledge

With attention to the constraints specified in this challenge, facilitate a large group discussion to elicit learners' prior knowledge of the materials used in unit 1 and 2 investigations, their properties (surface color, insulation type, thickness of insulation material), and their impact on surface temperature as it relates to building a model house with these materials. The following are suggested questions:

- ✓ What materials did we explore?
- ✓ What properties of these materials did we investigate?
- ✓ How did these properties impact surface temperature?
- ✓ If you were to build a home with these materials:
  - what would you use for your outside surface color? Why?
  - what insulation material will you use? Why?
  - how thick will the insulation material be? Why?

Imagine Solutions

- As learners brainstorm ideas to meet the challenge, focus teams to pay attention to the specified engineering constraints. Consider the following questions as learners begin to plan the design of their model house:
  - ✓ What insulation material will you use? Why? What data do you have to support your decision? State data from your prior investigations.
  - ✓ How thick do you want your insulation to be? Why? What data do you have to support your decision? State data from your prior investigations.
  - ✓ What color do you want to make the outside walls? Why? What data do you have to support your decision? State data from your prior investigations.
  - ✓ What type of roof do you want? (e.g., flat, sloped, etc).

Plan the Design

Sketch and Describe the Design

- Encourage each team to sketch designs of their model house.
- Learners should save each sketch that you come up with. This is a process where teams can see the progress in their design ideas!
- For each design sketch, encourage teams to describe their design in brief as a part of their design documentation process.
- Learners' design sketches should include measurements for their model house. Measurements would include:
  - ✓ Model house floor area and perimeter
  - ✓ Wall height, width, and thickness (breadth) for each wall (area, perimeter)
  - ✓ Inside mid-shelf height
  - ✓ Roof size (area, perimeter)
- Finally, design sketches should include specifics of methods for connecting walls, floor, and roof.
  - ✓ Specify the materials (e.g., glue, duct tape) that you will use.

Build the Model using the Design

By now, your learner teams will be eager to build! They will want to implement their ideas from the designs they have created.

- Remind learner teams that they have to follow the specified engineering constraints. Limited resources are a significant characteristic of the constraints inherent in almost all engineering problems. That is, it is seldom that engineering teams have unlimited resources.
- If you have digital cameras available, say one per team, or a few that can be shared around your classroom, provide them to your teams to document their building activities. Photographs of the evolution of the products learner teams construct will become an important part of the documentation phase.

Test the Model

Encourage teams to test their model house by collecting data.

- Learners should test the model house design and construction by measuring the inside and outside temperatures as specified in the engineering constraints.
- As teams take measurements, remind learners to document the conditions under which they conducted the test. Consider the following questions:
  - ✓ Where will the team place the model house? (e.g., on concrete, grass, gravel, etc).
  - ✓ How many temperature measurements over time will they make?

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Once learners have collected data from their model house design, they will need to analyze their data so their next design iteration will benefit from their previous design(s). This would also be an appropriate time for teams to learn from each other's designs, models, and test data. Encourage teams to do the following through brief whole group presentations and demonstrations. You may consider a gallery type sharing experience.

- Describe the benefits of model house design you created and tested. Consider issues of cost (of materials, construction time, etc.), ease of building, time to build from your design plan.
- How well did your design meet the challenge? Were you able to successfully build a model house with inside temperature at least 8-10ºF lower than the outside temperature on a sunny day in an Urban Heat Island environment?

- What impact did your design decisions have on your success? Consider the following:
  - ✓ insulation material and thickness
  - ✓ outside wall color
  - ✓ model house size
  - ✓ roof style and shape
  - ✓ the location where you conducted your tests

Iterate!

Before learner teams engage in modifying their designs they should conduct a careful analysis of what worked and what did not from their current design. They need to think about the improvements they intend to make and explain their reasoning in their engineering notebook. You as the facilitator of learning could serve as the client, who needs to be convinced by the teams that their reasons for design changes are appropriate to the challenge.

Celebrate!

Invite family members, colleagues, and peers for a final gallery style presentation where your class teams will share their learning via a poster that documents their journey in meeting the engineering challenge. Teams should also demonstrate their products from each iteration noting changes in the designs.

Conduct your Color Investigation (page 1)

Unit 2: Lesson 1. Color: Black is Hot!

Learning Objectives

Design an experiment to investigate the impact of surface color on surface temperature.

Instructions

You will design an experiment to investigate the following question:

What is the best color for the outside of a house in an Urban Heat Island environment?

Equipment

infrared thermometer, glue stick, foam board 1x1 squares (five pieces), construction paper 1x1 squares (four in total – one each of red, blue, yellow, and black), and color pencils

Before you design your experiment, consider the following:

List the colors of the surface (this is your independent variable, that you will vary in the experiment)

Create a plan for how you will keep the following variables constant for each surface color:

Time between temperature measurements for a ***particular*** *surface color (note: the time between measurements should be kept consistent)*

Location (that is, shaded, not shaded, etc.) Note that it is important that the measurements for all of your surface colors need to occur at the same location.

Note that it is important that you use the appropriate measurement device. Use the infrared thermometer to measure the surface temperature.

Conduct your Color Investigation (page 2)

Unit 2: Lesson 1. Color: Black is Hot!

Learning Objectives

Design an experiment to investigate the impact of surface color on surface temperature.

Instructions

Design your Experiment

Now that you know which variable you want to test, you need to determine how you will perform the experiment. Write down step-by-step what you will do and how you will collect data. **Someone who is not in your group should be able to follow your design exactly the way you would. Carefully provide details.**

Conduct your Color Investigation (page 3)

Unit 2: Lesson 1. Color: Black is Hot!

Learning Objectives

Design an experiment to investigate the impact of surface color on surface temperature.

Instructions

Make a Prediction

Before you start your experiment you should ***predict*** what you expect to find after you collected the data. What impact do you think the surface color will have on surface temperature? Describe.

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As a part of your prediction, rank order the surface colors by what you believe will have lowest surface temperature.

Predicted Rank Order *(note: 1 will represent the surface with the lowest temperature)*	Surface Color
1	
2	
3	
4	
5	

Conduct your Color Investigation (page 4)

Unit 2: Lesson 1. Color: Black is Hot!

Learning Objectives

Design an experiment to investigate the impact of surface color on surface temperature.

Instructions

Conduct your experiment. As you conduct your experiment, record the measurements in the data tables below.

	Surface Temperature °F			
Surface Color	*Time 1*	*Time 2*	*Time 3*	*Time 4*

Conduct your Color Investigation (page 5)

Unit 2: Lesson 1. Color: Black is Hot!

Learning Objectives

Design an experiment to investigate the impact of surface color on surface temperature.

Instructions

Analyze your data

Answer the following questions based on your data.

1. Which surface color had the ***lowest*** surface temperature? Speculate why?

2. Which surface color had the ***highest*** surface temperature? Speculate why?

3. Based on the data collected, rank order the surface colors from lowest to the highest surface temperature.

Rank Order (*note: 1 will represent the surface with the lowest temperature)*	Surface Color
1	
2	
3	
4	
5	

Now, compare this rank order table with your *predicted* rank ordering of surface colors from the lowest to the highest surface temperature [see "Conduct your Color Investigation (page 3)"]. If your prediction was correct, how did you know what would happen? If your prediction was incorrect, how has your thinking changed?

Conduct your Heat Transfer Investigation (page 1)

Unit 2: Lesson 2. Material: Is Cotton Just for Shirts?
Learning Objective
Design an experiment to investigate the impact of different insulation materials on surface temperature.

Instructions
You will design an experiment to investigate the following question:
What is the best insulation material for a house in an Urban Heat Island environment?

Equipment
infrared thermometer, foam board 1x1 squares (six pieces), tape, and insulation materials (bubble wrap, cotton batting, fabric, paper, cardboard, Easter grass, Styrofoam, etc.)

Before you design your experiment, consider the following:
List the insulation materials that you want to investigate (this is your independent variable, that you will vary in the experiment)

Create a plan for how you will keep the following variables constant for each insulation material:
*Time between temperature measurements for a **particular** insulation material (note: the time between measurements should be kept consistent)*

Thickness of insulation material (this refers to the space filled with insulation material between the two pieces of foam board) Note that it is important that this variable be the same for all of your insulation materials. We suggest that you select from the following options: 0.5 inches, 1.0 inch, 1.5 inches, and 2.0 inches. Once you make your decision, note that in the space below and explain your reasoning.

Location (that is, shaded, not shaded, etc.) Note that it is important that the measurements for all of insulation materials need to occur at the same location.

Note that it is important that you use the appropriate measurement device. Use the infrared thermometer to measure the surface temperature.

Conduct your Heat Transfer Investigation (page 2)

Unit 2: Lesson 2. Material: Is Cotton Just for Shirts?

Learning Objective

Design an experiment to investigate the impact of different insulation materials on surface temperature.

Instructions

Design your Experiment

Now that you know which variable you want to test, you need to determine how you will perform the experiment. Write down step-by-step what you will do and how you will collect data. **Someone who is not in your group should be able to follow your design exactly the way you would. Carefully provide details.**

Conduct your Heat Transfer Investigation (page 3)

Unit 2: Lesson 2. Material: Is Cotton Just for Shirts?
Learning Objective
Design an experiment to investigate the impact of different insulation materials on surface temperature.

Instructions
Make a Prediction
Before you start your experiment you should ***predict*** what you expect to find after you collected the data. What impact do you think the type of insulation material will have on surface temperature? Describe.

____

____

____

____

As a part of your prediction, rank order the insulation materials by what you believe will have lowest surface temperature on the "bottom" side of the foam board. Here the "bottom" side refers to the surface that does NOT face the sun directly.

Predicted Rank Order (*note: 1 will represent the surface with the lowest temperature)*	Insulation Material
1	
2	
3	

Conduct your Heat Transfer Investigation (page 4)

Unit 2: Lesson 2. Material: Is Cotton Just for Shirts?

Learning Objective

Design an experiment to investigate the impact of different insulation materials on surface temperature.

Instructions

Conduct your experiment. As you conduct your experiment, record the measurements in the data tables below.

	Surface Temperature °F							
Insulation Material	*Time 1*		*Time 2*		*Time 3*		*Time 4*	
	Top	*Bottom*	*Top*	*Bottom*	*Top*	*Bottom*	*Top*	*Bottom*

Conduct your Heat Transfer Investigation (page 5)

Unit 2: Lesson 2. Material: Is Cotton Just for Shirts?
Learning Objective
Design an experiment to investigate the impact of different insulation materials on surface temperature.

Instructions
Analyze your data
Answer the following questions based on your data.
1. Which insulation material allowed the ***least amount of heat from the sun*** to pass through? Speculate Why?

2. Which insulation material allowed the ***most amount of heat from the sun*** to pass through? Speculate Why?

3. Based on the data collected, rank order the insulation materials from lowest to the highest surface temperature for the "bottom" side of the foam board.

Rank Order (*note: 1 will represent the surface with the lowest temperature)*	Insulation Material
1	
2	
3	

Now, compare this rank order table with your *predicted* rank ordering of insulation materials from the lowest to the highest surface temperature [see "Conduct your Heat Transfer Investigation (page 3)"]. If your prediction was correct, how did you know what would happen? If your prediction was incorrect, how has your thinking changed?

Engineering Design Challenge

Design and construct a model house using the Engineering Design Process so the inside temperature is at least 8-10°F lower than the outside temperature on a sunny day in an Urban Heat Island environment.

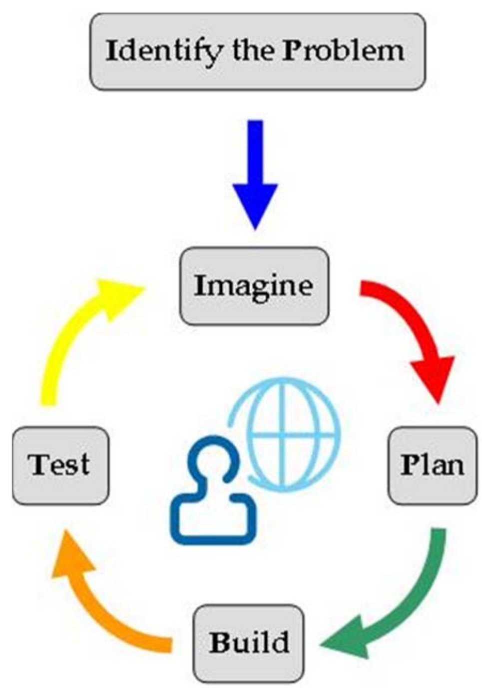
Materials for each model house: two foam boards, infrared thermometer, glue, duct tape, construction paper (various colors), heavy-duty scissors for cutting foam boards
Insulation materials: bubble wrap, cotton balls, fabric, shredded paper, fiber fill, etc.

Over the past two months you have been learning about the natural and built environments that we find around your school grounds. Today you will use all the information you have learned to design and build a model of a house. You will use the Engineering Design Process to design, build and test your house. The first step in Engineering Design is to state the challenge. Your charge is to build a house, which allows the least amount of heat to enter it.

You will design, build, and test three model houses in succession using the Engineering Design Process. Document your design and test results for each model, 1 to 3. Explain your design decisions. What changes did you make to your design? Why? Did it improve your design.

The Engineering Design Process

You may not know it, but you are a problem solver. Everyday you encounter problems that require action. Whether the problem is simple or complex, you always seem to find a solution. Sometimes your solutions work great and other times your solutions don't seem to help at all.



Like you engineers are problem solvers and just like you not all of their solutions work perfectly. To help engineers find the best solution(s), they try many different ideas (good and bad), learn from their mistakes, and modify their ideas based on what the have learned. This series of steps is called the **design process**.

Identify the Problem
Before you begin to gather solution ideas, it is important that you understand the problem. Identify what needs the problem addresses.

Imagine
Imagining a solution begins with brainstorming as many new ideas or improvements on old ideas as you can. Always remember that brainstorming is a technique used to generate all types of ideas, judgment and criticism is not allowed.

Plan
Select a one or more of the most appropriate new ideas (or improved old ideas) created during the *imagine* stage and create a plan of action for each idea. Each plan should include drawings and descriptions for the overall look, size, parts, material, functions, etc. Each plan should be specific enough for you to use them in the next stage.

Build
Follow your plan(s) to build your design.

Test
At this stage you want to evaluate how your built design(s) solve the needs of the problem. Consider the following questions:

- ✓ Does your design meet the needs of the problem?
- ✓ Can your design be improved and still meet the needs of the problem?

Identify and Understand the Problem

Engineering Constraints:
Design constraint

- Repeat the design, build, and test phases for your model house three times. [Note: This repetition is known as iterations. This is frequently referred to as "design iterations" which is a part of the Engineering Design Process.]
- Use information from each successive design-build-test phase to inform the next.

Construction materials:

- You will be provided with two foam boards for each design effort.
- Maximize your usage of the foam board (make as large a house as possible with these materials).
- Use these materials to construct outside and inside walls, floor, and the roof.
- Construct a shelf at mid-height on the inside of your house.

Insulation material:

- Choose an insulation material first. Use that insulation material ONLY for that particular design.
- This means that you cannot mix insulation materials within one design.
- However, you can use a different insulation material for your next design.

Insulation thickness:

- For each design keep your insulation thickness the same for all walls. Thickness cannot exceed 2 inches.

Inside temperature:

- Use the inside mid-height shelf surface to measure the inside temperature of your house.

Outside temperature:

- Use the outside wall surface of your house that faces the sun to measure the outside temperature.

- Take your measurement at mid-height of this outside wall surface.

Measurement device:

- Use the same infrared thermometer to measure the inside and outside temperature for each of your three designs.

Imagine Solutions

Consider the following questions as you begin to plan a design for your model house:

- ✓ What insulation material will you use? Why? What data do you have to support your decision? State data from your prior investigations.
- ✓ How thick do you want your insulation to be? Why? What data do you have to support your decision? State data from your prior investigations.
- ✓ What color do you want to make the outside walls? Why? What data do you have to support your decision? State data from your prior investigations.
- ✓ What type of roof do you want? (e.g., flat, sloped, etc).

Plan the Design

Sketch and Describe the Design

- As you plan your design, keep in mind the specified engineering constraints. Your design should directly respond to the challenge with attention to these constraints.
- You will want to save each sketch that you come up with. This is a process where you can see the progress in your design ideas!
- For each design sketch, describe in brief your design.
- Your design sketches should include measurements for your model house. Measurements would include:
  - ✓ House floor area and perimeter
  - ✓ Wall height, width, and thickness (breadth) for each wall (area, perimeter)
  - ✓ Inside mid-shelf height
  - ✓ Roof size (area, perimeter)
- Your design sketch should include specifics of methods for connecting walls, floor, and roof.
  - ✓ Specify the materials (e.g., glue, duct tape) that you will use.

Build the Model using the Design

Implement your design as planned!

- Remember that you have to follow the plan you designed to meet the specified engineering constraints. You should know that almost all engineering problems have one thing in common. Engineers who work on finding ways to solve these engineering problems do not have unlimited resources. You too should carefully use the provided resources to meet your design challenge.
- If you are provided with a digital camera, use it to carefully document your building activities. You will want to photograph the evolution of the product as you build it. You can then use these photographs to document your Engineering Design Process.

Test the Model

Did you meet the challenge? Test your model house by collecting data.

- Test the house design and construction by measuring the inside and outside temperatures as specified in your engineering constraints. As you take measurements, remember to document the conditions under which you performed the test. Consider the following questions:
  - ✓ Where will you place your house? (e.g., on concrete, grass, gravel, etc).
  - ✓ How many temperature measurements over time will you make?
- Analyze your data so your next design iteration will benefit from your previous design(s).
- Describe the benefits of model house design you created and tested. Consider issues of cost (of materials, construction time, etc.), ease of building, time to build from your design plan.
- How well did your design meet the challenge? Were you able to successfully build a model house with inside temperature at least 8-10°F lower than the outside temperature on a sunny day in an Urban Heat Island environment?
- What impact did your design decisions have on your success? Consider the following:
  - ✓ insulation material and thickness
  - ✓ outside wall color
  - ✓ house size
  - ✓ roof style and shape
  - ✓ the location where you conducted your tests

Iterate!

- Review designs from other teams and share ideas on your successes.
- Document what worked and what did not. Describe why?
- Defend the design changes you will make for your next design iteration.
- Repeat the design, build, and test phases using the Engineering Design Process.

Celebrate!

Plan a celebration with your family, friends, teachers, and peers to share your success! Make a gallery style presentation of your models and showcase what you know as a young engineer.