

# **Phase II – Implementation**

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## The Engineering Design Process

I am using the design process outlined by NASA (Fig-1). The process is simple and easy for my students to understand, recall and apply the process effectively.



Figure -1 NASA Engineering design process

<https://www.nasa.gov/audience/foreducators/best/edp.html>

## **Implementation Timeline**

It took three weeks for the students to gain good conceptual understanding about thermal energy, heat transfer, and temperature by performing hands on science activities, classroom demonstrations and discussions. They also collected scientific data's through relevant investigation to compare and know the ability to various materials thermal insulating properties. Subsequently, the general use of the engineering design process was introduced to the students through simple activities.

## **Implementation of the design activity**

I have chunked the implementation of the design process into three phases. Each phase will framework the design process activities.

➤ ***Phase 1: Literature connection (estimated time - 40 minutes)***

Students will read a book that hooks the underlined topic and the purpose of the challenge.

➤ ***Phase 2: Exploration (estimated time - 60 minutes)***

Students will explore possible solution using the prior knowledge they possess and by discussing their views with their team members.

➤ ***Phase 3: Design (estimated time - 120 minutes)***

Students will plan and do the design activity

# Engineering Design Notebook

## **Phase 1: Literation Connection**(*estimated time - 40 minutes*)

### ***Identify the problem:***

The book entitled *THE MOON* by Seymour Simon is read aloud. Students pay attention to the fact that moon has no air, water, clouds or even weather and that the temperature in the moon gets very hot or very cold because there is no air for heat transfer. We identify and discuss the difficulty in existing in places that have greater temperature fluctuation. Students are asked to restate the problem and to say what they know about insulators and its role in temperature regulation. The main concept underlying is that insulators are essential to protect ourselves from extreme temperature fluctuations.

## **Phase 2: Exploration** (*estimated time - 60 minutes*)

### ***Brainstorm:***

A quick review on the concepts of heat transfer and the scientific data collected from the previous investigation is done. Students are paired, and the design challenge is presented to them. Enough time is given to read and understand the challenge. They highlight and make a note on the constraints. **Challenge:** Students will design a protective insulator for a cup of hot water and a cup of cold water to be used in lunar environment. The students will also conduct a scientific experiment and compare the data between the insulated cups and unprotected cups. They can use any combination of materials given to create a protective insulator to keep 100ml of hot water and 100ml of cold water at a constant temperature.

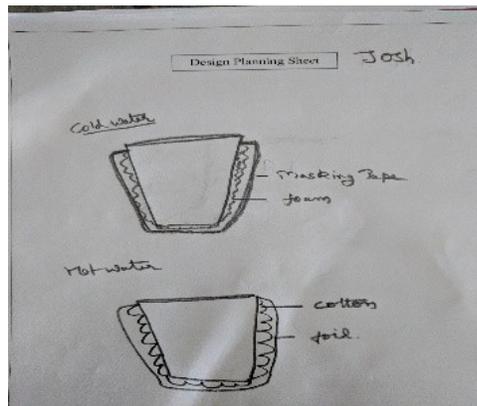
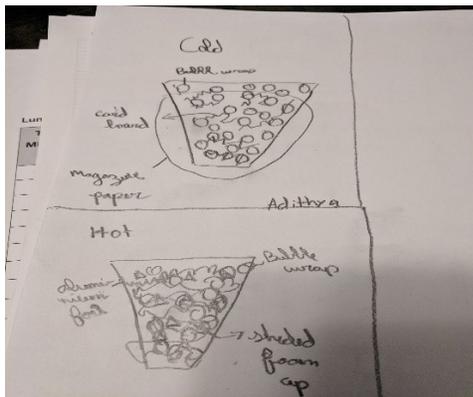


Next, to facilitate students with brainstorming, a video named, the history of thermos flask is played. It shows the evolution and the basic principle of thermos flask that has revolutionized people's life style. This video aids students to understand the structure of a vacuum flask and how it is designed innovatively to reduce heat transfer. Then, materials required for the design challenge are provided to the students:

- |                  |                     |                  |
|------------------|---------------------|------------------|
| 1. Bubble wrap   | 5. Styrofoam        | 9. Sand          |
| 2. Paper         | 6. Cardboard shreds | 10. Masking tape |
| 3. Cloth         | 7. Cotton           |                  |
| 4. Aluminum foil | 8. Woolen socks     |                  |



Each group receive all the materials listed above. Students are examining and discussing on the thermal insulating properties of materials provided. Based on the prior knowledge they are deciding on which material to use. They can either combine all materials or a few. I emphasis them to recall the design constraints. Each student is given a design planning sheet and are asked to sketch their design. I am giving enough time to think and brainstorm different ideas. Students are getting excited in constructing the prototype.



### **Phase 3: Design (estimated time - 120 minutes)**

#### ***Design:***

I constantly encourage them to label the design with materials they have selected. After students have finished drawing their brainstormed ideas, I ask them to review the design carefully to check if their design respect the constraints that are discussed in the challenge. Next, I ask them to discuss their designs with each other in the group and finalize on the best solution. It could be either a blend of their individual design or just any one of their ideas.

#### ***Build:***

Based on the design plan, students began to create a protective insulator for the cups. They are very keen in creating a neat and perfect insulating covering for the cups. They find it difficult to cover the base of the cups, sometimes the cups are not stable and keeps on falling. I am motivating them to continue even if any mistake happens while constructing the prototype.



### ***Test and Evaluate:***

Students have finished building their prototypes. Next, I provided each group experiment and record sheets and asked them to follow the directions. I help them if they need more clarification. Before we start the scientific experiment, timer is set for every 30 seconds and room temperature is recorded. I place the unprotected cups with hot and cold water (controls) separately with thermometer. Within the group, one of them records the temperature for the hot water cup and other for the cold-water cup. Simultaneously, I am recording the temperature for the unprotected cups with hot and cold water as a control data. We evaluate the prototypes based on the data collected and will work on the unsuccessful prototypes to decrease the temperature fluctuation.



Time Min:sec	Cold Water Cup (°C)		Hot Water Cup (°C)	
	Trial 1	Trial 2	Trial 1	Trial 2
0:00	5.5	5.00	96.7	98.0
0:30	5.7	5.9	95.8	97.8
1:00	5.8	6.5	94.6	97.6
1:30	5.9	7.2	93.1	97.4
2:00	6.0	7.9	91.9	97.2
2:30	6.3	8.6	90.9	96.9
3:00	6.5	9.7	89.7	96.7
3:30	6.8	10.1	88.0	96.6
4:00	7.0	10.8	86.3	96.4
4:30	7.2	11.6	85.1	96.2
5:00	7.3	12.5	84.2	96.0

### ***Redesign:***

Students with unsuccessful prototypes examine and discuss the errors and the scope for improvements in the design with their partners. They redesign their prototypes by trying different combination of materials and construct a new prototype. I anticipate them to ask my suggestions and help in redesigning. Students with successful prototypes also redesign and construct with different combinations of materials. Once improvements are completed, prototypes are again tested to check whether temperature fluctuation is decreased.



### ***Share:***

Students share their design for others to see. They give a brief explanation on the materials they have used to create the insulator. It is interesting to see the way they have built. We conclude the activity by watching Aerogel Insulation video by NASA hallmark of success

(<https://vimeo.com/54290499>).



## **Design Challenge Reflections**

This is a perfect culminating activity for teaching heat transfer unit. I felt the activities were refreshing and re-engaging their efforts. Students got into an excitement mode especially

when they imagined themselves in a lunar environment. Without much effort, students made connections with their design plan and prior experiences. It was astonishing for me to see when students valued their failure as a chance to improve. This important mind-shift gave me assurance that I am doing a right job. At first, I didn't have any idea of how implementing engineering challenges would help my students become the motivated and independent problem solvers that they needed to be. But, as I began it became apparent that there was merit to this approach. I really enjoyed their ability to link their mistakes or errors as an evidence of misconception and not because of predicting or carelessness.

### **The Design Process:**

I am glad for selecting NASA's engineering design process. It is an excellent process that nurtures both engineering and scientific practices among younger graders. I feel, the best part of the design process is its inclusion of experiment step between create and improve steps. This aids in an effective integration of science process skills that makes the learning experiences richer and more meaningful.

### **The Challenges:**

Despite of demonstrating positive attitudes towards teamwork and being responsible, I wish my students to:

- Avoid comparing the solutions presented by different student groups instead each group can compare their solution to the design criteria and constraints and to prior designs the group has constructed.
- Improve group communication skills. At times, they find it difficult to accept others views and ideas. This is especially when they must design an alternative design solution.
- Be responsible in using the stationery materials such as rubber bands, glue.
- Reduce arguments during clean up.

### **Scope for Improvements:**

After completing the project, I realize that several possibilities are there to improve the design challenge to be more effective.

- **Materials:** I like to replace sand with clay or paint as students are finding difficult to handle sand particles. I will also make them work on budget planning for their thermos.
- **Constraints:** I will include lid as criteria and make them understand the effect of a lid by testing temperature with and without a lid. I will also vary the amount of water used in the design to determine the impact the amount of water has on the experiment.
- **Brainstorming:** Students found it difficult in design an alternative solution especially when they successfully designed their first prototype. They are not ready to let go the best solution. In future, I need to include more brainstorming activities (visual prompts, storyboard, brainwriting...)
- **Design Planning:** There is great interest in 3-D prototyping than 2-D. I feel the level of learning the design process needs to be improved.
- **Share:** I should do video recording of my student's presentation.

### **Science and Mathematics concepts:**

The challenge helped student use of science vocabulary words and a working knowledge of thermal energy transfer and insulation. The design challenged student to devise an insulation system to keep water at a constant temperature. Students made observations to provide evidence that heat energy can be transferred from place to place and apply scientific principles to design, construct, and test a device that minimizes thermal energy transfer. The engineering design process facilitated students to:

- Use prior knowledge to describe problems that can be solved.
- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
- Represent data in tables to reveal patterns that indicate relationships.
- Use data to evaluate and refine design solutions.
- Use graphs/data generated to compare alternative solutions to an engineering problem
- Apply scientific ideas to solve design problems.
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.
- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
- Respectfully provide and receive critiques from peers about a proposed procedure, explanation or model.by citing relevant evidence and posing specific questions.

- Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts.

## **The Standards and Topics covered:**

### **The Topics:**

- Thermal energy transfer and Insulation
- Engineering Design Process
- Measurements and Data

### **The Standards:**

#### ***Next Generation Science Standards***

- **3-ESS3-1.** Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
- **3-5-ETS1-1.** Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- **3-5-ETS1-1.** Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- **3-5-ETS1-2.** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **3-5-ETS1-3.** Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved
- **4-PS3-2.** Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- **MS-PS4-2.** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- **MS-PS3-3.** Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
- **MS-PS3-4.** Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **MS-ETS1-2.** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **MS-ETS1-3.** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

- **MS-ETS1-4.** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved

### **Common Core State Standards Connections:**

#### **ELA/Literacy-**

- **RST.6-8.3-** Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
- **WHST.6-8.7-** Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.

#### **Mathematics**

- **SP.B.4-** Display numerical data in plots on a number line, including dot plots, histograms, and box plots.
- **SP.A.1-** Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.

### **International Technology Education Association Content Standards**

#### **Design**

- **Standard 8:** Students will develop an understanding of the attributes of design.
- **Standard 9:** Students will develop an understanding of engineering design.
- **Standard 10:** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving

#### **Abilities for a Technological World**

- **Standard 11:** students will develop abilities to apply the design process.
- **Standard 12:** Students will develop abilities to use and maintain technological products and systems.
- **Standard 13:** Students will develop abilities to assess the impact of products and systems.

#### **The Designed World**

- **Standard 16:** Students will develop an understanding of and be able to select and use energy and power technologies.

Overall, my thought about learning has changed. Prior to this project, I held a belief in the STEM integration, but now I have valid evidence that it is meaningful and promotes higher level thinking, conversation, and problem-solving skills. The design process activity helped my students to gain confidence that they can also build like engineers and investigate like scientist. I am contented that both the design process and the challenge, I have selected encouraged students to independently identify what a successful design is, then develop and improve their own trials at their pace. Observing students performing tasks, I developed a better understanding of how to structure my classroom with more of a constructivist approach where students do the inquiry.