NAVSEA
SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS

#SeaworthySTEM

Cool Your Cargo

A Heat Transfer Challenge for Seafaring Engineers

Grades 9-12

Teacher Guide

Seaworthy STEM™ in a Box Series

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Office of Naval Research
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Science & Technology

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Seaworthy STEM™ in a Box Educator Kit description:

Seaworthy STEM™ in a Box activities are a Navy initiative to provide enhanced Naval-relevant, standards aligned, hands-on activities to K-12 teachers and students. Components of this program include, curated sets of classroom activities that aim to build deep conceptual understanding in Naval-relevant content areas. The kits also includes comprehensive lesson plans, material lists, scientific background information, STEM related literacy books, and student activity sheets. The Seaworthy STEM™ in a Box program is designed to support teachers as they select content, acquire materials, and implement more hands-on STEM activities in their classrooms. Increasing student access to hands-on STEM activities, also increases awareness of STEM career paths, engage students in STEM, and support development of student's abilities in STEM content.

The Seaworthy STEM™ in a Box kits were designed to guide students through the scientific inquiry-based theory and the engineering design process. The content and Naval-relevant activities are aligned with the Next Generation Science Standards. The topics and content covered within the lessons are connected and scaffolded based on distinct grade bands (K-2nd, 3rd-5th, 6th-8th, and 9th-12th).

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Introduction

Welcome to an innovative curriculum designed to engage students in the world of engineering, problem-solving, and creative thinking. This curriculum is structured around three fundamental components, each carefully crafted to provide students with a comprehensive learning experience. In this curriculum, each lesson is divided into three parts: Journal Entry, Part 1, and Part 2.

Parts of Each Lesson

Journal Entry

The first part of every lesson serves as a bridge between what students already know and what they are about to learn. The Journal Entry is an opportunity for students to reflect on their prior knowledge and experiences related to the topic. These questions will stimulate critical thinking and prime students for the exploration of new concepts. The teacher can mold these questions into a format that best fits their class. This entries can be done in the student workbook, a separate journal notebook or another location determined by the educator.

Part 1: Introduction & Research

Following the Journal Entry, Part 1 of each lesson is dedicated to research and in-depth exploration. The students will delve into the subject matter, investigate key concepts, and gather valuable information. This phase is essential in providing the foundation for the Engineering Design Challenge, ensuring that students have the necessary background knowledge and skills to approach real-world problems effectively. Do not feel as though you have to strictly follow these instructions. Use the tools that are necessary for your students. This could include adding teaching strategies, word banks or other differentiation techniques to the lessons.

Part 2: Engineering Design Challenge

The culmination of each lesson is the Engineering Design Challenge. This is where students put their newfound knowledge and research skills to the test. They will work through the engineering design process, applying their problem-solving abilities to develop practical solutions. The challenges are crafted to mimic real-world scenarios, allowing students to experience the fulfillment of creatively designing their own products. Engineering education can be enriched by infusing elements of business-style competitions into your lessons. This approach not only deepens students' technical understanding but also hones their teamwork, critical thinking, and real-world problem-solving skills. This can be done by using the team dynamics page as a "business" team page. Remember, as the teacher you create your materials pricing list from what you have. This will allow you to have more control over the outcome of the lesson. The educator becomes the customer while the students incorporate regular pitch sessions as part of the final presentation. Play with the style of the lesson and build students up to feel the business dynamic that unfolds through the engineering process.

Here We Go!

By the end of this curriculum, students will have the tools and confidence to address real-world challenges in a systematic way. This curriculum is designed to provide the basics and help organize a young engineers thought patterns. Teaching students how to map out their thinking is essential in the development of world changing solutions. We are excited to embark on this educational journey with you! Let's get ready to journal, research, and create as we embark on a #SeaWorthySTEM learning adventure!

Table of Contents

Lesson Title:

Cool Your Cargo

A Heat Transfer Challenge for Seafaring Engineers

Time:

Average learning time is 4-5, 50 minute class periods

Student Objectives:

1. Understand the principles of heat transfer, specifically conduction, convection, and radiation.
2. Apply knowledge of heat transfer to design a cooling system for cargo transported via sea vessels.
3. Collaborate effectively in a team to create a functional and efficient solution to the heat transfer challenge.

Lesson Overview:

Students will explore the science behind heat transfer and its significance in the #SeaworthySTEM industry. They will engage in a hands-on design challenge to create an innovative cooling system for protecting sensitive cargo from heat damage during sea transport.

Next Gen Science Standards (NGSS):

HS-PS3-3
Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

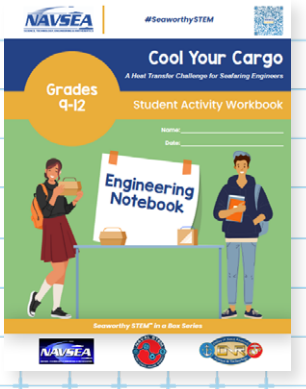
HS-ETS1-2
Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ESS2-4
Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Notes

Materials and Equipment List

- ☑ Insulating materials (foam, bubble wrap, etc.)
- ☑ Conductive materials (metal sheets, rods, etc.)
- ☑ Thermometers
- ☑ Water containers
- ☑ Heat sources (lamps, heaters) ANY source that can change temperature
- ☑ Fan or air blower
- ☑ Various sizes of cardboard boxes or containers
- ☑ Tape, scissors, and other crafting materials
- ☑ Miscellaneous items for insulation and cooling



Student Activity Sheets/Handouts:

Student Activity Worksheet:
Cool Your Cargo: A Heat Transfer Challenge for Seafaring Engineers

Technology Tools:

Computer

Internet access

Part I: Background Research

1 Pre-Assessment Activity:

The student journal response can be used as a pre-assessment for this unit. Have the students answer these questions in the "Journal Entry" section of their engineering notebook.

Sample Journal Prompts:

1. What helps living things stay warm?
2. Why is heat important for living or nonliving things?
3. What do you know about structure and function as it pertains to heat transfer?

2 Pre-Activity:

Have the students answer these questions in the "Think about..." section of their engineering notebook. The teacher can post the questions below for the class to reference when answering.

Tell the students to "Think of a Hot and Cold items from real life" then answer the following questions:

1. What is heat transfer, and how does it occur in everyday situations, such as when touching a hot object?

2. How does a blanket keep you warm by minimizing heat transfer from your body to the surrounding environment?

3. How does a fan help cool you down on a hot day, and what type of heat transfer does it primarily facilitate?

4. Can you think of an example of radiation that you experience regularly, such as feeling the warmth of the sun on your skin?

3 Hook:

Show this video "Heat Transfer" and have students reference questions from the journal and pre-activity section: https://www.youtube.com/watch?v=IvyCe0UaqJY&t=3s

YouTube:

4 **Background Research- Primary Sources:**

Research Artifacts:

- Have students complete the: "**Let's Explore Primary Sources & Research**"

5 **Background Research- Information:**

Research Sheets:

- Have the students complete the: "**Type of Materials Research Sheets**"

6 **Student Discussion:**

After the students complete their research, use the information within both research sections to review with the students. Class discussions, share outs, partner shares or gallery walks are effective methods of communicating findings.

7 **Engineering Design Challenge:**

Discuss protecting cargo and share Navy examples and explain the upcoming design engineering challenge. Some examples are included below:

1. Insulation
2. Heat Exchangers
3. Thermal Barriers
4. Cooling Systems
5. Radiative Cooling Methods

Part 2: Engineering Design Challenge

Background Information:

Heat transfer is the process of energy exchange between objects or systems due to temperature differences. This concept plays a role in our daily lives and engineering applications. There are three primary modes of heat transfer: conduction, convection, and radiation. Conduction involves the transfer of heat through direct contact between objects. For example, when you touch a hot stove, heat is conducted from the stove to your hand. Convection, on the other hand, refers to the transfer of heat through the movement of fluids, such as air or water. A example of convection is the way a radiator heats a room by circulating warm air. Radiation is the transfer of heat through electromagnetic waves, such as the heat we feel from the sun.

The Engineering Design Challenge:

The Navy has tasked your design team with creating cooling system for precious cargo on a ship near in a hot climate. Your cooling system must be able to maintain a temperature within the range that the teacher indicates. The goal of your design is to use materials that keep your cargo temperature within this range. Your team must be creative in determining what type of materials and features should be included for success.

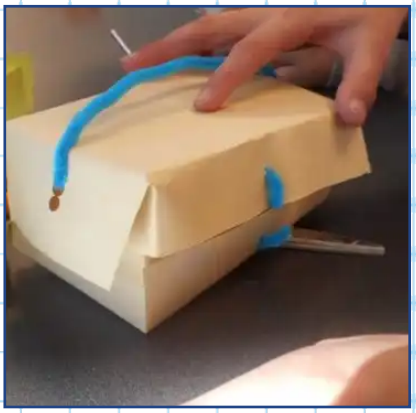
Procedure:

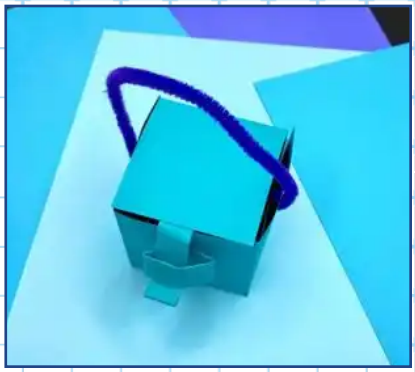
Pre-Activity: Students will fill out a Team Dynamics page to review expectations and goals of the challenge.

I **What is the <u>Problem</u>?**

- Have the students discuss the basic scientific principles associated with the lab: stability and buoyancy.
- Introduce the engineering challenge:
  - ***Design and build a cooling system for cargo that needs to be maintained at the following range:***
    _____ to _____ . *This can be

Examples





Source: https://teachersareterrific.com/2020/08/designing-containers-stem-challenge.html

determined by teacher as the room temperature and availability of materials will potentially change the range.

- ***There are many ways to change the temperature surrounding or within the cargo box. Using a fan or heater surrounding the outside of the box to change external temperature. Alternately, the teacher can also use ice within the box and measure the amount melted (water) as the factor to determine which box was insulated more effectively.***

- Form small teams and distribute the materials. Note: If allowing students to choose materials at random, create a materials home-base (a large box or storage container) designated for hand-selected materials.
- Have the students formulate a problem (in question form) from the scenario provided.

2 What are the Criteria and Constraints?

- Have the students list out the criteria and constraints for the lab.
- Constraints: Provide your students with a list of constraints for the engineering design challenge.
- Discuss budget constraints (a limited number of materials per team).
- Have the students fill out the budget form for their design.

Possible ideas are listed below:

- You will have (pre-determined number) of class periods to design, build and test your project.
- Budget Constraints

3 How can we Brainstorm and construct the Prototype?

- Have the student brainstorm multiple designs for

their prototype.

- Students will choose one design, justify their choice in the writing section and build their models according to their designs.
- Emphasize teamwork, creativity, and adherence to budget.

4 How can we Test and Data Collection?

- Each team tests their prototype by:
    A. Instruct students to design and build a prototype cargo cooling system using the provided materials.
    B. Encourage students to test their systems using heat sources and measure the temperature inside their cargo containers.
    C. Students should collect multiple data points by moving the heat source around the cooling system and checking the temperature.
    D. Students should enclose their "cargo" within a structure and measure the internal temperature of the closed structure.

Note teachers are encouraged to have students create their own step-wise procedures as well. Students may develop different models then the ones listed above, allow for experimentation and flexibility in data collection.

5 What are our Findings? Data Analysis and Reflection

- Team present their findings by creating a data chart, graph and reflection statement to discuss the findings of their prototype.
- Teams discuss what worked and what did not in their design.
- Reflect on the engineering design process by answering the following questions:

A. Does my prototype meet the requirements of the design challenge?

B. Can I improve the design from its original specifications?

C. How can I reduce the cost of my final prototype without sacrificing quality?

6 **Let's Improve it! Class Discussion, Team Redesign Conclusion**

- Discuss the most successful designs and strategies.
- Relate the activity to real-world applications in naval engineering and design.

7 **Peer Evaluation of Teamwork**

- Students will be providing feedback of teammates and collaboration.

Teacher Background Information / Notes:

Teachers should have a good understanding of heat transfer concepts, including conduction, convection, and radiation. They should also be familiar with the challenges faced in the shipping industry due to heat-related damage to cargo. Heat transfer is the process of thermal energy moving from an area of higher temperature to one of lower temperature. The three primary modes of heat transfer are conduction, convection, and radiation. Conduction involves the transfer of heat through direct physical contact between objects, while convection refers to the transfer of heat through the movement of fluids. Radiation occurs through electromagnetic waves and does not require a medium for heat transfer. Teachers should emphasize real-world applications of heat transfer, such as insulation in energy-efficient buildings, the functioning of cooling systems in electronic devices, or the heat transfer on climate patterns.

Vocabulary Terms:

- **Heat transfer**
- **Conduction**
- **Convection**
- **Radiation**
- **Insulation**
- **Cooling system**
- **Cargo transportation**
- **Maritime industry**

STEM Related Careers:

- Marine Engineer
- Mechanical Engineer
- Materials Scientist
- Environmental Engineer
- HVAC (Heating, Ventilation, and Air Conditioning) Engineer


Notes

The Seaworthy STEM™ in a Box curricula was developed through collaborative efforts of a team of individuals at the Naval Surface Warfare Center Carderock Division and Albert Einstein Distinguished Educator Fellows via an inter-agency agreement with the U.S. Department of Energy for the Albert Einstein Distinguished Educator Fellowship (AEF) Program. We are grateful to the following Content Specialists who contributed their knowledge and expertise by researching and writing on selected topics: Suzanne Otto, Stephanie Klixbull, Thomas Jenkins and Melissa Thompson. We'd also like to acknowledge the contributions of AEF participant Ms. Deborah Reynolds, the inaugural AEF Educator at Carderock that helped inspire the design of Seaworthy STEM™ in a Box content. Special thanks to Albert Einstein Fellow Melissa Thompson, for the creation of a collaborative high school engineering curriculum and supplemental additions to the early grade bands; career portfolios, workforce trading cards, and in-house short story publications. Gratitude to Carderock Outreach Specialist Ashlee Floyd, STEM Program Manager, Charlotte George, and Media Specialist Kristin Behrle for the creation and support of this naval endeavor that showcases the diversity of NAVSEA Sites.

It is the goal of the Seaworthy STEM™ Curriculum to embrace NAVSEA technologies from sites nationwide to empower the youth of our nation to purse STEM-centric career pathways. The views and opinions of the Content Specialists expressed herein do not necessarily state or reflect those of the AEF Program, the U.S. Department of Energy, or the U.S. Government. Reference herein to any specific commercial product, process, or service by trade name, trademark, service mark, manufacturer, or otherwise does not constitute or imply endorsement, recommendation, or favoring by the AEF Program, the U.S. Department of Energy, or the U.S. Government.

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