Travel Mug Design Activity

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1. Overview

This activity was created to enhance students' knowledge of engineering and design in a thermodynamics activity. The activity takes approximately 5 class periods to design, build, test, and present a travel thermos/coffee mug. This lesson also uses the scientific method and gives some students the opportunity to apply creativity and science to develop a mug. Furthermore, the lesson allows students to create visuals and a three-minute infomercial to reach more students' interests.

2. Purpose

The purpose of the lesson was to understand engineering design and the thermodynamics involved in heat transfer in a coffee mug. The activity incorporates Math and Science, as well as including a marketing scheme to encourage student creativity.

3. Objectives

The objectives for this project were to:

- Demonstrate the mathematical components of a scientific problem.
- Illustrate that engineers and scientists work together to develop new products.
- Provide an opportunity to use critical eighth grade math skills, such as rate calculation, graphing, and linear equations.
- Encourage student creativity and improve presentation skills through a three-minute infomercial.
- Illustrate how liquids cool (Newton's Law of Cooling)

4. Indiana Eighth Grade Standards Met

4.1. Math

4.1.1. Standard 5 – Measurement

8.5.1 Convert common measurements for length, area, volume, weight, capacity, and time to equivalent measurements within the same system

4.1.2. Standard 6 – Data Analysis and Probability

8.6.4 Analyze, interpret, and display single- and two-variable data in appropriate bar, line, and circle graphs; stem-and-leaf plots; and box-and-whisker plots and explain which types of display are appropriate for various data sets.

8.6.5 Represent two-variable data with a scatterplot on the coordinate plane and describe how the data points are distributed. If the pattern appears to be linear, draw a line that appears to best fit the data and write the equation of that line.

4.2. Science

4.2.1. Standard 1 – The Scientific View of the World

8.1.1 Recognize that and describe how scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory* leads to looking at old observations in a new way.

8.1.3 Recognize and describe that if more than one variable changes at the same time in an experiment, the outcome of the experiment may not be attributable to any one of the variables.

8.1.4 Explain why accurate record keeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.

8.1.6 Identify the constraints that must be taken into account as a new design is developed, such as gravity and the properties of the materials to be used.

4.2.2. Standard 2 – Scientific Thinking

8.2.2 Determine in what units, such as seconds, meters, grams, etc., an answer should be expressed based on the units of the inputs to the calculation.

8.2.3 Use proportional reasoning to solve problems.

8.2.4 Use technological devices, such as calculators and computers, to perform calculations.

8.2.6 Write clear, step-by-step instructions (procedural summaries) for conducting investigations, operating something, or following a procedure.

8.2.7 Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions.

8.2.8 Use tables, charts, and graphs in making arguments and claims in, for example, oral and written presentations about lab or fieldwork.

4.2.3. Standard 3 – The Physical Setting

8.3.10 Explain that increased temperature means that atoms have a greater average energy of motion and that most gases expand when heated.

8.3.13 Explain that energy cannot be created or destroyed but only changed from one form into another.

8.3.14 Describe how heat* can be transferred through materials by the collision of atoms, or across space by radiation*, or if the material is fluid, by convection* currents that are set up in it that aid the transfer of heat.

8.3.15 Identify different forms of energy that exist in nature.

4.2.4. Standard 5 – The Mathematical World

8.5.3 Demonstrate that mathematical statements can be used to describe how one quantity changes when another changes.

8.5.4 Illustrate how graphs can show a variety of possible relationships between two variables.

8.5.5 Illustrate that it takes two numbers to locate a point on a map or any other two-dimensional surface.

4.3. English/Language Arts

4.3.1. Standard 4 – Writing: Processes and Features

8.4.2 Create compositions that have a clear message, a coherent thesis (a statement of position on the topic), and end with a clear and well-supported conclusion.

8.4.3 Support theses or conclusions with analogies (comparisons), paraphrases, quotations, opinions from experts, and similar devices.

8.4.10 Create an organizational structure that balances all aspects of the composition and uses effective transitions between sentences to unify important ideas.

8.4.5 Achieve an effective balance between researched information and original ideas.

4.3.2. Standard 5 – Writing: Applications

8.5.4 Write persuasive compositions that:

- include a well-defined thesis that makes a clear and knowledgeable appeal.
- present detailed evidence, examples, and reasoning to support effective arguments and emotional appeals.
- provide details, reasons, and examples, arranging them effectively by anticipating and answering reader concerns and counterarguments.

8.5.5 Write technical documents that:

- identify the sequence of activities needed to design a system, operate a tool, or explain the bylaws of an organization's constitution or guidelines.
- include all the factors and variables that need to be considered.

- use formatting techniques, including headings and changing the fonts (typeface) to aid comprehension.

8.5.6 Write using precise word choices to make writing interesting and exact.

4.3.3. Standard 6 – Listening and Speaking: Skills, Strategies, and Applications

Organization and Delivery of Oral Communication

8.7.2 Match the message, vocabulary, voice modulation (changes in tone), expression, and tone to the audience and purpose.

8.7.3 Outline the organization of a speech, including an introduction; transitions, previews, and summaries; a logically developed body; and an effective conclusion.

8.7.4 Use precise language, action verbs, sensory details, appropriate and colorful modifiers (describing words, such as adverbs and adjectives), and the active (I recommend that you write drafts.) rather than the passive voice (The writing of drafts is recommended.) in ways that enliven oral presentations.

8.7.5 Use appropriate grammar, word choice, enunciation (clear speech), and pace (timing) during formal presentations.

8.7.6 Use audience feedback, including both verbal and nonverbal cues, to reconsider and modify the organizational structure and/or to rearrange words and sentences for clarification of meaning.

8.7.13 Deliver persuasive presentations that:
- include a well-defined thesis (position on the topic).
- differentiate fact from opinion and support arguments with detailed evidence, examples, reasoning, and persuasive language.
- anticipate and effectively answer listener concerns and counterarguments through the inclusion and arrangement of details, reasons, examples, and other elements.
- maintain a reasonable tone.

5. Methods

5.1. Materials & Resources

The materials required for this lesson are:
- 12 oz. Styrofoam cups
- 16 oz. Styrofoam cups
- 20 oz. Styrofoam cups
- Aluminum Foil
- Kitty Litter

- Bubble Wrap
- Fiberfill
- Duct Tape
- Masking Tape
- Electrical Tape
- Packaging Tape
- Markers/Colors
- Stopwatches
- Paper
- Pen
- Posters
- Water
- Percolator/Coffee Maker/Tea Pot (a device to make hot water readily available)

5.2. Procedures

5.2.1. Preparation

Although extensive knowledge of thermodynamics, engineering or marketing is not required for this activity, the students should have a basic understanding of how to build and create a travel coffee mug. The activity is designed to encourage student creativity and student awareness to the engineering discipline.

5.2.2. Introduction to the Activity

Approximate Time: 15 minutes. This activity is intended to complement topics presented in science class during the thermodynamics unit. In order to convey the practical nature of this activity, it should be emphasized that the students are to create something unique and distinctive. The general idea of the activity and the role the teacher plays is to promote student exploration in designing and creating their travel coffee mug. The importance of the specifics of the travel mug can be explained at the conclusion of the activity, as well as to explore the theory of Newton's Law of Cooling and the transfer of heat and energy. A brief review of how use the scientific method in testing the product's efficiency and how to construct a scatterplot may be needed, depending upon the students' familiarity with these concepts.

Students should then be put into groups, either by their own choosing or as instructor-assigned cooperative learning groups. Once in groups, students were required to create a design and develop a "shopping list" of supplies for the Fellows General Market for their travel mug. They were free to look at the list of products, as well as to window shop, but they had to have a basic design in mind before buying the products. The cost of each product the students bought, regardless if it was actually used, was factored into the total cost of their product. Their product cost was simply the summation of all materials purchased. The consumer price was double the wholesale cost; therefore, the profits were equal to the cost to build the travel coffee mug as all other expenses were paid for by the Fellows Insulation Company of West Lafayette. In determining the

annual profit, the “Projected Sales” table in Appendix 11.2 was used. The number of mugs sold multiplied by the profit equaled the annual profit.

5.2.3. Building and Testing

Approximate Time: 3 periods (100 - 120 minutes). Once the student groups had their basic design, they were allowed to buy the needed products and construct their design. As student travel mugs will vary in level of complexity, the time needed to complete the design also varies. As groups finish the construction of their travel mug, they can be encouraged to start writing the script for their infomercial.

Testing for the travel mug takes a full period (minimum of 45 minutes). Students were able to freely determine the interval they would check the temperature of their water. They were told they would need to take at least 2 measurements (start and stop), but they were encouraged to determine what would be the best time interval to monitor changes in temperature throughout the testing. The students were also given the following table to help record data information.

Data Table:

Time	Temp (℃)
0:00	

5.2.4. Presentation and Infomercial

Approximate Time: 2 periods (75-100 minutes). Students were advised to start/continue working on their script of their infomercial during the testing of their travel mugs. They could also begin designing and developing the visual(s) needed for their presentation. Students were told they would evaluated on the specifics of their design, such as cost to build, insulation properties, portability, consumer affordability, target demographics of design and presentation, aesthetic appeal, creativity in presentation, use of visual, and equal division of the work. A second class period was also used for students to finalize their scripts and infomercials.

5.2.5. Discussion and Final Thoughts

Some points for a wrap-up discussion include:

- Marketing and engineering concepts

- Newton's Law of Cooling
- Heat transfer
- Effectiveness of insulation and conduction of heat of the materials used

6. Scope

The entire activity, from the building to the wrap-up discussion, should take no longer than 7 days. From this activity, additional discussion or introductory material could extend the activity to allow students to change their design based on the discussion and retest the design to see the effects of the design modification.

7. Activities, worksheets, and templates

7.1. Hot Enough for Ya?

Hot Enough For Ya??

Your job as a research and design engineer is to build and test a prototype coffee mug. Using the materials available, you need to construct a mug that will be most marketable and profitable for the company, Fellows Investment Company of West Lafayette. The accompanying chart will provide information to determine the projected annual sales of your mug. Things to consider in mug design are cost to build, insulation properties, portability, affordability for the consumer, target demographics, and aesthetic appeal. To pitch your idea and prototype to the Fellows Insulation Company, you will need to create a three-minute infomercial. In the infomercial you must use at least one visual. A data table is provided to record the temperature measurements to determine the total change in temperature during the trial.

*Note to teacher: the general market pricing guide and projected sales table used in this lesson are appended at the end of this document.

8. Evaluation

The goal of the lesson was to encourage creativity and student design in a thermodynamics activity. The evaluation in this lesson was based on the teacher evaluation as well as student feedback. The teacher evaluation was the overall grade of the project, but students were also allowed to "vote" on the product/infomercial they thought was the best. The votes were tallied and the winning team per each period was awarded "100 Grand" (a candy bar).

Teacher Evaluation

Group Members:

Score 1 – 5, 5 being the highest/best, 1 being the lowest

Cost to build	_____
Insulation properties	_____
Portability	_____
Consumer Affordability	_____
Target demographics	_____
Aesthetic appeal	_____
Creativity in presentation	_____
Use of Visual	_____
Equal group work	_____

Total _____ / 45

9. Reflection/Lessons Learned/Alterations for future use

- Students need more guidance in developing the infomercials.
- Students should be encouraged to create their own design, and not worry about what other students are doing (try to decrease the amount of 'copying' of designs).
- Although students had a great deal of previous graphing experience, it was found that students did not understand which type of graph would be useful in this activity (many choose a bar graph over the requested scatterplot), and it may also be helpful to review the fundamental requirements of a graph, especially in terms of setting the scales on the axes using the range of available data.

10. Appendices

10.1. Thermo Unit “Fellows General Market”

Fellows General Market

Items	Cost
12 oz. Styrfoam Cup	$0.15
16 oz. Styrfoam Cup	$0.21
20 oz. Styrfoam Cup	$0.25
Aluminum Foil	
6" Aluminum Foil	$0.12
12" Aluminum Foil	$0.20
Kitty Litter	
25 g Kitty Litter	$0.03
50 g Kitty Litter	$0.05
100 g Kitty Litter	$0.24
200 g Kitty Litter	$0.45
Buble Wrap	
0.25 sq. ft. Buble Wrap	$0.30
0.50 sq. ft. Buble Wrap	$0.57
1.0 sq. ft. Buble Wrap	$1.00
Fiberfil	
1 cupful Fiberfil	$0.08
2 cupful Fiberfil	$0.14
Tape	
3" Duct Tape	$0.05
6" Duct Tape	$0.08
12" Duct Tape	$0.14
6" Masking Tape	$0.02
12" Masking Tape	$0.03
24" Masking Tape	$0.05
3" Electrical Tape	$0.06
6" Electrical Tape	$0.11
12" Electrical Tape	$0.20
6" Packaging Tape	$0.04
12" Packaging Tape	$0.07
24" Packaging Tape	$0.12
Markers/Colors	
1 Color	$0.05
Each Additional Color	$0.02

10.2. Thermo Unit "Projected Sales"

Cost To Build	Change in Temperature in 40 Minutes: < 1°	1.1 - 4°	4.1 - 7°	7.1 - 10°	10.1 - 13°	13.1 - 16	16.1 - 19°	19.1 - 22°	22.1 - 25°	25.1 - 28°	28.1 - 31°	31.1 - 34°	34.1 - 37°	3
< $ 0.50	A	A	A	B	B	C	C	C	D	D	E	E	F	F
$ 0.51 - 0.75	A	A	B	B	C	C	C	D	D	E	E	F	F	G
$0.76 - 1.00	A	B	B	C	C	C	D	D	E	E	F	F	G	G
$1.01 - 1.25	B	B	C	C	C	D	D	E	E	F	F	G	G	H
$1.26 - 1.50	B	C	C	C	D	D	E	E	F	F	G	G	H	H
$1.51 - 1.75	C	C	C	D	D	E	E	F	F	G	G	H	H	I
$1.76 - 2.00	C	C	D	D	E	E	F	F	G	G	H	H	I	I
$2.01 - 2.25	C	D	D	E	E	F	F	G	G	H	H	I	I	J
$2.26 - 2.50	D	D	E	E	F	F	G	G	H	H	I	I	J	J
$2.51 - 2.75	D	E	E	F	F	G	G	H	H	I	I	J	J	K
>$2.76	E	E	F	F	G	G	H	H	I	I	J	J	K	K

	# Of Units Sold
A	5,000,000
B	3,000,000
C	1,500,000
D	1,000,000
E	750,000
F	500,000
G	300,000
H	250,000
I	100,000
J	75,000
K	50,000
L	25,000
M	10,000

You will sell your thermos at double the cost of building it. Therefore, your profits are equal to the cost of building the thermos assuming extras costs, such as advertising and distribution costs, are payed by Fellows Investment Company.