Design Challenge:

How to Keep Gelatin from Melting?

Lesson Overview

Design Challenge Summary

Students will design and build a platform that will be placed on top of a heat source. A 6 cm x 6 cm x 6 cm cube of gelatin will be placed on the platform, with a thermometer inserted in it. The goal is to keep the temperature inside the cube as cool as possible and prevent the gelatin from melting.

Objectives

Students will be able to:

- ▼ Design a solution to the challenge using the scientific method.

Concepts

- ▼ The scientific method can be used to find solutions to many problems.
- ▼ There can be more than one solution to a problem.
- ▼ Food and other items need to be kept at certain temperatures in order to maximize their usability and maintain their structural integrity.

MESSENGER Mission Connection

The MESSENGER mission designers have come up with various ways to keep the temperatures on the spacecraft tolerable in the hot Mercurian environment.

Grade Level
5 - 8

Duration
1 week - 1 month

Essential Question
How can the scientific method be used to develop a structure that protects an item exposed to a high temperature?

This lesson was developed by the National Center for Earth and Space Science Education (http://ncesse.org).

INTRODUCTION TO DESIGN CHALLENGES

Design Challenges are intended to focus on real-life situations that give students the chance to deal with many of the same issues with which scientists, engineers, and researchers are confronted in laboratories and offices.

Design Challenges provide motivating experiences for children by incorporating problem-solving, scientific approach, and cooperative teamwork into a standards-based activity. Students will discover their own and others' strengths as they take on different roles in a team, and they will witness firsthand the importance of both successes and failures, for they can learn from both.

Each member of the Design Challenge team is responsible for his or her part of the final project, whether it be research, drawing, building, analyzing, testing, or whatever may be required. There must be support and back-up from all team members to ensure the success of the whole team and of each individual member. The value in this type of a cooperative arrangement is its ability to allow for creativity and independence within a supportive environment, to teach responsibility, and to keep all students engaged in learning. Yet we do not lose sight of the value of healthy competition, and encourage teachers to use our criteria for judging each team's work, awarding the most successful in age- and grade-appropriate ways.

The Design Challenge may be used to prompt theoretical discussions in the classroom and further research only, or it may be used in its entirety, including the actual building of a working model. We recommend that at least one Design Challenge per year be assigned to the students, to give them the unparalleled experience of working together on applying the scientific process in their daily lives; it is sure to change their way of thinking in the years to come.

The Design Challenge is meant to encourage students to use a trustworthy scientific process for which they can provide a rationale, and which will yield verifiable results or answers to a question. While the scientific method has traditionally been taught in fairly rigid terms, we maintain that much creativity is, in fact, necessary within the basic methodology to best pursue any investigation thoroughly.

A scientist must be able to create research and design processes to fit an investigation, and keep well-documented records of each step so that the experiment and the results are verifiable by others. We include a guideline to help your students move through the scientific process, while providing for variations necessary to fit their individual designs and inventions.

STANDARDS & BENCHMARKS

NATIONAL SCIENCE EDUCATION STANDARDS

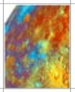
Standard E1 Abilities of technological design

- Design a solution or product: Students should make and compare different proposals in the light of the criteria they have selected. They must consider constraints—such as cost, time, trade-offs, and materials needed—and communicate ideas with drawings and simple models.
- Implement a proposed design: Students should organize materials and other resources, plan their work, make good use of group collaboration where appropriate, choose suitable tools and techniques, and work with appropriate measurement methods to ensure adequate accuracy.
- Evaluate completed technological designs or products: Students should use criteria relevant to the original purpose or need, consider a variety of factors that might affect acceptability and suitability for intended users or beneficiaries, and develop measures of quality with respect to such criteria and factors; they should also suggest improvements and, for their own products, try proposed modifications.

Related Standards

Standard E2 Understandings about science and technology

- Perfectly designed solutions do not exist. All technological solutions have tradeoffs, such as safety, cost, efficiency, and appearance. Engineers often build in back-up systems to provide safety. Risk is part of living in a highly technological world. Reducing risk often results in new technology.
- Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials, or effects of weather and friction; other constraints limit choices in the design, for example, environmental protection, human safety, and aesthetics.



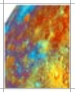
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, PROJECT 2061

Benchmark 4E1 Energy cannot be created or destroyed, but only changed from one form to another.

Benchmark 8F1 Sanitation measures such as …safe food handling are important in controlling the spread of organisms that cause disease. Improving sanitation to prevent disease has contributed more to saving human life than any advance in medical treatment.

Benchmark 12A1 Know why it is important to keep honest, clear, and accurate records.

Benchmark 12E5 Notice and criticize the reasoning in arguments in which (1) fact and opinion are intermingled or the conclusions do not logically follow from the evidence given, (2) an analogy is not apt…



SCIENCE OVERVIEW

MESSENGER in Space

The concept of keeping cool in a hot environment is central to the success of the MESSENGER mission to Mercury. The MESSENGER spacecraft will venture into the inner parts of the Solar System, where radiation from the Sun will reach levels that are 5-11 times as high as they are near Earth, depending on where Mercury is on its orbit around the Sun. Since the Earth's atmosphere stops about half of all solar radiation from reaching the surface, the spacecraft will be exposed to more than 20 times the amount of solar radiation as it would here on Earth. In addition, infrared radiation emitted and reflected from the sunlit side of Mercury adds to the high-temperature environment. This has created a great engineering challenge for the mission design team: How can the spacecraft be protected from temperatures of over 400˚C (750˚F)?

The solution employed by the MESSENGER design team involves using heat-resistant materials and building a sunshade to protect the instruments from the Sun. Also, the spacecraft's orbit around Mercury has been designed so that its closest approach to the planet is away from the most sun-baked region of the surface and so that it flies quickly over the sunlit areas. This is achieved by an orbit where the periapsis (the closest point to the surface of Mercury and also the part of the orbit where the spacecraft's speed is at its highest) is at a high latitude and the apoapsis (the farthest point of the orbit and also the part of the orbit where the spacecraft's speed is at its lowest) is far away from the surface of Mercury. In this manner, infrared radiation received by the spacecraft can be kept at safe levels. For example, MESSENGER's instruments are in a thermal environment that is roughly comparable to room temperature: during Mercury's orbit around the Sun, the temperature on the instrument deck of MESSENGER is expected to vary from a few degrees below 0˚C (32˚F) to 33˚C (91˚F).

Some Practical Problems Here on Earth

One way to better understand the problem of a high-temperature Mercurian environment for the spacecraft is to study the more familiar problem of keeping food products cool in a warm environment here on Earth.

One way to keep food at a constant temperature is to use a thermos of some kind, but how does a thermos do its job? Why is keeping things at their proper temperatures not only nice—to help us enjoy a cold soda instead of a lukewarm one—but sometimes even necessary? One of the answers comes from the need to preserve food—making sure that the food we eat is not spoiled.

Food Preservation

The main reason that food spoils is because it is slowly deteriorating. Deterioration begins as soon as food is harvested or slaughtered—i.e., the living entity (a potato plant or a cow, for example) stops being alive and starts to decay. The main causes for the decay are various microorganisms (such as molds and yeast), bacteria and their enzymes. In some cases the changes can be beneficial—e.g., aged cheeses or the production of wine and beer—but most of the time they are something we want to tightly control and limit, because they can not only make the food taste unpleasant, but even make it dangerous.

People have looked for ways to preserve food for centuries. Some of the early methods of food preservation included drying, smoking, salt curing, and fermentation, and many of these methods are still in use. For example, instant coffee and dried milk are dried products used today, and metal and glass cans and jars are popular for storing food, whether at home for your own use or by food manufacturers for sale in grocery stores.

One of the most popular ways to preserve food throughout the centuries has been to store food products in a cold environment. In cold climates, this has always been possible during the winter, when people could cool or even freeze food just by leaving it outside. Ice could also be cut from ponds and lakes during the winter and then stored in ice houses, where food could be kept cold even during the summer. The production of the first ice-making machines in the mid-1800s led to the large-scale use of refrigeration for shipping and storing foods, and they are basically ubiquitous today.

Cold storage is a good way to preserve food because low temperatures slow the growth and activity of harmful microorganisms, slow undesirable chemical reactions, and slow or stop the breakdown of nutrients. Foods can be stored above or below freezing temperatures, in which case we talk about refrigeration or freezing, respectively. Foods requiring refrigeration include eggs, fish, meats, milk, and vegetables. Even at refrigerated temperatures, most fresh foods can only be preserved one to four weeks. Freezers prolong the useable life of food products to a few months or even longer, depending on the product.

Transmitting Heat

To understand how various items can be kept cool in a warm environment, we need to understand the basic ways heat can move from one substance to another.

In general, heat passes from one substance or an object to another by

1) Conduction

- Heat is transferred through material without any of the material moving.
- E.g., the tip of a metal pitchfork placed in a fireplace; heat spreads through the pitchfork but none of the matter in it moves.

2) Convection

- Heated material moves and carries heat with it.
- E.g., heating water on a stove; hot liquid from the bottom of the pot rises up, while cold water sinks down to be heated.

3) Radiation

- Heat is transmitted via radiation, either through a medium (such as air) or without need for intervening material (such as through space).
- E.g., infrared rays, visible sunlight.

Insulation

The movement of heat from one place to another can be restricted by insulation, which keeps heat from entering or flowing out of a substance or an object.

To combat the three ways in which heat can travel, there are three basic methods of insulation:

1) To fight conduction, some materials are used as insulators.

- E.g., many pots and pans have plastic or wood handles.

2) To fight convection, the space between hot and cold areas can be filled with "dead air."

- E.g., double-pane window: The layer of air between the outer and the inner windows stops the convection from transferring heat between them; narrow dead air space is better than wide since it makes the formation of convective air circulation currents more difficult.

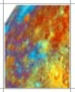
3) To fight radiation, reflective or blocking materials can be used.

- E.g., reflective car sunshades placed against a windshield to prevent the inside of the car from heating up; sunscreen spread on skin to prevent sunburn.

Oftentimes, insulators are designed to combine different methods to make them as efficient as possible. For example, insulators may be composed of a poorly conducting material, have cell-like spaces to reduce the motion of cold or hot air, and be coated with reflective material.

Insulation is used in houses to reduce heat flow outward during cold weather and inward during hot weather. Insulation is also used in many industrial applications to keep temperatures at a desired level in various processes. For example, industrial furnaces are sometimes lined with insulating blankets of ceramic fibers so that high temperatures can be maintained inside it without damaging the surrounding equipment. Insulation is also used for fire-fighting suits and wherever high temperatures are encountered.

Insulation is also essential for spaceflight. For example, astronauts wear space suits composed of multiple layers of insulating material to shield them from the cold vacuum of space and the broiling heat of sunlight. Insulating materials can also be used to protect sensitive spacecraft systems and instruments, as necessary. For example, the MESSENGER mission to Mercury will have to operate in an environment where the temperature can reach over 400˚C (750˚F), and various methods are employed during the mission to keep the temperatures tolerable.



A Brief Guide on Using the Scientific Process in the Design Challenge

Professional scientists and researchers follow the scientific process when conducting scientific research and developing new concepts. The strength of the scientific method is that it takes away guesswork, beliefs and opinions. By following the process, a scientist or engineer can determine whether the proposed solution is robust enough to meet the standards set forth by hundreds of years of scientific progress. Although the steps are numbered for convenience, many scientists must return to previous work to reformulate a question, redesign a procedure, re-examine a plan, retest a hypothesis, etc. It would therefore not be unusual to have even more steps in an individual investigation. This overview has been designed to help students understand how the steps they take to come up with solution of the Design Challenge parallels the process a professional scientist, researcher, or engineer follows.

Using the scientific process, a scientist or an engineer:

1) States the problem or asks a question;
2) Conducts research to see what is already known, if an answer or solution already exists;
3) Proposes a possible solution;
4) Tests the proposed solution by building a prototype, conducting an experiment or making observations, and recording the results;
5) Analyzes results, then revises, rejects, or accepts the hypothesis, and reports conclusions.

The following steps describe what steps you would typically take to solve the Design Challenge by following the scientific method.

1) State the problem or ask a question

What Professional Scientists and Researchers Do:

Scientists and engineers spend a lot of time becoming familiar with a research area. They do this by studying specific areas in college, reading current research on the topic, and having discussions with other experts in the field. All of this happens before they embark on the process of developing informed questions about the topic. These questions then need to be answered through experimentation.

What You and Your Students Can Do:

The topic of the Design Challenge is to keep comfortable in a hot environment. You can have students research the ways with which scientists and engineers have grappled with the issue in various circumstances, from keeping food from spoiling in the kitchen to insulating industrial furnaces or keeping spacecraft comfortable when flying through Earth's atmosphere. After sharing information about their preliminary research, students should brainstorm. By doing this, students will formulate the critical questions which drive how they design and build their models later during the Design Challenge. Brainstorming gives students the opportunity to think of many ideas related to a particular topic. By brainstorming as a team, they can listen to each other's ideas and come up with even more ideas. Frequently, students will get more ideas when hearing and seeing the ideas of their teammates. Before beginning the brainstorming activity, make sure you lay out these basic rules to your students:

- Students must speak one at a time.
- Students must listen to each other.
- The ideas must relate to the question.
- There are no wrong ideas.
- The teams should come up with as many ideas as possible.

Students can keep track of their ideas by keeping a Brainstorming Journal. You can set the students in the spirit of brainstorming with the following question: How have previous generations grappled with the problem of keeping items (or people) comfortable in a hot environment?

After becoming familiar with the current state of research in their chosen topic, scientists and engineers typically develop an informed question that cannot be reasonably answered except through experimentation, research, or observation. To follow this procedure, the students could pick a specific topic proposed during the brainstorming session and refine it into a specific question to follow further. However, for this particular Design Challenge, the MESSENGER program provides the problem to be solved. The problem was chosen to be similar to what the MESSENGER engineering team had to grapple with: keeping comfortable in a hot environment. You can have the students come up with something similar to the following challenge by leading questions, such as "What kind of hot environments can we encounter during our daily lives—such as in a kitchen?" (if students suggest an oven, you may lead them to the idea of a hot plate by suggesting that you might not have an oven available for testing—what would be another hot environment?) Or you can just pose to students the Design Challenge:

"How to keep gelatin from melting?"

2) Conduct research to see what is already known and if an answer or solution already exists.

What Professional Scientists and Researchers Do:

Scientists and researchers conduct research not merely to determine if an acceptable solution has already been found to a problem, but to be inspired by the ideas of others who have attempted and failed. In this stage, they build upon their own experiences and those of persons before them to guide their investigation. By studying what did not work, you can learn without having to experience the failure yourself; this is one reason why it is so important to study history—so we don't make the same mistakes as our forefathers.

What You and Your Students Can Do:

Where to do research and gain insight into the attempted solutions by others depends on the nature of the original problem. For the proposed Design Challenge, we suggest that you start in the following places: Web sites, books, journals, magazines, and experts.

3) Propose a possible solution.

What Professional Scientists and Researchers Do:

With the necessary background information gathered, scientists and engineers can come up with a suggestion how to answer the question or solve a problem. Often, there are several external factors that play a part in their designs, such as a budget limitations, available technology, and sometimes even nature itself. This is when engineers and scientists use their ingenuity to find creative solutions. This is also the time when scientists and engineers come to a fundamental understanding of their solution. It is not enough to simply come up with a design—to be able to test and interpret the results correctly requires knowing exactly how it works.

What You and Your Students Can Do:

Have students brainstorm in their teams solutions to the Design Challenge based on the specific requirements and constraints set for the solution.

4) Test the proposed solution by constructing a prototype, conducting an experiment or observations and recording the results.

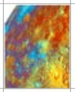
What Professional Scientists and Researchers Do:

Once a scientist or an engineer has come up with a proposed solution to the problem, the proposal can be tested. If the solution is a physical object, a prototype (the first of a kind of object) may be built based on the design, so that it is possible to quickly determine what works, and why, in a real situation. Scientists and engineers must be able to deal with any unexpected challenges that may crop up during the testing of the solution. Not every test goes flawlessly, and often people rely on their creativity and ingenuity to help them overcome obstacles. At the same time, scientists and engineers are (ideally) rewarded with the first glimpses of their creation in action. This stage can be the most exhilarating part of the process, because it can be a chance to see the solution work—or, if it does not work, provide invaluable further insight into the problem.

What You and Your Students Can Do:

In order to see if your students' solution works, they must test it by building the model and following the testing procedures described in this Design Challenge. Make sure that the students write a plan that includes:

▼ Specific protocols and detailed procedures you intend to follow so you can answer the question (be prepared to explain why each step is necessary). You may have to make rough sketches of your invention.



▼ A list of the materials you will need, including tools for testing the success of your solution. Charts and tables may be helpful in organizing your ideas.

▼ A calendar to schedule deadlines that you agree to meet, in order to efficiently complete your investigation.

Make sure that you check the students' proposed solution to ensure that they are following reliable, safe, rational, and reasonable procedures that account for or control unwanted intervening variables.

After the students have come up with a proposed solution, have them write a plan on how to test their solution, following the testing procedures described in the Student Worksheets. Have them include in their plan steps such as:

▼ The materials they will need.
▼ The steps of the experiment.
▼ A data table for collecting the measurements.
▼ Prediction of what will happen.

Whatever happens during this part of the process, be sure to record every step of the way, since it may be important in the final analysis of your results. When possible, you may want to repeat this part of the process to verify your results.

5) Interpret and analyze results; revise, reject, or accept the proposed solution; and report conclusions.

What Professional Scientists and Researchers Do:

Once testing provides information, scientists and engineers can begin interpreting the results. Some interpretations of the results are immediately obvious, while others can take years of analysis to interpret. Sometimes, after the information has been looked at and shared with other scientists, ("peer review"), there is disagreement on what the information means. Who is right or wrong might not be determined until more tests are performed, but all points of view are important to consider. Regardless of the results or how they are interpreted, new questions invariably arise from such investigations, bringing us full circle in the scientific process.

An important aspect of the scientific process is sharing with other scientists your results and a description of the design and the testing your solution went through. Your solution can then be tested by others, if they so choose. This ability to replicate an experiment is at the heart of the scientific process—if an experiment or its results cannot be independently verified, the original results are deemed to have been wrong, because of over-interpreting the results, a glitch in the experiment or, in rare cases, due to forging of data or results. This is how real scientific results can be separated from forgeries and wishful thinking.

What You and Your Students Can Do:

Once your students have completed their tests, they need to look at the data they collected.

Make sure the students look objectively at their test results. Sometimes people want their solutions to work so much that they imagine more success than there really is. Be careful to base your conclusions only on what can be demonstrated from the actual object, testing, or calculations.

Have students hold a symposium to discuss their proposed solutions and results from testing. Have students contemplate improvements on their design after seeing their solution in action. If the design solution worked, are there ways to improve it? If the model did not work, what improvements could be made to make it work? Make sure other teams have a chance to contribute ideas to other teams' solutions. Teams can make improvements and then retest their designs. Or, you may choose to have the students work together, combine best elements from different teams' solutions and come up with the final class solution to the Design Challenge.

LESSON PLAN

PREPARATION

- Divide the class into teams, or allow students to form their own. Ensure that each team has a variety of abilities represented evenly so that the team will be able to work well together. The roles of different individuals are described on Page 1 of the Student Worksheet.

- Decide how long to give the students to design and build their projects, and if you want to use classroom time. This can be a project that takes a month or more, and for which you expect high-quality work, such as for a science fair. Alternatively, the project could proceed at a faster pace, perhaps in two weeks, and include time in class or during lunch to help certain groups.

Materials

Per group:

- Materials for insulation: Chosen by the group within an assigned budget
- Thermometer with a scale at least up to 50°C
- 1 sheet of graph paper
- 6 cm × 6 cm × 6 cm cube of gelatin
- Heat source: a hot plate, Bunsen burner, or something similar.

WARM-UP & PRE-ASSESSMENT

1. Pose one or two of the following problems to students: If we take a cold soda can out of a refrigerator and bring it with us in a car, it will quickly get warm. How can we keep it cold? Or how can we bring hot chocolate with us down a ski slope and keep it warm? How can you keep something hot once it is removed from a stove or oven? Help students come up with a clearly-worded, critical question about the object or circumstances under discussion.

2. Have the students brainstorm ideas related to the topic. Help them look for other categories or places in which the topic may have an effect. Based on their ideas, have students think up questions that they would really want to have answered but which are initially difficult to answer.

Teaching Tip

Remind the students to remember some basic rules of brainstorming as described in "A Brief Guide on Using the Scientific Process in the Design Challenge."

PROCEDURES

1. Before class, make the gelatin in a cake pan. It is important that the gelatin used by the class all comes from the same pan. Be sure to use enough gelatin to make cubes sufficiently sturdy to withstand testing. Pour gelatin to a thickness of 6 cm. After the gelatin has cooled, use a metric ruler to cut it into 6 cm cubes.

2. Help the students understand the scientific process as described in the section "A Brief Guide on Using the Scientific Process in the Design Challenge." You may want to modify the depth of the tasks undertaken by the students in following the scientific process, depending on how much time you want to spend on the Design Challenges.

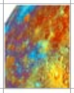
3. Go through the basic design requirements and the testing procedure with the students so that they understand what they need to design.

4. Remind students to keep a clear journal of their design process. The documentation of the design needs to be comprehensible by anyone not associated with the project. In this manner, the design could be reproduced and re-tested by anyone interested. Adequate documentation is essential for maintaining the integrity of the scientific process in all endeavors.

5. After the students have completed their solution to the Design Challenge, have the students test their platform design by following the directions on the Student Worksheet. On the day of testing, make sure the heat sources are preheated to the same temperature in all tests. You can use a hot plate set on the same burner setting, or you can have a test object (such as a pot of water) where the temperature can be measured before starting the test.

Teaching Tip

Note that if students place the platforms directly on the hot plate, the platforms may begin to scorch or break. You may want to use this as the first test of the students' design: if scorching or breakage occurs, the platform fails the test. If you choose to do this, be sure to take appropriate precautions in case of a platform catching fire or shattering. Alternatively, if you want to avoid the possibility of the platforms breaking, you could place a frying pan on the hot plate, and have the students place the platforms in the frying pan.



Discussion & Reflection

Once a winner has been established, gather the students for an open discussion. Ask them to list ideas as to why the winning team was successful. Ask students to analyze methods or procedures that failed. Understanding why something did not work can provide as valuable insight into the problem as understanding why something else did work. Have the groups discuss how they could have improved their designs, and have a representative from each group explain their ideas to the class. Brainstorm ways in which the students could keep the gelatin cool for longer, if, for example, there were no budget constraints.

Curriculum Connections

- *Health:* Discuss with students the implications of getting burned, heat exhaustion, dehydration, other heat-related problems and their remedies.

Closing Discussion

Discuss with students the connection between what they have done and the MESSENGER mission to Mercury. Ask them how their challenge was similar to or different from the one that the mission engineers faced. Ask them how, even if their solutions were very different, were the processes similar?

ASSESSMENT

You can assign points in several different categories, to make sure the students understand the importance of the process in addition to the end result. Here are some suggestions:

Category A: How effectively the platform insulated their gelatin cube (important for meeting the challenge).

Points	**Degrees Temperature Increased in Gelatin**
10	Less than 5˚C
8	Less than 10˚C
6	Less than 15˚C
4	Less than 20˚C
0	Gelatin started to melt

Category B: How well the team documented the design process and the final design (important for the capability of repeating the experiment by others – essential for a proper scientific investigation)

Points	**Clarity of documentation**
10	Design could easily be repeated by others.
4	Document allows final result to be repeated but little documentation on process.
2	Documentation not clear on either final design or the process.
1	Documentation of the final design or the process missing.
0	No documentation.

Category C: How well the team documented the experiment (e.g., graphs; important for making sure the experiment results are verifiable by others and support the final results)

Points	**Clarity of documentation**
4	Clear documentation of the experiment.
2	Experiment documented but graph missing or unclear.
1	Experiment documentation not complete.
0	No documentation.

Final grade:

Grade	**Total points from Categories A-C:**
A	22-24
B	18-21
C	14-17
D	10-13
E	0-10

DESIGN CHALLENGE
HOW TO KEEP GELATIN FROM MELTING?

Materials	Approved Materials for Constructing the Container
Per group: ▼ Thermometer with a scale at least up to 50°C ▼ 1 sheet of graph paper ▼ 6 cm × 6cm × 6cm cube of gelatin ▼ Heat source: a hot plate, Bunsen burner, or something similar.	▼ Metal ▼ Glass ▼ Cardboard ▼ Wood

Objective

Your goal is to design and build a platform that will keep a 6 cm cube of gelatin as cool as possible when placed on top of a heat source.

Specific Requirements of the Design Solution

- All heat sources must be preheated to the same temperature.
- Your invention must consist of any easily accessible materials, all of which need to be on the list of Approved Materials. The total cost of all materials must not exceed $10.
- The maximum dimensions of your platform are 30 cm x 30 cm x 1 cm.
- All gelatin cubes must be placed in the center of the platform directly over the heat source.

Teams

If you work in teams, we suggest you organize yourselves so that the members have the following roles:

Lead Scientist: Collects and maintains all team members' research information.

Design Engineer: Coordinates the designing of the solution.

Team Ambassador: Main liaison between teams. Keeps records of all collaboration.

Mission Specialist: Oversees team. Keeps team on task, using a schedule as a reference.

Writer: Incorporates team members' ideas into the project description.

Artist: Draws the illustrations to accompany the design, assists with technical drawings for the Design Solution. Creates Team Member binders for the members.

You can have more than one person share tasks of a specific role. For example, you can have more than one Design Engineer in the team. Also, you may want to have backup persons for all responsibilities of the team in case a team member happens to be unavailable to fulfill their responsibility at a critical time, due to illness, for example.

Name ________________________________

Name	Roles	Primary Responsibilities	Back-up Responsibilities	Extra Work

In your team, remember to:

▼ COLLABORATE

All team members can collaborate with other teams, asking questions as to how they might approach the problem, but the team ambassador should be informed when anyone does so. You may want to consider your invention as a "trade secret," until you put it into action, so be sure that your team is aware of how much you share with other teams.

▼ COOPERATE

Your team will come up with a better solution if you cooperate with each other. As a team member, make sure that you complete your tasks and then cooperate with the other members by sharing information, ideas, work, and compliments.

Guidelines

1. Your solution must be guided by the scientific process as well as by your own creativity.

2. Research materials that are good insulators. Use a variety of sources (books, magazines, scientific and engineering journals, Web sites, CD-roms, DVDs) for research. Keep notes of your research.

3. Based on your research and your ingenuity, choose a design solution.

4. You must keep a journal in which you write and illustrate a full description of your design solution. Keep the following points in mind while writing the journal:
    - Include a section on how you made certain choices, decided to choose certain materials, if you conducted any preliminary testing, if you had to change plans, and at least two labeled diagrams or photographs of the solution.

    - The goal of the documentation is to make it possible for someone unfamiliar with your design process to repeat the design and the experiment based on your notes alone.

5. Collect required materials.

6. Build your design solution.

7. Test your device in class according to the testing procedures described below.

8. Write your final report. Write about your observations during the testing, what conclusions you made about the effectiveness of your solutions, what you learned, and what your next investigation might be, based on your conclusions.

Testing Procedures

- Each group will place a 6 cm×6cm×6cm cm cube of gelatin in the center of their platform. Insert a thermometer in the middle of the gelatin cube so that it stands up on its own and reaches to about halfway through the gelatin (see Figure S1). If the thermometer does not stand on its own, hold the tip of the thermometer with your finger so that the thermometer does not fall over.

- After 2 minutes place the platform and gelatin on top of the heat source. Immediately take a temperature reading and record it in the Data Table for minute 0.

- Record the temperature every minute for the next ten minutes in the Data Table. If you need to hold the thermometer to keep it upright, continue the experiment until the Data Table is complete or the thermometer heats up so that it is uncomfortable to touch. If this occurs, stop the experiment immediately, and record the time and the final temperature on the data table.

- If the temperature in the cube rises to within 5°C of the maximum temperature on the thermometer, stop the experiment immediately, and record the time and the final temperature on the Data Table.

- Make a graph of the temperature of the gelatin versus time on a piece of graph paper.

Data Table

Minute	Temperature
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

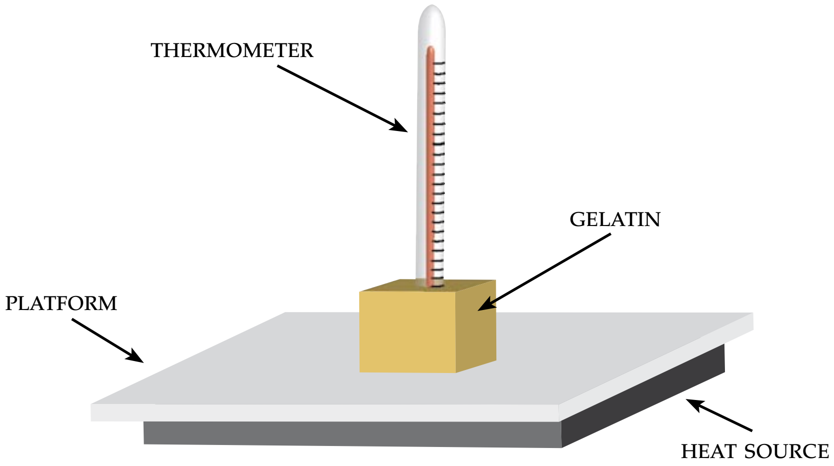


Figure S1. The setup for testing the effectiveness of your platform solution. Place a gelatin cube on top of the platform and insert a thermometer in it. Place the platform on top of a burner or a hot plate and start the test.