ENERGY FAIR EXPERIMENTAL DESIGN

A guide to teaching students the scientific method using the experimental design model with an emphasis on energy science fair projects.

SCIENCE OF ENERGY

GRADE LEVEL
2–6

SUBJECT AREAS
Science
Language Arts

NEED
2009-2010
Putting Energy into Education

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Teacher Advisory Board

Teacher Advisory Board Vision Statement
NEED Mission Statement

The mission of the NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

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Putting Energy into Education

Correlations to National Science Standards

UNIFYING CONCEPTS AND PROCESSES (FOR ALL GRADE LEVELS)

1. Systems, Order, and Organization

a. The goal of this standard is to think and analyze in terms of systems, which will help students keep track of mass, energy, objects, organisms, and events referred to in the content standards.

b. Science assumes that the behavior of the universe is not capricious, that nature is the same everywhere, and that it is understandable and predictable. Students can develop an understanding of order–or regularities—in systems, and by extension, the universe; then they can develop understanding of basic laws, theories, and models that explain the world.

c. Prediction is the use of knowledge to identify and explain observations, or changes, in advance. The use of mathematics, especially probability, allows for greater or lesser certainty of prediction.

d. Order—the behavior of units of matter, objects, organisms, or events in the universe—can be described statistically.

e. Probability is the relative certainty (or uncertainty) that individuals can assign to selected events happening (or not happening) in a specified time or space.

f. Types and levels of organization provide useful ways of thinking about the world.

2. Evidence, Models, and Explanation

a. Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems.

b. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have an explanatory power. Models help scientists and engineers understand how things work.

c. Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. As students develop and as they understand more scientific concepts and processes, their explanations should become more sophisticated.

3. Change, Constancy, and Measurement

a. Although most things are in the process of change, some properties of objects and processes are characterized by constancy; for example, the speed of light, the charge of an electron, and the total mass plus energy of the universe.

b. Energy can be transferred and matter can be changed. Nevertheless, when measured, the sum of energy and matter in systems, and by extension in the universe, remains the same.

c. Changes can occur in the properties of materials, position of objects, motion, and form and function of systems. Interactions within and among systems result in change. Changes in systems can be quantified and measured. Mathematics is essential for accurately measuring change.

d. Different systems of measurement are used for different purposes. An important part of measurement is knowing when to use which system.

4. Evolution and Equilibrium

a. Evolution is a series of changes, some gradual and some sporadic, that accounts for the present form and function of objects, organisms, and natural and designed systems.

b. Equilibrium is a physical state in which forces and changes occur in opposite and offsetting directions.

c. Interacting units of matter tend toward equilibrium states in which the energy is distributed as randomly and uniformly as possible.

5. Form and Function

a. Form and function are complementary aspects of objects, organisms, and systems in the natural and designed world.

b. The form or shape of an object or system is frequently related to use, operation, or function.

c. Students should be able to explain function by referring to form and vice versa.

PRIMARY STANDARD–A: SCIENCE AS INQUIRY

1. Abilities Necessary to do Scientific Inquiry

a. Ask a question about objects, organisms, and events in the environment.

b. Plan and conduct a simple investigation.

c. Employ simple equipment and tools to gather data and extend the senses.

d. Use data to construct a reasonable explanation.

e. Communicate investigations and explanations.

2. Understandings about Scientific Inquiry

a. Scientific investigations involve asking and answering a question and comparing the answer with what scientists already know.

b. Scientists use different kinds of investigations, which include describing objects, events, and organisms; classifying them; and doing a fair test (experimenting).

c. Simple instruments such as magnifiers, thermometers, and rulers provide more information than using only senses.

d. Scientists develop explanations using observations (evidence) and what they already know (scientific knowledge). Good explanations are based on investigations.

e. Scientists make the results of their investigations public, so others can repeat, review and ask questions about the results.

INTERMEDIATE STANDARD–A: SCIENCE AS INQUIRY

1. Abilities Necessary to do Scientific Inquiry

a. Identify questions that can be answered through scientific inquiry

b. Design and conduct a scientific investigation

c. Use appropriate tools and techniques to gather, analyze, and interpret data

d. Develop descriptions, explanations, predictions, and models using evidence

e. Think critically and logically to make the relationships between evidence and explanations

f. Recognize and analyze alternative explanations and predictions

g. Communicate scientific procedures and explanations

h. Use mathematics in all aspects of scientific inquiry

2. Understandings about Scientific Inquiry

a. Different kinds of questions require different kinds of scientific investigations, including observing and describing, collecting, experimentation, research, discovery, and making models.

b. Current knowledge and understanding guide scientific investigations.

c. Mathematics is important in all aspects of scientific inquiry.

d. Technology enhances accuracy and allows scientists to analyze and quantify results.

e. Scientific explanations emphasize evidence, have logical arguments, and use scientific principles, models, and theories.

f. Science advances through legitimate skepticism. Asking questions and investigating other scientists' explanations is part of scientific inquiry.

g. Scientific investigations sometimes result in new ideas and phenomena for study, generate new methods or procedures for an investigation, or develop new technologies to improve the collection of data.

TEACHER GUIDE

INCLUDED IN THIS BOOKLET

Correlations to the National Science Education Content Standards

Experimental Design Model with class projects and student worksheets

Suggested science fair projects focusing on energy

OBJECTIVES

Students will learn how to design experiments with directed activities.

Students will design an experiment of their own.

ABOUT THE ACTIVITY

Students learn about the experimental design model by participating in class experiments, completing worksheets, and designing an individual experiment.

GRADE LEVEL

These activities are designed for students in grades 2-6.

TIME NEEDED

Each classroom activity is designed to take from 15-30 minutes.

EXPERIMENTAL DESIGN MODEL

Choose a Topic

Make a list of ten favorite activities, interests, subjects, or things you'd like to know more about.

Choose two topics from the list and circle them.

For each topic you circled, make a list of things you already know about the topic, things you'd like to know, and items, behaviors, and activities associated with the topic.

Look at the two topics and the lists. Decide which topic you'd like to study.

Ask a Question about the Topic

Which is .... better, stronger, faster, healthier, warmer, more energy efficient?

What would happen if ....?

How many ....?

Make a Hypothesis (an educated guess): Think about the Question and Try to Answer It

What do you already know?

What do you think the answer is?

What do you think will happen? Why?

Design the Procedure (the experiment): Design a Test that will Answer your Question

How can you find out the answer to the question?

Write down what kind of test you will do to answer your question.

Materials: The Things you Need to do the Test

Make a list of the materials you will need to do the test.

Gather the materials you will need.

Conduct the Experiment: Do the Test Using your Design

Follow the procedure you designed and conduct the experiment.

Record your Data: Write what Happened in the Test

Write down everything that happened in your test.

Analysis & Conclusion: Think About and Write what your Data Shows

What did the test show?

What did it not show? Being wrong is okay.

Was the test valid (fair)? If you did the test ten times, would the same thing happen? If another class did the test, would the same thing happen?

If you did the test again, what would you change?

Terms

Controls:	The things that you keep the same in the test.
Independent Variables:	The things that you change to do the test.
Dependent Variables:	The things that change because you change the independent variable.
Data:	The record of what happens during the test.
Trials:	The number of times you do the test.

EXPERIMENTAL DESIGN EXAMPLE

Topic
I'm interested in sports, especially gymnastics. In gymnastics, you need balance, speed, strength, and endurance. I don't know much about balance. I wonder if boys or girls have better balance.

Question
Who has better balance—girls or boys?

Hypothesis
What do the students think? (Take a vote.) How many people think girls have better balance? How many people think boys have better balance? *(Write the opinions on the board. Make it into a hypothesis.)* The class hypothesis is this: More students in the room think ...

Procedure
Let's do a test. Standing on one foot is a good test for balance. Let's see who can stand on one foot longer—boys or girls.

Materials
I need one boy and one girl for the test. *(Pick two students.)*

Experiment
I want both of you to stand on one foot for as long as you can. If one person puts a foot down, I want the other one to keep on as long as you can. Start when I say go, and I will count until both of you have put your feet down. GO!

Control: The action of standing on one foot

Independent Variable: The gender of the participants

Dependent variable: The length of time the participants can stand on one foot

Data
Here is the data. *(Write on board the count for both students.)*

Analysis/Conclusion
Looking at the data, I would say that girls (or boys) have better balance.

Discussion
Does everyone agree we showed that? No? Then what did we show? *(Discuss what was shown by the test.)* We showed that this time (name of winner) stood on one foot longer than (name of loser).

Let's change the procedure to make it more fair. If we do more trials, the test should be more fair. Would it be more fair if we had these two students do the test three more times? Would it show that one group had better balance than the other? No, it might show that one of the students could stand on one foot longer than the other, at least today. We need to design a better test. We need to use more students.

New Procedure
Let's have everyone in the room stand up and do the test. I will count. When your foot touches the floor, remember the number I have just said. Is everyone ready? GO!

New Data
Here is the data. *(Record the data in two columns--one for boys and one for girls--and total the results.)*

New Analysis/Conclusion
We've used more people in this test. Our data shows that girls (boys) have better balance. Have we proven who has better balance? What exactly does our data prove? Today, the girls (boys) in the class stood on one foot longer than the boys (girls) did. Is that a fair statement of what our test showed?

What could we do to make the test more valid (fair)? Would the test be fair if we tested everyone in the school? It would be more fair, but it wouldn't show who had better balance—it would just show who could stand on one foot longer.

What could we do to make the test fair? We could add lots of different balancing skills. We could add more people. We could have the people do the tests lots of times. Whenever you add more trials to a test, it is more valid (fair).

EXPERIMENTING WITH GLUE

Topic
Glue

Question
How does heat affect glue? Will glue flow faster when it is warmer?

Hypothesis: What you think the answer is to your question and why
I think the glue will flow faster when it is warmer. I know liquids expand as they get warmer. This means the glue won't be as thick and will flow faster when it is warm.

Procedure: How you do the test
Draw three circles along the edge of three pieces of cardboard. Label the circles 'hot', 'room', and 'cold' on each piece of cardboard.

Use three bottles of the same glue. Put one bottle of glue in ice water for five minutes and one bottle of glue in hot water for five minutes. Leave one bottle of glue at room temperature.

Place five drops of glue from each bottle in the circles on the pieces of cardboard.

Tilt the cardboard by placing the upper end on a book so that the glue flows down the cardboard.

After the glue stops flowing, measure the distance each drop of glue flowed.

Repeat the test two times.

Materials: What you need to do the test
3 bottles of the same kind of glue

1 container of ice water

1 container of hot water

3 pieces of cardboard (8 1/2" x 11")

1 ruler

1 thick book

Controls: The things that stay the same
The kind of glue.

The amount of glue.

The height of the cardboard.

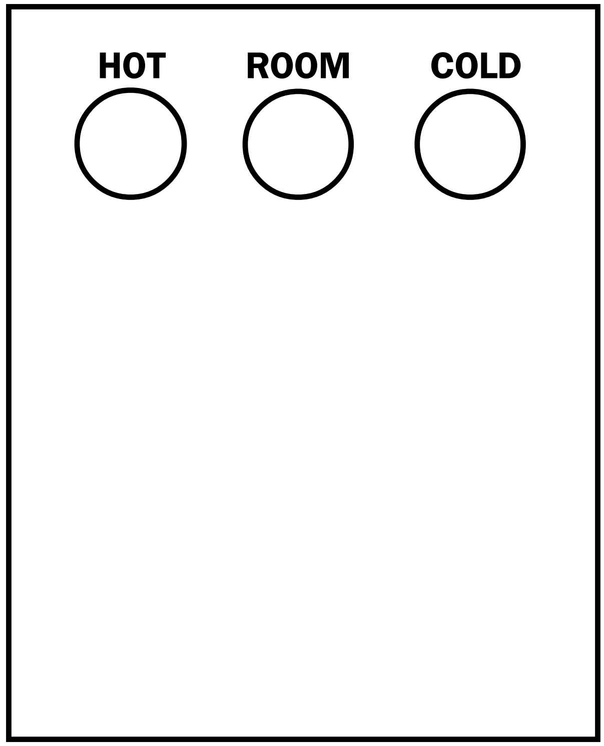
Independent Variable: The things you change in the test
The amount of heat in the glue.

Dependent Variable: The things that change because you change something in the test
The distance the glue flows on the cardboard.

Data: What happens in the test
Make a record of how far each drop of glue moves down the cardboard in each trial.

Analysis/Conclusion: What your data shows; what you could do differently
The data shows that ...

If I did the test again, I could use a thermometer to measure the temperature of the glue and I could use a balance scale to measure the amount of glue I used. I could use different brands of glue to see if all kinds of glue act the same way.



GLUE	DISTANCE		
	Trial 1	Trial 2	Trial 3
Hot			
Room			
Cold			
TOTAL			

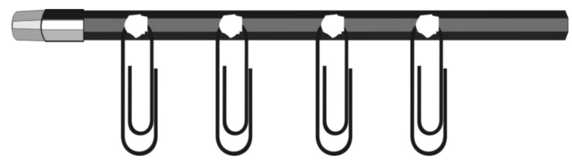
OTHER THINGS TO DO WITH GLUE

Questions to Test:

Which brand of glue is the thickest?
Use the brands that students have in the classroom. Place five drops of each on a piece of cardboard and see how far each one flows when the cardboard is tilted.

Which kind of glue dries the fastest?
Use the different types of glue in the classroom. Place an equal amount of each kind of glue on a piece of cardboard and spread it out with a toothpick to fill a circle drawn on the cardboard. Decide with the students how to judge when the glue is dry.

Which kind of glue is the strongest?
Use the different types of glue in the classroom. Place an equal amount of the different kinds of glue (about one drop) on the side of a pencil (or several pencils). Hang a sandwich bag from each paper clip, then place the small end of a paper clip in each drop of glue. After the glue has dried, hang the pencil between two desks. and add equal numbers of marbles (or other small weights) to the bags until the paper clips come loose from the pencil.



Which kind of glue dries the clearest?
Use the different types of glue in the classroom. Place an equal amount of each type of glue on colored and white construction paper and see which one dries the clearest. Place a drop of each kind of glue on a piece of plastic and see which one dries the clearest. Discuss the difference between porous and non-porous materials.

Will glue wash out of clothes once it has dried?
Place different kinds of glue on several pieces of old cloth (you might use cotton, polyester, and wool samples) and let it dry overnight. Make a map of each piece of cloth and where you put each kind of glue. Wash the pieces of cloth by hand with detergent and see if the glue comes out.

Which glue has the most useful container?
Discuss with the students how to design a fair test to answer these questions.

Discuss the difference between objective and subjective data.








THINGS I LIKE

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________
6. ______________________
7. ______________________
8. ______________________
9. ______________________
10. ______________________

TOP TWO TOPICS

1. ______________________
2. ______________________

PICK A TOPIC

Make lists of things you know about your two favorite topics, things that remind you of the topics, things you don't know, and things you would like to know.

For example––POPSICLES: frozen juice, mostly water, taste good, refrigerator, melt, different flavors. Can you freeze any juice into a popsicle? Can you make a popsicle out of soda? Do some juices freeze faster than others? Do some popsicles melt faster than others?

TOPIC ONE

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

QUESTIONS

1. ______________________

____

2. ______________________

____

TOPIC TWO

1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

QUESTIONS

1. ______________________

____

2. ______________________

____

TOPIC AND QUESTION

Look at the lists and pick a topic and question you want to answer. Make sure it is a question you can answer by doing a test. Make sure you can get the materials you need. Write the question here:

For example: Do popsicles made from orange juice melt faster than popsicles made from apple juice?

HYPOTHESIS (ANSWER YOUR QUESTION)

Think about your question. What do you think the answer will be? Write what you think here:

For example: I think popsicles made from apple juice will melt faster. Because orange juice seems thicker than apple juice, I think it will freeze harder.

I think:

PROCEDURE (DESIGN A TEST)

Design a fair test to answer your question. Write down how you will do the test here:

For example: I will fill one ice tray with orange juice and one ice tray with apple juice, freeze them, and see which melts first.

I will:

These are my controls:

For example: The size of the ice trays, the amount of juice in each tray, the amount of time I freeze each tray.

This is my independent variable:

For example: The type of juice in each tray.

These are my dependent variables:

For example: How long it takes the different popsicles to melt.

I will do my test __________ times to make sure it is fair.

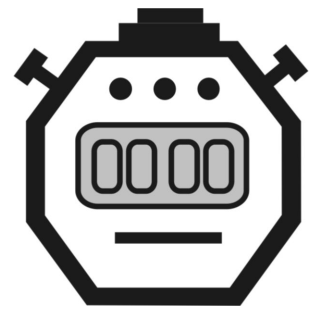
For example: I will measure the time it takes for all 12 of the popsicles in the ice trays to melt.

MATERIALS

Write down all of the materials you will need to do your test.

For example: I will need two ice trays, a quart each of orange juice and apple juice, a freezer, two cookie sheets and a timer.

I will need these materials:



MY TEST

Write down everything you did in your test.

For example: I filled one ice tray with orange juice and the other ice tray with apple juice, making sure that there was an equal amount of juice in each hole of the trays. I put both trays in the freezer at the same time and left them in overnight. The next day, I emptied both trays at the same time onto two large cookie sheets. I recorded the amount of time it took each cube to melt completely with my stop watch.

This is how I did my test:

DATA

Write down what happened in your test–your data. You might want to use a table or graph to show your results.

For example: I recorded the length of time it took the ice cubes to melt like this:

Orange Juice	**3 min 20 sec**	**3 min 30 sec**	**3 min 30 sec**	**3 min 40 sec**	**3 min 50 sec**	**4 min 10 sec**
Apple Juice	**3 min 45 sec**	**4 min 15 sec**	**4 min 30 sec**	**4 min 30 sec**	**4 min 30 sec**	**4 min 30 sec**

Then I added all the times for the juices and divided by six to get the average times. First, I changed all the times into seconds and added them together, like this:

Orange

3 min 20 sec = 200 sec
3 min 30 sec = 210 sec
3 min 30 sec = 210 sec
3 min 40 sec = 220 sec
3 min 50 sec = 230 sec
4 min 10 sec = 250 sec
1320 sec

Apple

3 min 45 sec = 225 sec
4 min 15 sec = 255 sec
4 min 30 sec = 270 sec
4 min 30 sec = 270 sec
4 min 30 sec = 270 sec
4 min 30 sec = 270 sec
1560 sec

Then I divided the totals by six, like this:

1320 ÷ 6 **=** 220 sec **=** 3 min 40 sec

1560 ÷ 6 **=** 260 sec **=** 4 min 20 sec

Write down your data here:

ANALYSIS & CONCLUSION

Look at your data. Think about the data. What does it show? Was your hypothesis right?

For example: My data shows that popsicles made out of orange juice melt faster than popsicles made out of apple juice. My hypothesis was wrong. When I looked at the frozen juice and touched the cubes, the orange juice cubes were softer, not harder, as I thought they would be. I wonder if the pulp in the orange juice made a difference? I think I will compare orange juice with pulp and orange juice without pulp to see if there is a difference in how fast they melt.

Write your analysis and conclusion here:

PICTURE OR GRAPH

Draw a picture of your experiment or a graph of your data here:

DESIGNING FAIR TESTS

Design a fair test to answer these questions.

In winter, will you be warmer with one thick pair of socks or two thin pairs?

Does a change in temperature change the force of a magnet?

Do plants need dark to grow, as well as light?

Will plants grow better with rain water than water from the house?

Will a flashlight be brighter with three batteries than with two?

Which brand of battery really keeps going and going and going?

If you lived in the desert, what color roof would keep your house cooler?

Do plants grow as well in lamp light as in sunlight? With incandescent or fluorescent lights?

Do ice cubes melt faster in warm or cold water? Will warm or cold water freeze faster?

Do people use more water taking a shower or a bath?

Does a heavy object fall faster than a light object?

Will a cold ball bounce as well as a warm one?

Do you lose weight when you play a game of soccer?

Are you stronger in the morning or in the afternoon?

Which is a better insulator—a foam cup or a paper one?

ENERGY FAIR
Evaluation Form

State: ___________ **Grade Level:** ___________ **Number of Students:** __________

1.	Did you conduct the entire activity?	Yes	No
2.	Were the instructions clear and easy to follow?	Yes	No
3.	Did the activity meet your academic objectives?	Yes	No
4.	Was the activity age appropriate?	Yes	No
5.	Were the allotted times sufficient to conduct the activity?	Yes	No
6.	Was the activity easy to use?	Yes	No
7.	Was the preparation required acceptable for the activity?	Yes	No
8.	Were the students interested and motivated?	Yes	No
9.	Was the energy knowledge content age appropriate?	Yes	No
10.	Would you use the activity again?	Yes	No

How would you rate the activity overall (excellent, good, fair, poor)?

How would your students rate the activity overall (excellent, good, fair, poor)?

What would make the activity more useful to you?

Other Comments:

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