“Experimental Design”
“Scientific Method”

A guide to help you assist your student prepare a project for the Greater Kansas City Science and Engineering Fair

INSPIRING SCIENTIFIC CURIOSITY AND LEARNING FOR A BETTER COMMUNITY

Steps to Designing an Experiment

Vocabulary:

Measuring	Collecting Data	Variables
Predicting	Hypothesis	Dependent Variable
Control	Constant	Independent Variable

Background Information:

Students need a strategy to develop a topic into an experimental design. The Four Question Strategy gets students involved from a different prospective, and they come up with endless ideas. With this method, science teachers can have their students explore the possible variations of a research topic before attempting to state a problem, write a hypothesis, identify variable, constants, and the control. Students need a method that is tried, and then practiced several times before designing an original experiment on their own. The Four Question strategy is a skill that is guaranteed to strengthen with practice but is not likely to be mastered in one session. Younger students can even apply the approach but must be given simple materials with few variations.

Teaching Suggestions:

1. Use the **Four Question Strategy** to guide students through the experimental design steps. Before students can begin designing an experiment, a **topic** or **prompt** must be identified. Have the students **first** identify the topic they will study. Examples may include:

Seeds	Fertilizers	Inclined plane
Acid rain	Light	Detergents
Felt-tip markers	Glue	Baseballs
Shampoo	Plastic Wrap	paper airplanes
Soil	Paint	Soft drinks
Tennis shoes	Batteries	Popcorn
Cereals	Flower bulbs	Chewing gum

2. Introduce *Step One* by asking: **What materials are readily available for conducting experiments on the topic** (e.g. plants)**? Write the list of materials on the board or overhead.**

For example:

Soil	Plants or seeds	Water
Chemicals	Heat or light	Containers

You might also ask if there are any other things in the environment besides heat or light (e.g. sound or air) that could be considered when experimenting with plants. If students do not bring this up, it may come later. For younger children, keep the materials list as simple as possible. List these materials on the chalkboard, chart paper, or overhead as they are suggested.

3. Begin *Step Two* by asking: **How do/does topic** (i.e. plants) **act?** One response is: **Plants grow**. This step is the most difficult because children typically think actions are behaviors and in a sense, here you can say, **"How do plants behave?"** However, with other physical or earth science topics, it may be more difficult to identify how the topic acts. For example, **"How do batteries act?"** (give energy to make things work); **"How does paint act?"** (spreads or covers materials); **"How does soil act?"** (helps roots grow, feeds earthworms). You can give other examples. The point of this question is to focus on what about the *action* can be measured, which is *Step Three*.

4. Introduce *Step Three* by asking: **How can I measure or describe the response or action of the topic** (i.e. plants) **to change?**

Some responses may include:

Measure the length of the longest stem.
Count the number of flowers.
Count the number of leaves.

If students had difficulty with *Step Two*, going on to *Step Three* may make *Step Two* easier to understand. This is the data collection phase of experimental design. An important part of the question is: What can I measure? Linear measurement comes quickly to students. However, counting objects, frequency, time, volume, mass, etc. are other measurement options that might be more appropriate than linear measurement in an experiment. Another important point is that an experiment is not always contingent on actual measurement. Written descriptions are very acceptable. If a written description is the method of data collection, spend time teaching students to be precise about the words they use. For example: The carpet cleaner that best removes stains from carpet. Guide them away from using nonspecific or inappropriate words like nice, ugly, stinks, etc. This part of the experiment is call the **Dependent Variable** or how you can document change.

5. *Step Four* is the step where brainstorming and creativity begins to evolve. It is here that students will identify the variables they will be testing in the experiment. Each variable tested becomes a different experiment.

   Introduce *Step Four* by going back to *Step One*, which was to identify the materials needed to experiment with the topic. Ask: **How can I change the set of topic** (i.e. plant) **materials to affect the action or behavior?** (Remember the action or behavior is that which will be measured.) At this point refer to the list of materials in *Step One*. If these are listed in a vertical column, put them as horizontal "column headlines". (See below.) Exploring one material item (i.e. water) at a time, rather than skipping around is better because students remain focused. After they have exhausted the way they could vary this item, go on to the next. Some examples for three of the materials listed above may include:

Water	Light/Heat	Containers
Amount	Source	Porosity
pH (acidity)	Angle	Size
Source (river, ocean, pond)	Distance from plants	Shape
Temperature	Color of light	Number of holes
Method of application	Exposure time	Transparent/translucent, opaque
Frequency	Fluorescent or incandescent	Volume

   The variable that will be deliberately changed or altered becomes the **Independent Variable**. All other variables (materials) listed must remain constant because if more than one is altered it will be too difficult to know which caused the change. As students increase in their skill and sophistication, they can alter more than one variable or study correlations. The **control** is the "set-up" that is not affected by the independent variable. It will not receive the treatment. This set-up is the one that the others will be compared to.

6. Now students are ready to write their experimental question, purpose, and hypothesis. The **question** contains two items: material (variable in *Step Four*) and how the change will be measured (*Step Three*). For example, if the independent variable is <u>amount of water</u> and the dependent variable <u>is how the change in plant growth will be measured</u>, the question is: ***Does the amount of water*** affect ***plant growth***? Write the form: Does (<u>material</u>) affect (<u>topic</u>) (<u>behavior change</u>)?

7. The **hypothesis** can simply answer the question: **The amount of water affects (or does not affect) plant growth**. For young children, the hypothesis or statement of the outcome that can be either supported or not, is all that is necessary. When writing the hypothesis, children frequently start it out, "*I think* the amount of water affects plant growth." Point out that the results will either support or not support the hypothesis. Discourage them from using the words "*I think*" in their hypothesis.

8. In the scientific method, the **purpose** is an expansion of the explanation (more explanation) of the hypothesis. What do you want to find out or what knowledge do you want to support? The **procedure** should be a sequence of steps the student will follow to find the answer to the question or fulfill the purpose. Include **data** collection strategies in this part. Discourage students from using transition words for sequence. Having them write the steps in sequence and beginning each step with a verb will help them make the directions become more precise and clear. The **material** is a thorough list of items needed to complete the experiment. Encourage students to be very specific. The **results** includes the data display (i.e. charts, graphs, tables), and an explanation of the data. It is also a good place for notes taken that might explain along the way the effect of the outcome. The **conclusion** is an explanation of **<u>why</u>** the researcher thinks he/she arrived at their results. This is the point when the researcher is most ready to do research on the question. In the conclusion, the student should reflect on why the data did or did not support the hypothesis. This is also a good place to suggest the next steps the researcher might do to further explore the topic.

Further Sessions

As stated earlier, designing experiments is a skill that needs to be introduced as simply as possible and practiced often. You may want to spend a session on one step at a time. Or if students are familiar with the experimental design, one session of the four-step strategy may be enough to get them going. For follow-up session, give student groups a topic and have them run it through the steps and reach a research question and hypothesis. Allow each group to state their hypothesis and then ask**:**

1) What is the topic?
2) What will you vary?
3) How will you measure the effect?
4) Can the hypothesis be supported?

Following several sessions of "group work" practice, students should be ready to accept the task individually.

Resource: Cothron, J; Giese, R. & Rezba, R, *Students and Research, Practical Strategies for Science Classrooms and Competitions*

Four Question Strategy

Name the topic (Prompt) _____

1. What materials are readily available for conducting experiments on _____(topic) _____?
2. How do/does (topic) act?_____
3. How can you measure or describe the response of _____(topic) _____?
4. How can you change the set of (topic) materials to affect the action?

Sample Student Sheet

Designing Experiments with Plants

What materials do you need to do an experiment about plants (independent variable) from seeds?

_____ _____

_____ _____

_____ _____

What will you measure? _____
(dependent variable)

List what you can vary under each material.

Seeds	**Soil**	**Container**
_____	_____	_____
_____	_____	_____
_____	_____	_____

Water	**Light**	**Fertilizer**
_____	_____	_____
_____	_____	_____
_____	_____	_____

Name _____ Date _____

Sample Student Sheet

Designing Experiments with Plants

Design some questions about some experiment you can do with plants from seeds.

1. Does _____ affect the _____
(material, e.g. seeds) (what you will measure)

of _____?
(the topic)

2. Does _____affect _____
(material, e.g. soil) (what you will measure)

of _____?
(the topic)

3. Does _____affect _____
(material, e.g. container) (what you will measure)

of _____?
(the topic)

4. Does _____affect _____
(material, e.g. water) (what you will measure)

of _____?
(the topic)

Name _____ Date _____

Sample Student Sheet

Designing Experiments with Plants

Write a hypothesis for question #1:

_____ does/does not
(material, e.g. seeds- independent variable.)

affect the _____
(what is measured- dep. var.)

of _____?
(the topic)

Write a hypothesis for question #2:

_____

_____

Write a hypothesis for question #3:

_____

_____

Write a hypothesis for question #4:

_____

_____

Name _____ Date _____

Writing an "If ….then" Hypothesis from the Four Question Strategy

Name the topic (prompt)

1) What ***materials*** are readily available for conducting experiments on _____(topic) _____?

2) How do/does (topic) ***act***?_____

3) How can you ***measure or describe*** the response of ___ (topic) __?

4) How can you change the set of (topic) materials to affect the ***action***?

To write a hypothesis, relate the response to question 4 above with a response to question 3. **If** I change (an independent variable from question 4, **then** the (dependent variable from question 3) will change. Have students design an experiment by selecting one variable that they will deliberately change or vary… the **independent variable**, and one specific response that they will measure… the **dependent variable**. It is more appropriate for elementary students to choose **only one** independent variable, e.g. the type of soil, and **only one** dependent variable, e.g. the growth rate.

Students tend to confuse the terms **constants** and **control**. In the experimental design, all other materials that might influence the dependent become **constants** for the experiment. In other words, every other factor for all repeated trials is the exact same. Constants are often called **controlled variables**. In an experiment the non-treatment group that serves as a comparison standard to the experimental or treatment group, is the control. Use the tem independent variable for the factors that are changed to see the effect. Use the term **constants** for those factors that are kept the same.

If **I vary** _____, then **the**
(material – independent variable)

_____ will _____ in
(what is measure, dependent variable) (describe the effect)

Experiment with _____.
(topic)

Resource: Cothron, J; Giese, R. & Rezba, R, *Students and Research, Practical Strategies for Science classrooms and Competitions*

Sample Student Sheet

Writing an "If ….then" Hypothesis

Write a hypothesis by relating a response to Question 4 with a response to Question 3 by using the following format:

If I vary or change (**an independent variable**) from Question 4, **then** the (*dependent variable* from Question 3) will change.

Write a hypothesis for question #1:

If I vary _____ , **then** the
(**material, e.g. seeds- independent variable**)

_____ will _____ in an
(**what is measured- dep. var.**) (***describe the effect***)

Experiment with _____.
(**the topic or prompt**)

Write a hypothesis for question #2:

_____

_____

Write a hypothesis for question #3:

_____

_____

Write a hypothesis for question #4:

_____

_____

Name _____ Date _____

Sample Overhead for 4-Question Strategy

MATERIALS

Seeds	**Soil**	**Container**
age	**origin**	**type**
pretreatment	**density**	**size**
number	**pH**	**material**
brand	**natural vs. mix**	**drainage holes**

Water	**Light**	**Fertilizer**
amount	**type**	**amount**
color	**color**	**placement**
origin	**direction**	**frequency**
frequency	**intensity**	**brand**

The Scientific Method

A student record for an experiment or science project:

1. **What do you want to find out?**

   ***PURPOSE**

2. **What do you think will happen?**

   ***HYPOTHESIS**

3. **What materials do you need to use?**

   ***MATERIALS**

4. **What will you do to find out the answer to the question?**

   ***PROCEDURES**

5. **What happened?**

   ***RESULTS**

6. **Did the results support the hypothesis? What did you learn? What is another experiment you would like to do next?**

   ***CONCLUSIONS**

The Scientific Method

A student record for an experiment or science project:

1. **What do you want to find out? PURPOSE**
   What is the question or problem to be solved?

   Does _____ affect the _____
   (material) (action to be measured)

   of _____?
   (topic)

2. **What do you think will happen? HYPOTHESIS**

3. **What materials do you need to use? MATERIALS**
   (List the materials. Be exact. Think about the ingredients in a recipe.)

4. **What will you do to find out the answer to the question?**
   PROCEDURES
   State procedures in a sequence. Begin each procedure with an action word (verb). Think about how a recipe is written.

5. **What happened? RESULTS**

   Use quantitative results (e.g. data in a table, graph, etc.) or qualitative (descriptive) observations. Explain your graph or table.

6. **Did the results support the hypothesis? What did you learn? What is another experiment you would like to do next? CONCLUSIONS**

Did you gather enough evidence to support the hypothesis? Tell *why* you think you got the results. Support your findings with other research. Next steps?

Simple Plan for Organizing a Notebook

Predict: I think _____

because _____

Today I (or we) _____

I observed _____

Today I learned _____

I wonder _____

Simple Plan for Organizing a Notebook

Predict: I think __**(what you think will happen)**__ _____

because _____**(why you think it will happen)**_____

Today I (or we) ___**(description of activity)**_____

I observed _____**(data that you collected and what you saw)**___

Today I learned ___**(summary of what happened)**_____

I wonder ___**(next steps, questions)**_____

Science Investigation Notebook Entry

Question? _____
(What do you want to find out?)

Predict: _____
(State what you think will happen.)

because _____
(Explain why you think it will happen.)

Plans and procedures _____
(Describe how you will go about answering your question.)

Observations and Data _____
(What did you observe? How did you organize your data?)

_____

_____

I learned _____
(Summarize what you learned from your experiment.)

_____

_____

I* wonder _____
(next steps)

Name _____ **Date** _____

Science Experiment Performance Evaluation Rubric

Student: _____

Project/Experiment title _____

Date _____

0-Never 1-Rarely 2-Sometimes 3-Frequently 4-Always

1. Demonstrates understanding of dependent and independent variable.	0 1 2 3 4
2. Demonstrates understanding of repeated trials.	0 1 2 3 4
3. Demonstrates understanding of how to write precise instructions for experiences.	0 1 2 3 4
4. Demonstrates ability to accurately record data.	0 1 2 3 4
5. Demonstrates ability to formulate hypothesis using “if..then” statement.	0 1 2 3 4
6. Is able to use four-question strategy to generate ideas for investigable experiments.	0 1 2 3 4
7. Completes graphs and tables clearly and accurately.	0 1 2 3 4
8. Is able to orally explain key concepts.	0 1 2 3 4
9. Works cooperatively in a group setting.	0 1 2 3 4
10. Completes work independently.	0 1 2 3 4
11. Completes all work on time.	0 1 2 3 4