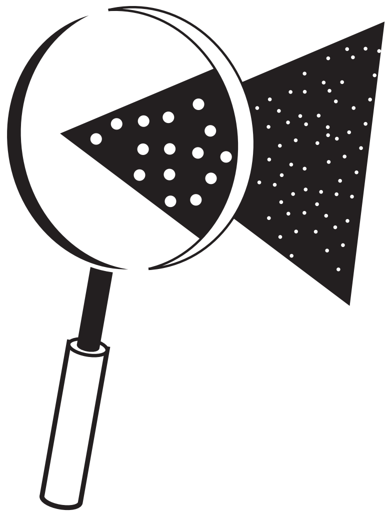
Virginia 4-H School Enrichment



SCIENTIFIC INQUIRY

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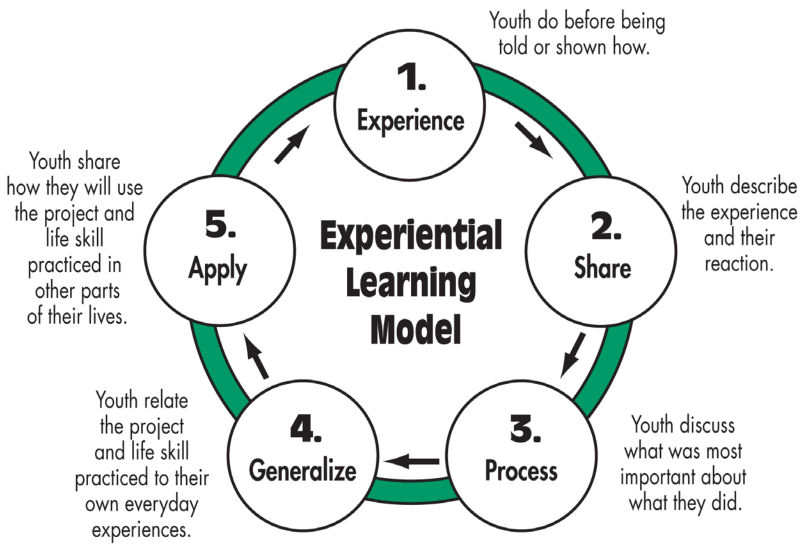
Scientific Inquiry

Virginia 4-H School Enrichment

This curriculum includes six lessons intended for youth in grades three through six.

These activities are experiential and contain aspects of problem-based and inquiry-based learning.



Pfeiffer, J.W., & Jones, J.E., "Reference Guide to Handbooks and Annuals"

Experiential Learning in a Nutshell

Experiential learning is a process where a learner "does" something, reflects upon what he or she does, evaluates it, and gains new insight or learning that can be applied in other life settings. The experiential learning model used in Virginia 4-H is based on a five-step model adapted from Pfeiffer and Jones (1983). This approach encourages a hands-on exploration by learners with guidance from an adult facilitator. Learners are presented with a problem, task, situation, or activity. They "make sense" of the challenge and act upon it. Youth respond to questions representing inquiry at different stages of the model, for example: What happened? What did you do? What was important about what you did? How does what you did relate to your life, the skills practiced, and your future? How would you use the skills (life skills and project skills) you have practiced in your future? It is this reflective processing that takes place after the initial hook or involvement that sets experiential learning apart from simply "experiencing" or "doing" an activity. Ongoing, open-ended

Science SOL 3.1, 4.1, 5.1, 6.1

questioning works best to promote inquiry that is intentional. A facilitator, who often becomes a co-learner, provides intentional opportunities for focus, debriefing, and support throughout the learning process.

In *Scientific Inquiry*, each activity is broken into eight sections for the adult leader and includes a Youth Activity Sheet for the youth. The eight sections for the adult leader consist of the following:

- Overview,
- Life Skills,
- Learning Outcomes,
- Objectives,
- Background Information,
- Materials List,
- Conducting the Activity, and
- Discuss What Happened.

Many of the concepts for this curriculum, especially those related to experimental design, were adapted from *Students and Research, Practical Strategies for Science Classrooms and Competitions* by Julia H. Cothron, Ronald N. Giese, and Richard J. Rezba, Kendall/Hunt Publishing Company, Dubuque, Iowa, 1993. This resource is highly recommended for more detail on this subject.

Words that appear in bold in the activities are included in the glossary.

The Overview section provides a brief description of the activity. The Life Skills section lists the life skills that are to be practiced through the activity. The Learning Outcomes section describes the learning or content goal for the activity and the Objectives section lists a measurable outcome. The Background Information section is general information provided for you, the adult leader. This information will help you understand what will be explored in the activity and help you guide the discussion that takes place after the activity begins. However, it is important NOT to lecture the youth using the background information before they have an opportunity to conduct the activity. Present the situation and the task at hand and provide facilitation of the learning process. The Materials List describes everything necessary to conduct the activity, and the Conducting the Activity section provides step-by-step instructions. Finally, the Discuss What Happened section directs you to guide youth to process what happened, discuss what they learned, and think of ways that the experience applies in their lives, thus helping

Science SOL
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them to develop targeted life skills, deepen the learning, and better anchor science concepts. As leader, it is up to you which of the questions in the Discuss What Happened section to use to stimulate discussion at the end of the learning activity and to determine what additional open-ended questions could deepen the learning during the learning process to catch that teachable moment.

Every Youth Activity Sheet has a space entitled "Journal Entry" where youth can record thoughts and observations related to their learning or respond to specific questions that you as leader instruct them to answer. If you want them to address a specific question, you must provide it. One way to do this would be to write in your question before you reproduce the sheet(s) for distribution to youth. For reflection, you might want to ask an open-ended question to prompt reflection. The youth should keep their completed Youth Activity Sheets in a folder. Responses on these sheets serve as an assessment of the student's progress and understanding of key concepts.

The six lessons are:

1) Do You See What I See?

2) Classify This!

3) Measuring "Best"

4) Tell Me How It's Done

5) What Makes the "Best" Flyer Best?

6) Telling What You Know

Lessons one and two are designed to help youth to observe closely and to understand how to classify objects. Activities 3, 5, and 6 are designed to teach youth how to design, conduct, and report a science experiment, using the scientific method. Activity 4 demonstrates to youth the importance of writing clear, detailed instructions. This skill is needed to write experimental procedures that contain sufficient detail so that someone else may repeat an experiment. The scientific method relies on observation, repeatable phenomenon, and on every scientist building on the work of others. This can only happen if scientists clearly describe how they conducted their experiments.

Rationale

Science is a process. Science involves cognitive and physical actions that include: observation, classification, predictions (inferences), conclusions, and reporting results.

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6.1

Scientific Inquiry

Everyone is born a scientist. We all observe, question, organize, classify, and draw conclusions. Science is not about "being right" or "knowing the answer;" it's about questioning and observing to find things out or to create more questions. This curriculum helps youth understand the process of science and discover the excitement of finding answers for themselves. It advances the life skills and science abilities of communicating with others, problem solving, critical thinking, acquiring and evaluating information, and interpreting information.

Generalizations

- Science begins by observing.
- Classification and sequencing help organize our thinking and understanding of the world.
- Experiments are designed to answer specific questions.
- Data from experiments must be collected, interpreted, analyzed, and reported.
- Good communication is necessary so that experiments can be repeated.

Using This Curriculum: Audiences and Settings

These activities are designed to introduce youth to the process of scientific inquiry and to help develop the following inquiry skills: observing, classifying, and sequencing; communicating; measuring; predicting; hypothesizing; inferring; defining, controlling and manipulating variables in experimentation; and interpreting, analyzing, and evaluating data (*www.pen.k12.va.us/VDOE/Superintendent/ Sols/sciencesol.pdf*).

These activities may be used in a variety of settings including the following:

- in-school;
- special interest SET (science, engineering, and technology) 4-H clubs;
- themed, sequential, after-school programming; and
- day or overnight camps.

For use with in-school groups, activities one and two are appropriate for students in grades three or four. Activities 3 through 6 are appropriate for grades five and six.

Activities 3 through 6 could be used in non-formal settings such as after-school programs, special-interest clubs, or camping programs. In these

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settings, you may wish to use the flying object from the activities to introduce the concepts of experimental design, but then allow youth to design, conduct, and report on a science experiment of their own design. This could begin with a brainstorming activity where youth, in their research teams, decide on something they are interested in and then arrive at a question they wish to investigate. The Youth Activity Sheets can easily be modified to help youth develop an experimental design for any question they wish to answer.

Your role as leader is to do the following:

- Assure the safety of the group,
- Arrange for needed materials and community resources (help connect youth to experts where appropriate),
- Facilitate group discussions, and
- Encourage the pursuit of learning.

These activities are written to coincide with Virginia's Science Standards of Learning (SOLs), roughly corresponding to third through sixth grades. In addition to the SOLs, Virginia provides a Curriculum Framework that is presented by grade level and subject matter. The Curriculum Framework provides a detailed explanation of the accomplishments expected of students at each grade level. The Curriculum Framework for science can be found on the World Wide Web at *www.pen.k12. va.us/VDOE/Instruction/Science/sciCF.html.*

This curriculum is written to support Virginia Science SOLs 3.1, 4.1, 5.1, and 6.1. These SOLs involve scientific investigation, reasoning, and logic.

This curriculum also supports the National Science Education Standards, (National Research Council, 2004, *www.nap.edu/readingroom/books/nses/*). Specifically, from National Science Education Standards, Table 6.1 states that for grades K through 8, students should possess the following:

1. abilities necessary to do scientific inquiry and
2. understanding about scientific inquiry.

Evaluating Outcomes

After students complete the curriculum, use the following evaluation tool to allow them to evaluate what they learned.

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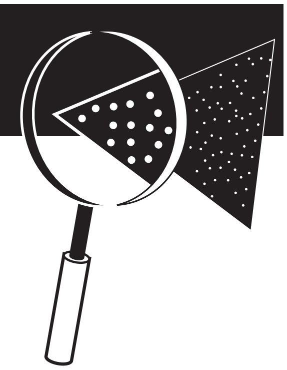

Student Directions

Directions: Circle the number 1, 2, or 3 that shows what you knew about or how to do before the activity (Before) and what you knew after doing the activity (After). The numbers mean:

1 - To a great extent   2 – Somewhat   3 – Not at All

Activity 1	**Before**	**After**
I know the difference between an observation and an inference.	1 2 3	1 2 3
I can express myself to others.	1 2 3	1 2 3
Activity 2		
I can classify objects: how they are alike and how they are different.	1 2 3	1 2 3
I apply rules when I classify objects.	1 2 3	1 2 3
Activity 3		
I can identify the responding variable in an experiment.	1 2 3	1 2 3
I know what an experimental constant is.	1 2 3	1 2 3
I know why trials must be repeated in an experiment.	1 2 3	1 2 3
Activity 4		
I can describe an experimental procedure in detail.	1 2 3	1 2 3
I can write directions that someone else can follow.	1 2 3	1 2 3
Activity 5		
I know what a manipulated variable is in an experiment.	1 2 3	1 2 3
I can collect data from an experiment.	1 2 3	1 2 3
Activity 6		
I can get meaning from data.	1 2 3	1 2 3
I can report experimental results in words and graphs.	1 2 3	1 2 3

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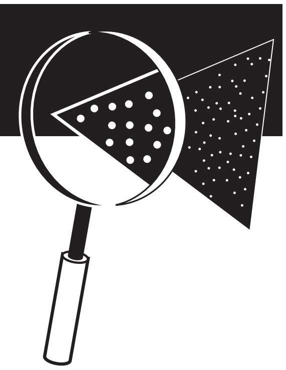

Activity 1: Do You See What I See?

Overview

In this activity, youth in groups of five or six are each given a similar but unique object and asked to describe it in writing. After completing their individual descriptions, they place their objects with all the objects within their group, exchange descriptions with someone in another group, and attempt to identify the object in the description they receive. As an additional activity, after they observe and describe the objects, the youth look at a picture and then decide if statements about the picture are observations or inferences.

Life Skills and Science Abilities

Communicating with Others (presenting basic ideas/information)

Making Decisions (gathering information)

Reasoning (examine information/data for relevance and accuracy)

Learning Outcomes

- Youth discover the importance of observation.
- Youth write a description that allows someone else to correctly identify the object described.
- Using the picture given, youth differentiate between observation and inference.

Background Information

Observation employs our five senses, alone or in combination, to inform us about our surroundings. Scientific observation is a learned skill. We constantly receive information from our environment, and we quickly learn to filter and ignore a great deal of it. Also, we tend to interpret new information by weighing it against what we already know, forcing it to fit our preconceptions. In this way, we tend to "see" what we already know and what supports our concept of how things work. Therefore, it is important to help youth develop skills of observing so they consciously seek information to extend their ideas and understanding of the world.

Your role as teacher or adult leader is to provide opportunities for using different aspects of observation and through discussion, to encourage youth to be good observers. Observation is not a great "stand alone" activity. Youth will quickly tire of it, and just because they observe closely in one activity, does not guarantee they will observe well in another. Please remember to encourage and direct observation skills as you

Science SOL 3.1, 4.1, 5.1, 6.1

conduct all of the activities in this curriculum. This activity on observing is offered to introduce the concept and to heighten youths' awareness of observation as a skill employed by scientists.

Inferences are conclusions we draw from observations. Generally, the inference or conclusion is then tested further to determine if it is true or not. It is very easy to confuse inferences with observations, because we are so used to drawing inferences from what we see. For example, if you live in Virginia and you look out the window on a December day and you see the trees swaying, you might conclude that it is cold and windy out. Both of these are inferences, not observations. You observed that the trees were swaying; and, based on life experience, you inferred that swaying trees mean that the wind is blowing. Also, based on life experience, you inferred that it is cold outside in December, especially when it is windy! Observation would have involved going outside and feeling or actually measuring the air temperature with a thermometer and the air movement with an anemometer.

Sometimes what is an observation about a "group" of objects is an inference if you assume that the observation holds true for ALL similar objects. For example, learners might observe a group of round, plastic buttons where each has four holes, and from this they might infer that ALL buttons are round, made of plastic, and have four holes. In fact, this is not true, but it is a logical inference based on what they observed. Youth should understand that inferences are generalizations, and could change as more information is gathered to show that an original inference was incorrect.

Materials List

- A set of objects, one for each member of each working group – buttons, leaves, peanuts in the shell, cookies, or donuts are possible choices. NOTE: Each object within a working group must be unique, but they should be similar enough to require a reasonably detailed description to identify one object from another. If you decide to use peanuts, make sure that none of the participants are allergic to them! If you use cookies or donuts, place each one in a food-grade, clear plastic bag, so they can be handled without touching and then eaten later. Tape a unique number on each object within a group so that they can be identified later.
- Rulers (one per child is ideal, but they can share if fewer are available)
- A scale or scales (optional)
- A copy of Youth Activity Sheet 1A for each child. You may wish to write in questions for the Journal Entry Section before making copies.

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Activity 1: Do You See What I See?

Conducting the Activity

1. This can be a long activity and, depending on the block of time available, you may wish to break it up into two learning sessions. The Discuss What Happened section, presented at two points within this activity, allows youth to process what they have learned before moving on. The session can be ended after the first Discuss What Happened section and resumed at another time.

2. Divide the class into working groups, each with five to six youth. Distribute a set of objects (remember to tape a number to each object), and a ruler to each group. Give a Youth Activity Sheet 1A to each participant. If a scale is available, make them aware of it. If they have not used the scale before, briefly show them how to use it and allow them to weigh an object of known weight to gain confidence using it.

3. Record on a piece of paper the number of the object that each child received. You may wish to ask each group to do this by writing their names and object numbers on one piece of paper. Collect their lists.

4. Ask the youth to observe their objects and to record as much information as possible about them on their Youth Activity Sheets. Explain that they SHOULD NOT include the object numbers in their descriptions! Allow five to ten minutes for observing. (If a scale is available, it may take a bit longer for each youth to use it.) You may have to remind the youth to measure the length and weight of their object. Just because a ruler is present doesn't mean that they will use it!

5. After they have had time to write their observations, instruct the youth to return their objects to a pile, and to place their Youth Activity Sheets in a pile next to the objects. Remind them to put their names on their Youth Activity Sheets.

6. Have the groups rotate so that each group is looking at the objects and Youth Activity Sheets from another group. Each youth should take one Youth Activity Sheet from the pile left by the previous group.

7. Ask the youth to read the description on the Youth Activity Sheet and to identify the object in the pile that they think is being described. Once they have identified the object, they should record the number of the object on the Youth Activity Sheet.

8. Return the youth to their original groups and their Youth Activity Sheets, and use the number key to see if their descriptions allowed someone else to identify the objects described.

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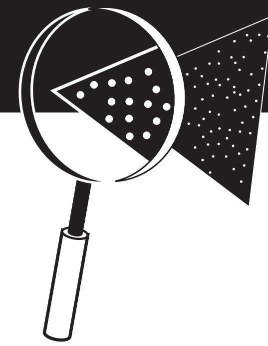
Activity 1: Do You See What I See?



Discuss What Happened

The following are possible discussion questions. While you may wish to lead a class discussion regarding most of the questions, it is a good idea to ask youth to answer one or two of the questions in writing in the space provided on their Youth Activity Sheets.

- Which piece of information was most useful to identify the object and why?
- Which was least useful and why?
- What information that was not listed would have been useful?
- When do you think taking length measurements would be useful to describe an object? Note: A logical answer is that length is useful when the objects are different sizes but similar in other characteristics. However, there is no “right” or “wrong” answer to the question.
- When do you think weight measurements would be useful to help describe an object?
- What happened when you tried to identify an object using someone else’s description?
- Describe another activity where accurate descriptions are important.

Conducting the Activity (continued)

Note: If you dismissed the group and are now resuming, conduct a brief group “warm up” exercise by asking youth to verbally provide a description of some object (a lit candle is a possibility). Remind learners that they observed an object in the last learning session by themselves and that this time they will work together in pairs or teams to read the description of the object just observed and add any information they felt was obviously missing. Share those missing pieces back with the large group. Proceed to step 9.

9. Ask youth to work independently to complete Youth Activity Sheet 1B (Observing versus Inference).

Discuss What Happened (continued)

- How did you decide if a statement was an observation or an inference?
- Ask youth to complete the following sentence: After doing this activity, I now observe myself doing ________________________ differently.
- What can you infer from this observation about yourself?

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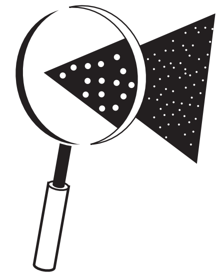
Do You See What I See?

Scientists discover things by observing closely and asking questions about what they see, hear, feel, smell, and taste. Everyone is a scientist!



Name: ______________________________

Describe your object:

NOTE: This section to be completed by someone else:

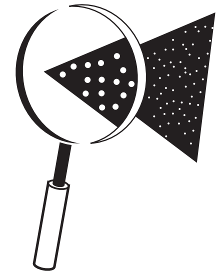
Observer's Name: ______________________________

What is the number on the object that you think is being described above? __________

Journal Entry:

Do You See What I See?

After observing carefully, scientists develop inferences or theories about what they observe. If, as they continue to observe, they find something that proves their theory wrong, then they change the theory to match the new evidence. A good scientist isn't always right! A good scientist keeps an open mind and is always trying to find out what is true! Everyone is a scientist – make sure you are a GOOD one!



Name: ____________________________________

An observation is something you can figure out using your five senses. An inference is a conclusion or generalization you make based on what you have observed. Look at the picture and decide if the following statements are observations or inferences.

Place an "O" beside the statement if it is an observation and an "I" if it is an inference.

___ The young girl is wearing an earring.

___ The family is about to eat a meal.

___ A woman is bringing a dish of food to the table.

___ There are flowers on the table.

___ They are eating a holiday feast.

___ Someone just told a joke.

___ Several people are smiling.

___ The man is wearing a checked shirt.

___ The brother and sister are hungry.

List two more observations about the picture:

____

____

List two more inferences about the picture (remember, inferences are not right or wrong, they are just logical conclusions based on what you see (or touch, or smell…). If you were to get more information (another picture for example), your inferences might change):

____

____

____

Journal Entry:

The correct answers to Activity Sheet 1B are: O, I, O, O, I, I, O, O, I.

Activity 2: Classify This!

Overview

Youth will work in small groups to develop a dichotomous classification key for a set of objects. After they develop the keys, the youth use the keys from other groups to reclassify their objects. Through this activity and the discussion that follows, youth learn to appreciate the value of classification systems for organizing and sequencing information.

Life Skills

Thinking Creatively (recognizes patterns/relationships)

Reasoning (applies rules/principles to process/procedures)

Learning Outcomes

- Youth create a classification system.

Objective

- Youth generate a dichotomous key to demonstrate that classification systems can have many tiers or levels.

Background Information

Classify means to arrange or group according to some system or principle. Dichotomy means the process of dividing into two parts. A dichotomous classification system arranges or groups items into two groups. Once divided into two groups, each subgroup can be further subdivided into two more groups.

To effectively study plants and animals, all scientists need to use the same names, so that they don't get confused when talking to each other. The current classification system used to organize and name plants and animals was devised by Swedish botanist Carl Linnaeaus in 1757 (*http://nmml.afsc.noaa.gov/education/taxonomy.htm*). This system is called taxonomy. There are many different ways to classify things. The earliest known system of classifying forms of life comes from the Greek philosopher Aristotle, who classified animals based on their means of transportation (air, land, or water).

By creating their own classification system, youth will quickly grasp the concept of subdivisions within major divisions and will learn to "key" items out using each other's classification systems.

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Activity 2: Classify This!

Materials List

For each group:

- Approximately ten similar (but not identical!) objects (buttons, shells, paper clips, cookies, seeds, etc.). Place a number on each object as in Activity 1.
- Youth Activity Sheet 2

Conducting the Activity

1. Divide the youth into working groups of three to five, and distribute a set of materials and one copy of Youth Activity Sheet 2A to each group. In addition, provide one copy of Youth Activity Sheet 2B to the group and one copy for each child.
2. Explain to each group that it is the group's challenge to look at a set of objects to determine how they are alike and different to create a dichotomous classification system for the objects. To do this, each group should complete Youth Activity Sheet 2A. Do not tell them how to sort. Allow them to make their own choices related to sorting.
3. After the group completes a classification system for their set of objects, ask them to "key out" the objects. To do this, they should first copy the classification system onto their individual Youth Activity Sheets. Next, take an object from the pile, decide which category it belongs in, and record the object number in the appropriate category on the sheet. Be aware of youth as they begin to "get it." Ask open-ended questions to prompt as needed; for example, "What would happen if…;" "How does your sorting system help you 'key out' objects?"

   The following two steps are optional and can be conducted if time allows and/or if you wish to challenge your class. They could be used as take home assignments.
4. Ask the groups to research the taxonomy system and to list the levels of categories used (kingdom, phylum, class, order, family, genus, species).
5. Ask the groups to research how the library classifies books.

Discuss What Happened

Possible questions include:

- How did you decide what categories to divide the objects into first?
- How did you decide on the second-level classifications?

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Activity 2: Classify This!

- What other ways could you have categorized the items?
- Think of a set of objects you have at home and describe the classification system you use for them. Possible object sets include CDs, DVDs, any hobby/collection, clothes, dishes, food, etc.
- Why do you think scientists use classification systems?
- What are other science things that are grouped or classified?
- How do you use classification systems in your life?

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6.1

Classify This!

Name: ___________________________________

Your challenge is to develop your own dichotomous classification key. Working as a group, use your objects to complete the blank classification key on the next sheet. An example is given to show you how.

1. Identify your set of objects and write the name of them at the top of the key.

Coins

2. Decide on a way to divide the objects into two groups. The number of objects in each group does not have to be the same. Possible groupings include large/small, round/not round, and shiny/dull. Write the two categories on line 2 of the diagram.

Coins

Less than 10 cents | 10 cents or more

3. Divide your pile of objects according to the groupings you decided upon in step 2. Now, set one group of objects aside and looking at the remaining objects, decide on a way to divide them into two groups. Write the new group names on line three of the diagram.

Coins

Less than 10 cents | 10 cents or more

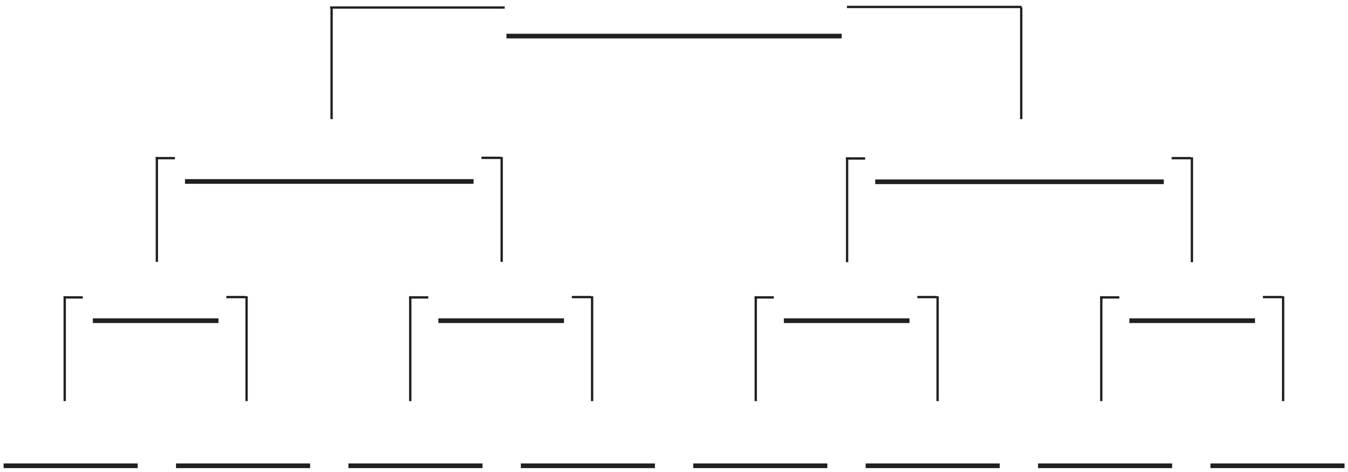
Older than 1990 | 1990 or newer

4. Continue dividing the groups into two classifications and recording names for the groupings on your classification key until all items have been differentiated. Then go to the top of the paper and repeat the process to differentiate the objects on the other side of the key.

Coins

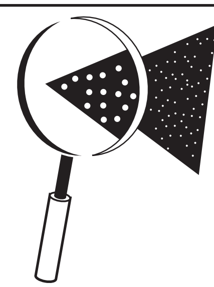
Less than 10 cents | 10 cents or more

Older than 1990 | 1990 or newer | Older than 1990 | 1990 or newer



Journal Entry: Thought questions from your leader.

There is so much information in the world that scientists organize or classify things into categories to keep track of them. That way, when we discuss them with each other, we have a common language and common understanding. Think about how many different insects there are, yet, when someone says the word insect, many characteristics pop into your mind. Everyone who organizes and classifies things in life acts like a scientist.



Activity 3: Measuring "Best"

Overview

Youth, working in small groups, build flying objects. The groups are invited to compete to determine which flying object is the "best." This leads to a discussion of three important concepts in designing science experiments.

Life Skills

Thinking Creatively (formulates new ideas/plans/approaches)

Reasoning (applies rules/principles to process/procedure)

Acquiring and Evaluating Information (creates data gathering process)

Learning Outcomes

- Youth identify the dependent or responding variable in an experiment.
- Youth understand the importance of repeated trials.
- Youth understand the role of constants in an experiment.

Objectives

- Youth select a responding variable for plane flight.
- Youth create a list of things that should be held constant in an experiment designed to determine how well a plane flies.

Background Information

A great way to teach youth how to design a science experiment is to get them involved in an activity, pose a question that could be answered by experimentation, and then let them brainstorm regarding what data they will collect and how they will collect it. Through this process, all the elements of experimental design can be introduced. This activity introduces three concepts used for experimental design: responding variable, repeated trials, and constants.

Throwing each flying object more than once is an example of a repeated trial in a science experiment. To be valid, a science experiment must include repeated trials. Otherwise, if something is only tested once, influences unexpected by the researcher may occur, and the data would not stand out as suspect, since there is no other data point to compare to. Repeated trials help to assure that data are valid.

If we allow each group to throw its object more than once, what will we do with the multiple observations? There are many possible things to do

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3.1, 4.1, 5.1, 6.1

with data to "reduce" it. For example, if the youth decided to evaluate "best" based upon distance, and they decided to go for three flights, they could let each group score only its longest flight (i.e. throw three times and keep the longest flight distance as its plane's performance) or they could add up all three flight distances and the flier with the combined greatest distance would be judged as "best." Yet another possibility is to average the three observations.

There is not a "best" way to judge, but by thinking about how to analyze data, other important considerations may surface (like what to do if a throw is "bad," i.e. the thrower knows he/she messed up).

Item 6 on Youth Activity Sheet 3 asks each group to "Make a list of things that might influence how the object flies." Possible answers include: the skill of the thrower, the angle at which the plane is released, the stillness of the air (a headwind versus a tailwind versus still air), and air temperature. The point of this question is to help youth understand that anything that might affect how the object flies should be held the same when they test each object if they want the test to be fair. An example of an unfair test would be if one object were flown into a headwind and another were flown with a tailwind. We would expect the one with the tailwind to fly farther than the one flown into the wind, even if it was not the "best" flying object. Discuss ways that they could assure that all the flying objects were tested under the same circumstances. Then explain that the things that are held the same to assure a fair test are called the experimental constants.

Materials List (one set per group)

- Soda straw
- One 8" x 10" sheet of heavy-weight paper such as construction paper
- Scissors
- Scotch tape
- Youth Activity Sheet 3 (one per youth) + a group sheet

Conducting the Activity

This is a long activity, and depending on the block of time available, you may wish to break it up into two meetings. The Discuss What Happened section is presented at two points within this activity, allowing youth to process what they have learned before moving on. The session can end after the first Discuss What Happened section, and then resume at the next meeting. If you do break it up, be sure to review the last activity briefly before resuming. A good refresher is to put youth into their

Science SOL
3.1, 4.1, 5.1, 6.1

Activity 3: Measuring "Best"

activity groups, give them a couple of minutes to discuss what they did the last time, and then ask each group to tell one thing they learned from the last meeting.

1. Give each group a set of materials and a Youth Activity Sheet 3. Ask each group to make a flying object as shown on the Youth Activity Sheet. Allow the youth time to fly their creations.

2. Ask each group to assign one member to be the official thrower. Have all of the throwers come to the front of the room and line up. Tell them that the challenge is to determine which flying object is best. On the count of three, ask them to launch their flying objects. Count, "one… two" then say, "WAIT! How will we know which one is best?"

3. Ask the youth to return to their groups to fill in the table on their Youth Activity Sheets entitled Possible things to measure to determine how well the object flies.

Discuss What Happened

- Can we measure "best"?
- List another example of when we say one thing is better than another and explain what is meant by "better". How would you prove it is better?

Conducting the Activity (continued)

4. Ask each group to read the list of things they generated from step 3 of the Youth Activity Sheet and record their answers on the board. Select a criterion that the class agrees will be used to determine which object flies best.

5. Explain to everyone that you are going to see which flying object _______________ (fill in the blank with whatever was agreed upon in step 4) and then line the throwers up again, and let them throw their planes. After the flight, ask, "Do you think one flight is enough, or do we need more?" Send the youth back to their groups to discuss the number of flights required for a good test (item 4 on the Youth Activity Sheet).

6. Ask the groups to report the number of test flights they suggested. Through class discussion, arrive at a reasonable number of flights for a test (two or three is a good number).

7. Ask the youth to complete numbers 5 and 6 on their Youth Activity Sheets.

Science SOL
3.1, 4.1, 5.1, 6.1

Activity 3: Measuring “Best”

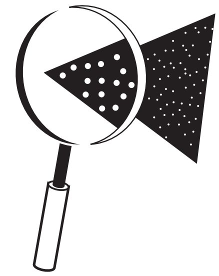
Discuss What Happened (continued)

- Why might we want to throw each object more than once? (Thought questions: Is one flight really “representative” of how well the plane can fly? What if the thrower messes up on one throw? Should they be given another chance? Does a bad throw tell us anything about how good the plane design is?)
- How do we decide how many times to throw the object?
- What are the advantages of a lot of throws?
- What are the disadvantages of a lot of throws?
- What did you list as things that might influence how the object flies?
- If you want to test one flier versus another, why is it important to know what will influence how it flies?
- What should be done to make sure the test is fair?
- Describe an occasion when you selected one thing as being better than another. How was this similar to selecting the “best” flyer?

Science SOL 3.1, 4.1, 5.1, 6.1

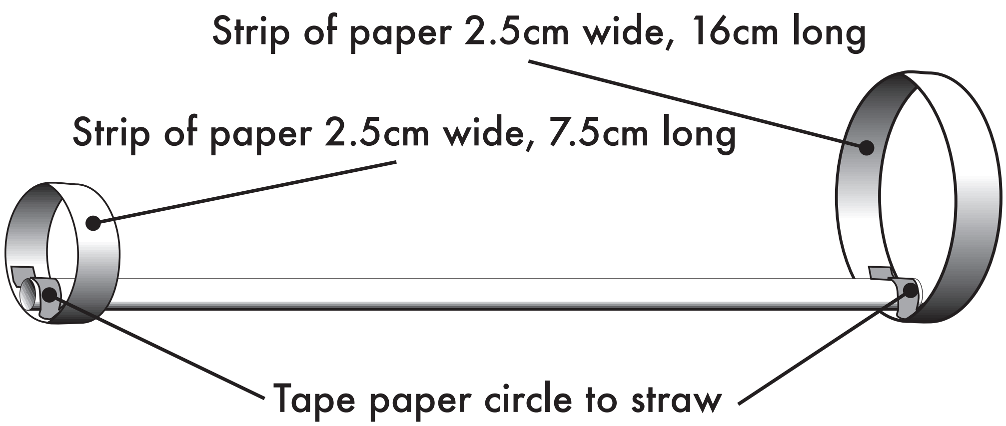
Measuring "Best"

Scientists observe, make inferences, ask questions, and conduct experiments (tests) to answer questions. You can design experiments to answer questions you have about how things work. Everyone can be a scientist!



Name: ___________________________

1. Make a flying object using a soda straw, two strips of construction paper, and tape.



2. Practice flying your object.
3. Make a list of things you could measure to determine how well the object flies. Examples include distance and height. For each thing you might measure, include what you would measure it with (stop watch, ruler, measuring tape, etc.). Also list the unit of measure you would use (such as seconds, centimeters, meters, etc.)

Possible things to measure to determine how well the object flies	**Measure with**	**Unit of Measure**
Distance the object flies	*measuring tape*	*decimeter*

4. How many times do you want to fly the object to determine how well it flies?

5. If you fly it several times and collect several observations, how will you use the data to decide how well the object flies?

6. Make a list of things that might influence how the object flies. Possible examples include skill of the thrower, wind speed, and wind direction. These will become the constants in your experiment.

Journal Entry:

Activity 4: Tell Me How It's Done!

Overview

In this activity, youth learn the importance of writing detailed experimental procedures by first writing directions on how to make a peanut butter and jelly sandwich and then, following each others' instructions, attempting to make the sandwich.

Life Skills

Communicating with Others (presents basic ideas/information)

Thinking Creatively (organizes new processes/procedures)

Learning Outcome

- Youth understand the importance of detailed descriptions for experimental procedures.

Objective

- Youth write clear, step-by-step, detailed instructions that someone else can follow to make a peanut butter and jelly sandwich.

Background Information

Scientific inquiry involves formulating questions and designing experiments to answer questions. But it also depends on building on the observations of others. Often, discoveries are only accepted as fact when they have been demonstrated over and over again. So that others may repeat an experiment, it is critical that the researcher document the exact procedure that was used to conduct the experiment. Typically, youth do not have experience writing detailed instructions, and it is a common mistake to leave out steps in a procedure because they seem so obvious. The following activity is designed to help youth appreciate the importance of detailed instructions.

Materials List

- Jar of peanut butter
- Jar of jelly
- Loaf of bread or box of soda crackers
- Knife for spreading peanut butter and jelly
- Paper plates for serving food
- Large sheet of paper or other surface for food preparation
- Napkins or paper towels

Science SOL
3.1, 4.1, 5.1, 6.1

Activity 4: Tell Me How It's Done!

Conducting the Activity

Tell the class to imagine that they are hosting an alien in their home. The alien, having traveled several light years to get there, is sleeping in for the morning. They need to get to school, so they are leaving the alien a jar of peanut butter, a jar of jelly, a loaf of bread, a knife, a cutting board, and a plate. While the alien speaks and reads perfect English, its practical, life skills are nonexistent. In other words, the alien has never made a sandwich before.

Ask each youth to write a set of instructions for the alien guest describing how to make a peanut butter and jelly sandwich.

After the youth have written their instructions, ask for a volunteer to read his/her instructions. Tell the youth that you are the alien, and you will do exactly what he/she says.

If the instructions say, "put the peanut butter on the bread," but do not mention opening and removing a slice of bread, or opening the jar of peanut butter, then place the jar on the loaf of bread. The idea is to be silly and have fun with this. Unless the instructions are explicit, do "alien" things!

After attempting to make sandwiches by following several different sets of directions, have the youth gather into working groups of three to five and ask them to work together to write a new set of instructions.

Again, have someone read a set of instructions and make a sandwich. Hopefully, the results will be dramatically different.

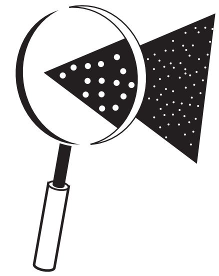
Discuss What Happened

- What did you assume that anyone would know when making a peanut butter and jelly sandwich?
- What did you leave out of your instructions the first time you wrote them?
- What did you learn from this experience?
- Describe another time when writing detailed instructions on how to do something would be important.
- Why do you think it is important to write detailed descriptions of experimental procedures?
- How is conducting a science experiment similar to an alien building a peanut butter sandwich?

Science SOL
3.1, 4.1, 5.1, 6.1

Tell Me How It's Done

Since science is about finding things out by observing and being willing to change a theory if the observations do not fit, it's important that others be able to repeat your experiments and observe the same things you do. If someone else is going to repeat your experiment, they need to know EXACTLY how you did it. A scientist is a clear communicator!



Name:____

Write a detailed set of instructions on how to make a peanut butter and jelly sandwich so that the alien that just landed from outer space and is staying in your room can fix itself something to eat while you are away. Assume that you left a loaf of bread, a jar of peanut butter, a jar of jelly, a plate, a napkin, and a knife on your dresser for it to use.

Journal Entry:

Activity 5: What Makes the "Best" Flyer Best?

Overview

In this activity, youth continue their discovery of scientific inquiry by deciding on a way to manipulate their flying object to alter the way it flies (hopefully to improve its flight!). They design an experimental plan for testing the effect of their modification, construct a data table, and collect a data set.

Life Skills

Thinking Creatively (utilizes brainstorming techniques, organizes new processes/procedure, formulates new ideas/plans/approaches)

Acquiring and Evaluating Information (selects/obtains data/information, predicts outcomes, creates data gathering process)

Learning Outcome

- Youth understand that the variable they manipulate in an experiment is called the independent or manipulated variable.

Objective

- Youth write a hypothesis that includes both a manipulated (independent) variable and responding (dependent) variable.

Background Information

In this activity, youth further explore designing science experiments by purposefully modifying their flying object and measuring the result that the modification has on its ability to fly. They are also led to consider concepts of repeated trails and fair tests.

In Activity 3, the youth defined what they meant by "best" in terms of the flight of a handmade flying object and discussed procedures for determining which flying object was best. However, they did not explore WHY one flying object flew better than another. In this activity, youth will expand their understanding of scientific process by purposefully manipulating something about their flying object in an attempt to make it fly better.

In theory, if the flying objects used in the previous activity were made from identical materials following the same pattern, then they should all fly the same. When tested by lining up a designated person from each group to throw the objects, if the flying objects were identical, then what was actually being tested was who threw the most effectively. If the same person threw all of the flying objects, the results of the test might

Science SOL 3.1, 4.1, 5.1, 6.1

be different. Hence, the person throwing the flyer is one of the variables that could be held constant in the experiment. However, in reality, the flying objects were probably not identical, due to slight variations in workmanship. This leads to the concept of a "fair" test. To be "fair," only one variable should be manipulated in the experiment and all others (to the extent possible) should be held constant. If more than one thing is changed, such as both the straw length and the circle size, then, if the plane flies differently, it is not possible to know which change caused the response.

Youth should discuss what things they intend to hold constant during their experiment, and how they intend to control the things they hold constant. An example might be to hold the wind speed constant during the tests. This could be accomplished by conducting the tests indoors with the windows closed and no fans running, so the wind speed is zero. Other things that could be held constant for the flying object experiment include size and type of the soda straw, size of the back circle, weight of the paper used for construction, etc.

Materials List

- Youth Activity Sheet 5
- Flying objects from activity 3 (if available)
- Soda straws
- Construction paper
- Scissors
- Scotch tape
- Paper clips
- Measuring devices as needed (measuring tape, stop watches, etc.)

Conducting the Activity

This is a long activity and, depending on the block of time available, you may wish to break it up into two meetings. The Discuss What Happened section is presented at two points within this activity, allowing youth to process what they have learned before moving on within the activity. The session can be ended after the first Discuss What Happened section, and then resumed at the next meeting. If you do break it up, be sure to review the last activity briefly before resuming. A good refresher is to put youth into their activity groups, give them a couple of minutes to discuss what they did the last time, and then ask each group to tell one thing they learned from the last meeting.

Science SOL
3.1, 4.1, 5.1, 6.1

Activity 5: What Makes the "Best" Flyer Best?

1. Return the youth to their working groups from Activity 3 and distribute Youth Activity Sheet 5.
2. Have each group make another flying object. (If they have their flyers from Activity 3, this step is not necessary.) Allow about 10 minutes for each group to brainstorm for ideas on changing its flying object to improve how it flies. The youth should record their list of ideas on their Youth Activity Sheets in the space provided. Remind them that they need to decide what a "good" flight is (distance traveled, time in the air, number of loops it can fly, etc.), and then try for modifications to make the flight "better." Suggest that they try some of their modifications and see what happens.
3. Ask each group to predict the effect different modifications will have on their flying objects. Two example predictions are: "the wider the strip used to make the front circle on the flying machine, the farther it will fly," and "adding weight to the back circle will make it fly straighter." There is a space provided on Youth Activity Sheet 5 to list their predictions.
4. Ask each group to select one of the predictions listed that they would like to test to see if it is true. This is the hypothesis.
5. Next, ask each group to design an experiment to test their hypothesis and to write a detailed description of the experimental procedure. The goal is to create an organized, logical, and repeatable plan. Youth Activity Sheet 5 will help guide them.
6. Let each group present its research plan. Have the class critique each experimental plan. You may want to create a table on the blackboard that each group fills in prior to its presentation. The table should have a column for responding variable, manipulated variable, levels of the manipulated variable, number of repeated trials, and constants.

Discuss What Happened

- What did you chose as your manipulated variable?
- What did you choose as the responding variable for your experiment?
- Why is it important that the responding variable be something that you can measure?
- Why is it important to only change one thing for your experiment (that is, to have ONE manipulated variable)?
- Name something that you use often that you would like to improve.

Science SOL 3.1, 4.1, 5.1, 6.1

Activity 5: What Makes the "Best" Flyer Best?

Conducting the Activity (continued)

If this is the start of a new meeting, review what happened last time. Then, ask each group to generate a data table that it will use to collect data. There is a space provided on Youth Activity Sheet 5 for the data table. The table should show the values of the manipulated variable to be tested, provide space for all the repeated trials, include a column for derived data, and indicate the units (such as meters, centimeters, etc.) that will be used for data collection.

Allow each group time to conduct its experiment and to collect a data set.

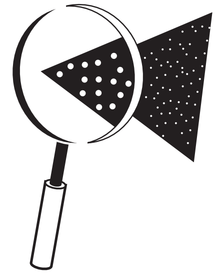
Discuss What Happened (continued)

- What did you decide to measure to determine how well the object flies?
- What did you use to measure it?
- What units did you use to report your data?
- What things about the experiment that you did not hold constant had an effect on the flying object?
- What was the effect of the modification you made on the object's flight?
- If you want to conduct an experiment to determine if one thing is "better" than another, what do you have to do to make it a fair test?
- What did you learn about conducting science experiments?
- What is the last thing you changed to make something better? How did it work?

Science SOL
3.1, 4.1, 5.1,
6.1

What Makes the "Best" Flyer Best?

Scientists design experiments to test the effect of one thing on another. Anyone can learn how to design good experiments. Everyone can be a scientist!



Name: ____

In a previous activity, you made a flying object and decided how to measure how well it flies. Your challenge today is to make a BETTER flying object and to design a science experiment to determine if it really is BETTER.

1. In your group, list possible ways to make the flyer better. At this point, do not try to build the modified flyer; just make a list of things you could change:

Things we could change to make the flying object better:

Example: Make the front circle smaller.

____

____

____

____

The thing you change in an experiment is called the manipulated variable. You just made a list of possible manipulated variables.

2. As a group, make **predictions** (educated guesses) about what affect each of the changes you listed in step 1 will have on the flight of the plane. An example prediction is "the smaller the front circle, the farther the object will fly." Make sure the prediction includes a **responding variable** that you can measure, not something that can not be measured like, "the smaller the front circle, the better the flyer will fly." You can measure farther with a measuring tape, but what do you measure "better" with?

Change	Prediction
Make front circle smaller	*The smaller the circle, the farther the object will fly.*

3. Make a new flyer, using **one** of the modifications listed in step 1. See how the new flyer flies. NOTE: **One** modification means to build the flyer exactly like the first one you made, but change one thing about it. Do not change more than **one** thing.
4. Decide which one of the modifications listed in step 1 you would like to investigate in more detail. List that modification, along with the accompanying prediction here.

The **prediction** that you decide to test becomes the **hypothesis** of your experiment.

5. Now, as a group, design an experiment to test if your hypothesis is true.

Experimental Plan to test (state hypothesis here):

The ONE thing (the manipulated variable) that we will change on our flyer is:

How many different levels of the manipulated variable will you test? What are the levels you will test? For example, if you decided to test the effect of front circle size on flight distance, you might decide to test four different circle sizes made from paper strips 2.5 cm, 5.0 cm, 7.5 cm, and 10.0 cm long. Specify the number of variations and levels for the manipulated variable here:

Number of variations of the manipulated variable:

Levels of the manipulated variable to be tested:

Number of times we will fly each flyer, i.e. the number of times we will test each level of the manipulated variable (number of repeated trials):

What we will measure:

(the responding variable)

What we will hold constant in our experiment: (These are the **experimental constants**. The list should include everything you decided not to change in step 1, such as length of the straw, size of the back circle, type of paper, etc. plus anything else you think should not change, such as wind speed – remember Activity 3?) List constants here:

6. Write a detailed description of the experimental procedure, that is a step-by-step explanation of how you will modify the flyers, how many times you will test each level of each modification, what you will measure, how you will measure it, what units you will record the data in, and what you will hold constant during the tests. Before you write, visualize each step you will have to take. Do not leave anything out! Remember, you want someone who has never made a flyer before to be able to repeat your experiment **exactly the same way you did it**! That requires good directions!

Experimental Proceedure

Experimental Procedure Continued

(Write on back of page if more space is needed.)

7. Generate a data table that you will use to record the data you collect.

The data table should be constructed as follows:

Make vertical columns for the **manipulated variable**, the **responding variable**, and a third column for **derived quantities** such as the average of the trials or the median value, etc. The column for the responding variable needs to be wide enough so you can subdivide it with a column for each repeated trial. So, if you have three repeated trials, you need three sub-columns within the responding variable column. See the example below.

List all the levels that the manipulated variable will take on in the first column. Generally, these values are listed from smallest to largest.

Be sure and show the units for the responding variable in the column heading.

Example Data Table for Flying Object Experiment

Manipulated Variable **Circle Size (centimeters)**	**Response Variable** **Flight Distance (decimeters)**			**Derived Quantity** **Mean Flight Distance (decimeters)**
	Trial 1	Trial 2	Trial 3	
2.5 cm				
5.0 cm				
7.5 cm				
10.0 cm				

8. Now it is time to conduct the experiment. Follow the directions you wrote up for your experimental procedure and collect a data set. You may wish to follow your experimental procedure once, and make any modifications that you think are necessary in the experimental design before you proceed.

For each trial, measure the responding variable carefully and enter the value you measure in your data table. Conduct the number of repeated trials you decided upon, measuring and recording a responding variable for each trial. Then, change the manipulated variable and repeat the trials. Continue until all levels of the manipulated variable have been tested and the data table is complete.

During the experiment, make note of any interesting things you observe. If it is difficult to make a measurement, make a note of it. If you have a camera, take pictures of the experiment for the report you will generate in the next activity. You may want to take a picture that shows the different levels of the manipulated variable (that is, a picture of all of the flying objects that you tested).

Manipulated Variable	**Response Variable**	**Derived Quantity**

Experimental Notes. During the experiment we observed:

Journal Entry:

Activity 6: Telling What You Know

Overview

In this activity, the youth analyze the data collected in Activity 5 and report their findings by preparing a report and making a poster. Ideally, the youth also will report their results orally.

Life Skills

Communicating with Others (presents basic ideas/information, evaluates information accuracy)

Interpreting Information (recognizes accuracy of information, provides accurate communication, interprets information, prepares basic summaries, prepares basic reports)

Learning Outcome

- Youth look critically at their data set and interpret meaning from it.

Objective

- Youth accurately report, graphically, in writing, and verbally, the results of their experiment.

Background Information

After collecting a data set, the next step is to analyze it and report the findings. Generally, some quantity is derived from the individual data points generated from the repeated trials. Often, this quantity is the average of the data points. However, if the youth are too young to understand averaging, help them to order the data points from the repeated trails from smallest to largest and then use the value of the data point that physically falls in the middle of the ordered numbers as their derived quantity. Hopefully, if taking this approach, they conducted an odd number of repetitions, so that one number will fall in the middle! For example, if one flyer design flew 7.2 m in the first trial, 6.0 m in the second trial, and 8.1 m in the third trial, the youth would order the trial results as 6.0 m, 7.2 m, 8.1 m, and record 7.2 m as the “derived” value, or the value that represents the flight. This value is the median of the data (as opposed to the mean).

Constructing graphs is a learned skill. To construct a graph, follow the steps adapted from Cothron et al., 1993. You may wish to invite a math teacher to help with this exercise.

Draw and label the X and Y axes. The axis label should name the variable and include the units of measure, for example: Flight Distance (m). The X axis (the horizontal line) is used to represent the manipulated variable and the Y axis (the vertical line) represents the responding variable.

Science SOL 3.1, 4.1, 5.1, 6.1

Activity 6: Telling What You Know

Decide if the data are continuous or discrete. Continuous data are measured and associated with a standard scale such as distance the flying object traveled in meters, time in the air in seconds, etc. Discrete data fall into categories or are counted such as brand of paper, or day of the week, or number of puppies in a litter. If the data are continuous, then a line graph is appropriate. If one or both of the data are discrete, then a bar graph is appropriate.

Write the data to be plotted in data pairs. By convention, the X value is written first in the data pair and the Y value is written second. The two numbers are separated by a comma and placed inside parentheses, e.g. (X, Y). Note: If the convention for generating a data table suggested in Activity 5 is followed, the data will appear in the table with the X value (the manipulated variable) in a column to the left of the Y value (the derived value), so the data pairs are easier to copy from the data table.

Decide on scales for each axis. To determine an appropriate scale, look at the data set and find the smallest and largest observation for each variable (responding and manipulated) Take the difference between the smallest and largest value, divide by 5 and then round the result to a convenient whole number. The resulting number would be the interval for the data scale. For example, if the manipulated variable was circle size, and the circles varied from 3 to 12 centimeters, the difference is 9 (12-3=9) and 9/5=1.8, which rounds to 2. So, 2 would be an appropriate interval for the X axis. If the shortest flight distance measured was 2 m and the longest flight measured was 7 m, the difference is 5 (7-2=5) and 5/5=1, which doesn't require rounding. One would be a good interval for the Y axis scale.

If the data for the X axis are discrete, then the number of intervals will equal the number of discrete values that the manipulated variable takes on. Subdivide the X axis to reflect the number of discrete values and place each value on the axis and equal distance apart, leaving a space between each value.

Place scales on the graph. The scale should start one interval smaller than the smallest variable and continue one interval above the largest variable, so that all of the data can appear on the graph. It is not necessary for a scale to start at zero, and the X and Y scales do not have to be the same.

Plot the data pairs on the graph. If the data are continuous and a line graph is being produced, then place a point on the graph for each (X,Y) pair listed. If the data are discrete, then draw a vertical bar from the value of the manipulated variable on the X axis to the corresponding value of the responding variable on the Y axis for each data pair.

Science SOL
3.1, 4.1, 5.1,
6.1

Activity 6: Telling What You Know

Materials List

- Youth Activity Sheet 6
- Computers and printers with software for generating graphs (optional)
- Art supplies to enhance poster presentations (colored paper, markers, glue or tape, and scissors)
- Digital camera and a way to print the pictures (optional)
- Poster board for each group

Conducting the Activity

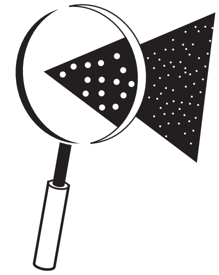
1. Organize the youth in their working groups from Activity 5. Allow them time to work with their data sets to derive quantities to represent the repeated trials (mean, median, total, whatever they decided upon).
2. Distribute Youth Activity Sheet 6 and ask the youth to graph their data. You may need to help them to decide if their data is discrete or continuous (bar or line graph needed), and to draw appropriate scales.
3. Allow time for the youth to make posters presenting their work. Guidance concerning the necessary parts of a poster report is on Youth Activity Sheet 6. Providing access to a computer lab and providing instruction/support to help youth graph their data by computer can enhance the learning experience. Digital pictures of the experimental setup, data collection, etc. can all improve the presentation. Computers can also be used to type the poster headings and written report sections.
4. Display the posters and allow time for each group to report its work and findings.

Discuss What Happened

- What did you like about this activity?
- What was difficult about this activity?
- Why do you think your flying object responded to the manipulated variable the way it did?
- What would you plan differently if you did it again?
- What additional data do you wish you had collected?
- What was the best thing about working in a group to present the results of your experiment?
- What did you learn from the other groups' experiments?
- How would you use what you learned to make a group presentation more effective?

Science SOL
3.1, 4.1, 5.1, 6.1

Telling What You Know



Scientists observe things and make inferences from what they observe. They form a hypothesis and then design experiments to test to see if the hypothesis is true. After conducting an experiment, scientists look at the data set and see what it tells them. Every data set tells a story. Scientists share their stories with others and build upon each other's stories. By carefully constructing an experiment, collecting data, and analyzing it, you have a story to tell. You too are a scientist!

Name:_______________________________

In Activity 5 you collected a data set. Now it is time to discover the story that your data have to tell and to share that story with others. To discover the story hidden in your data, you must work with it, think about it, and then write about it.

Working with the data

1. For each of the repeated trials conducted **derive** a variable to represent the trial. The derived variable might be the **mean** of the observations or the **median** of the observations, or something else that you decided upon when you designed the experiment. Write the derived variable in the column you made in your data table.
2. List all of the data pairs collected from your experiment. A data pair is the level of the manipulated variable followed by the derived quantity of the responding variable. Data pairs are written in parentheses with a comma between quantities. For example, if the manipulated variable was the size of the front circle and the 7.5 cm-circle plane flew an average of 10.1 cm, the data pair would be (7.5,10.1).

3. Graph the data pairs. If you do not know how to construct a graph, your teacher or leader will instruct you.

4. Look at the graph. Do the data points follow a pattern? Can you draw a straight line that comes close to most of the points? If not, can you draw one smooth curve that comes close to the data? Remember, there will be some variation in your data, but you are looking for trends to talk about.

5. With your group, make a poster to report the results of your experiment. The poster should contain the following elements:

Title: A good title includes both the manipulated and responding variables. You can always use the title Effect of ____________________ on __________________________, where the first blank is the manipulated variable and the second blank is the responding variable. Another option is to make the title a question to interest the audience, such as "Will a flying object with a large front circle fly farther than one with a small front circle?

Abstract: This is a short summary of your project. It should include a statement of the problem, your hypothesis, experimental procedure, your results, and conclusions.

Results: In addition to describing the results briefly in the abstract, provide your data table and a graph to show your findings. Also write a sentence or two describing what you observed. How did the flight of the flying object change with changes in the manipulated variable?

Journal Entry:

Glossary

classification: the systematic grouping of objects into categories based on shared characteristics.

constant: in experimental design, a constant is a thing that the scientists purposefully keep the same from one trial to the next. An experimental constant is also called a controlled variable.

controlled variable: also called the constant, a controlled variable is anything in an experiment that the scientist purposefully controls so that it remains the same for all trials within the experiment.

data: information, things known from which inferences can be drawn. In experimentation, data is the information that the scientist measures and records.

data pair: In experimentation, a data pair refers to a value of the manipulated variable and a corresponding value of the responding variable. Note that the corresponding value of the responding variable is often a derived value (such as a mean) from several repeated observations.

data point: One data pair, especially when it appears on a graph.

dependent variable: the variable that the scientist measures in an experiment. Also called the responding variable.

derived variable: a quantity that the scientist calculates from more than one observation of the responding variable. Mean and median are to examples of derived variables.

dichotomy: the process of cutting or dividing into two parts.

dichotomous classification system: a classification system that divides or arranges items into two groups.

hypothesis: an educated guess. Scientists often design experiments to test to see if a hypothesis is true or not.

independent variable: the variable that the scientist purposefully manipulates. Also called the manipulated variable.

inference: a generalization, conclusion, or assumption that is based on observation. Accurate observations are necessary to draw realistic and plausible conclusions.

Science SOL 3.1, 4.1, 5.1, 6.1

Glossary

manipulated variable: the variable in an experiment that is purposefully changed. Also called the independent variable.

mean: the arithmetic average, found by summing individual observations and dividing by the number of observations.

median: the middle value after all observations have been ranked from highest to lowest. If the number of observations is odd, the median is the observation that falls in the middle of a ranked list. However, if the number of observations is even, the median is the average of the two values that fall in the middle of the list.

observation: something that can be seen, felt, smelled, heard, or tasted.

observe: gain information using the five senses.

prediction: a forecast or guess about something that may happen in the future. Scientists often predict how things will respond, and then design tests (experiments) to test their predictions.

repeated trials: the number of times that an experimental trial is conducted for each level of the manipulated variable.

responding variable: the thing that is measured in an experiment. Also called the dependent variable.

Science SOL
3.1, 4.1, 5.1,
6.1