1.1 Understand the Challenge

Identify Criteria and Constraints

Before you start, it’s a good idea to make sure you understand what your challenge is. Design challenges have two parts: criteria and constraints.

**Criteria** are things that must be satisfied to achieve the challenge. For the book support, this will include the job the book support must do. It will also involve how the book support must do that job. One criterion (singular of criteria) is that you must build the book support.

**Constraints** are factors that limit how you can solve a problem. For this challenge, one of the constraints is that you can only use the materials your teacher gave you. Think about the constraints that have been placed on you for this challenge.

**Build and Test Your First Book Support**

To help you to begin to think about how to achieve your challenge, you will begin by getting familiar with the materials you will be using. You will also take some time to figure out how the product that you are designing is supposed to function (work). You will get 100 note cards, 50 paper clips, 50 rubber bands, and a ruler. You will have about ten minutes to build and test a book support. As you build your first book support, try out different ideas. Think about which ones seem to work better.

**Communicate Your Work**

**Share Your Designs**

Your group has built a book support. It is time to share your design with your classmates. Groups should take turns presenting their book-support solutions to the rest of the class. After each presentation, the teacher will test your design to see if it meets the criteria. Then there will be time for classmates to ask questions of the presenting group.

As you present your book support, try to give answers to these questions:

- How is your design constructed?
- Why did you design it the way you did?
- How did the challenge constraints affect the design?
- What things did you think about and try before getting to this design?
As you listen to everybody’s reports, make sure you understand the answers to these questions for each. If you don’t think you have heard answers to each question, ask questions (like those on the previous page). Be careful to ask your questions nicely.

After each book support is tested, the class should quickly discuss and agree about how well the design fulfills the challenge’s criteria.

**Update Your Criteria and Constraints**

Now that you’ve tried achieving the challenge, you’ve found that there is more to think about than you earlier imagined. You may now realize that the criteria and constraints are different than you had first expected. For example, you know that you have to be able to turn the pages of the text while it is on the book support. You will have a chance to design and build a better book support shortly. Before that, review your list of criteria and constraints. Update the list, making it more accurate. A more accurate list will help you design a better-performing book support.

**What’s the Point?**

You now understand what’s required for achieving this challenge better than you did when it was first presented to you. People often try to solve a problem without taking time to think about it first. If you do not understand a problem well, your solution won’t be the best it can be. In fact, you might fail. Each time you are presented with a new problem, take the time to think. Identify what you have to achieve (criteria). Also, consider what limits you are working under (constraints). You might also find it useful to explore the materials you will be using. You can make a first simple try at a solution. With better understanding of a problem and what is required to solve it, you are more likely to be successful.
2.1 Understand the Challenge

Identify Criteria and Constraints

Before you get started, make sure that you understand what your challenge is. You must understand two features of the challenge: the criteria and the constraints.

Remember that criteria are things that must be satisfied in order to achieve a goal or answer a question. Constraints are factors that will limit how you can go about doing that. Think about and record the goals the company has asked your lab to meet. Think about the limits that have been placed upon you for this challenge (for example, the materials you have available).

What’s the Point?

You have been given a new challenge. Remember, to be successful, you need to understand the parts of the challenge. You need to figure out what you need to achieve (criteria). You must also consider the limits you are working under (constraints). By identifying the criteria and constraints, you are more likely to be successful with your challenge.
2.2 Investigate

How Many Drops of Water Fit on a Penny?

Design Your Investigation

Meet with your partner and discuss a procedure you could use to answer the question: How much filling can be placed on the bottom cookie so it is completely covered but doesn’t leak over the sides? You will have about five minutes to develop a procedure. Use the materials shown in the list. Record your procedure on a sheet of paper. Each of you should have your own copy.

Run Your Investigation

You will have 10-15 minutes to carry out your procedure. You have five pennies. Your teacher will probably tell you to repeat your procedure five times.

You will need to record your data during this investigation. Remember, recording results allows scientists to accurately report their findings. Data help others understand a scientist’s work. They also help other scientists do future investigations.

Record your results on the same sheet of paper you wrote your procedure on. Be prepared to share your results with your class.

Communicate Your Results

Share Your Data

Last time you communicated your work, each group presented in a Solution Briefing. This time you’ll do it differently. Each group will report their results (number of drops that fit on each penny) to the class. You will record each group’s results in a line plot on your Drops and Penny Data page.

The line plot will help you see if your class has accurately determined the correct amount of filling for the cookie. This is what the cookie company is looking for.

Materials

- dropping pipette
- 5 pennies
- cup of water
- paper towel

line plot: a display of data in which each data item is shown as an “x” above its value on a number line.
Analyze Your Data

Look at the line plot. Answer the following questions. Discuss with your class how your answers may help you better achieve the Sandwich-Cookie Challenge.

1. Did your group have any problems (mistakes, spills, etc.) during the tests? Describe each one.

2. Did all groups get results similar to yours?

3. What did the distribution, or spread, of data on your line plot look like? What do you think this says about how reliable your lab’s data is? Do you think the cookie company will trust your results?

4. Why do you think there are differences between the data from different groups?

5. How might your procedure and problems you had relate to the differences?

6. What could the class do to get more consistent results in this challenge?

What’s the Point?

Most likely the distribution of data on your class line plot was spread very widely. This indicates that the results are not reliable. There may be many reasons why your results varied so much. However, one of the main reasons is that different groups used different procedures. Scientists face this problem too.

To confirm the results of other scientists, they must follow the exact same steps as the original scientist. If a scientist did not provide precise procedures, results cannot be accurately duplicated.
2.3 Redesign Your Investigation

Getting to a Better Procedure

Your class probably did not agree on how much water can fit on a penny. Your line plot may have shown that your lab couldn’t produce reliable results. You will now see if you can find a way to make the results more consistent across groups.

Think about what went wrong. You were all trying to answer the same question. You all dropped water onto pennies. You all counted how many drops of water fit on the penny. You also all had the same materials. But every group probably used a slightly different procedure. You all collected data in different ways. No wonder results were so varied.

Scientists only trust experimental results that are **repeatable** by other scientists. In order for other scientists to **replicate** the results of an experiment, the procedures must be reported very precisely. Then someone else can run the procedure again and get the same results.

For example, suppose you wanted to investigate the effect of a fertilizer on the growth of plants. You would need to keep many other factors the same. For example, you would need to control:
- soil type
- time spent in sunlight each day
- amount of water, and
- type of plant
Think about one factor, water. You would need to make sure that each group of plants got the same amount of water. They would need to be watered the same number of times. Also, they would need to be watered in the same way. You would need to follow these rules for watering every single time you watered each plant.

It is also important to make the same measurement each time. In this example, you could count the number of leaves on each plant. You could also measure the height of each plant.

The tools you use can often affect measurement. You have limits to what you can see when you make a measurement. Be sure to consider how accurate the tools you use are.

Here is a checklist that you can use to make sure your measurements are consistent:

- Measure from the same point.
- Measure with the same units.
- Repeat **trials** for more **precision**.
- Start fresh. Don’t compare data from before you make a change to the data after you make a change.
- Measure under the same conditions.

### Revise Your Procedure

With your class, work out a procedure for finding out how many water drops will fit on a penny. Try to describe each step in detail so it can be replicated. This way, maybe you’ll collect more reliable results. Record your new class procedure.

### Reflect

Review and answer the following questions:

1. What are three or four key differences between your previous procedure and the new class procedure?
2. What are you now controlling better in the new procedure?
3. What effect do you think this new procedure will have on the **range** of results across groups?
What’s the Point?
The points you thought about in this section are important to the Sandwich-Cookie Challenge. Every group was using a similar procedure. However, your procedures were probably not identical. In fact, some of the groups may not have followed the same procedure each time they tested how many drops of water fit on a penny. You probably saw a wide spread of data in the line plot. This is called variation. It is important to use the same procedure every time you test. Your results will then be consistent, and they will probably be repeatable.
2.4 Investigate

How Many Drops of Water Fit on a Penny?

Run Your New Procedure

Now that you have a new procedure, can your lab produce more reliable results? Your class will soon collect another set of data and produce a new line plot. As a class, update the criteria and constraints of the challenge if you need to.

Follow your new procedure. Use the materials listed. Obtain results for 5 to 10 trials. (Your teacher will tell you exactly how many to complete.)

Record your results on the same sheet of paper where you wrote your procedure. Be prepared to share your results with your class and teacher. You will have 10-15 minutes to perform your procedure and collect your data.

Communicate Your Results

Share Your Data

Use another sheet of graph paper. Make another line plot from the new data.

As before, each group will read aloud their results. Everyone will plot them on the graph paper.

Analyze Your Data

After your class creates the second line plot, answer the following questions together:

1. How do the results from this investigation compare to the ones from your first set of trials?

2. Did you have any problems (mistakes, spills, etc.) during the tests? List them.

3. Did all groups get results similar to yours?

4. Do you trust these results more? Why or why not?

Materials

- dropping pipette
- penny
- cup of water
- paper towel
Revise Your Procedure

Think about and discuss how the new, more specific procedure provides a closer answer to the question: How much filling can be placed on the bottom cookie so it is completely covered but doesn’t leak over the sides?

You might find that the range of results is still too large for you to trust. If so, come up with ideas to create an even better procedure.

Use this new procedure. Produce a third set of data that is more consistent. Be sure to run your procedure under the same conditions as you did before. You may need to do this part of the activity at home. As before, plot these new results on another line plot. Do you trust these results more? Why?

Reflect

After your class creates the second, or possibly third graph, answer the following questions:

1. What did the distribution, or spread, of data points on your latest line plot look like? What do you think this says about how precise your lab has been at determining the answer to the cookie company’s question?

2. Do you think it would ever be possible, given the materials and conditions you have in the classroom, to find an exact answer? Why or why not?

3. What do you think it would take to find an exact answer?

Discuss your answers and how they may help you better achieve the Sandwich-Cookie Challenge.

What’s the Point?

Revising your procedure was important for your Sandwich-Cookie Challenge. By developing a precise procedure for everyone in the class to use, your results became more consistent. The cookie company is relying on the “right” answer to their question of how much filling can be placed on the bottom of a cookie sandwich. The more consistent your class results are, the more the cookie company will trust your results.
Back to the Big Question

How do scientists work together to solve problems?

You and your classmates have been trying to find the answer to a question. In the end, you’ve probably realized that it would be very difficult to find an exact answer. But as the different groups in the class used more similar procedures, their answers got closer to each other. You found that the way you collect data affects the answers you can find.

The first time everyone tried to determine the number of drops of water that would fit on a penny, each group had different results. That is because each group used a similar, but not an identical, method. The class then came up with a standard procedure. When everyone followed this procedure, the results were closer to each other. Your data became more consistent. You and others could trust your data.

There are three likely sources of inconsistent data:

- Different procedures are used for different trials.
- Factors that can affect the measured result are not carefully controlled.
- The constraints of the tools used.

It is important for scientists that the results of their experiments can be trusted. They must develop very precise methods to use that give similar results each time. Other scientists will want to repeat the experiments to see if they also get the same results. This is the only way that scientists can trust the work of others.
Learning Set 3

The Whirligig Challenge

Cereal companies like to attract attention to their products. One company prints a paper helicopter on the back of its cereal box for children to play with. They call their simple paper helicopter a whirligig. The whirligig is cut out from the box. Parts of it are folded and paper clips are attached. When a child drops the whirligig, it spins as it falls.

The cereal company wants to create a new whirligig that will fall more slowly than the one they have been using. They think that would be more fun.

Your challenge is to determine how to make a whirligig that will fall more slowly than the current one. The company gives you the criteria and constraints.

Criteria

- The whirligig should fall more slowly than the one now on the cereal box.

Constraints

- The whirligig template has to fit on the back of the box of cereal.
- The only materials available are the cereal box and paper clips. Assume that people have scissors to cut out the whirligig template from the cereal box.

You’ll begin by identifying what you think you know about how things fall. You will then think about what you need to learn more about to be able to achieve the challenge. Then you’ll design and carry out experiments to find out more about some of those things. You will also read some science about how things fall. After that, you’ll use what you’ve learned to design a better whirligig. You will need to be able to explain what makes it fall more slowly than the old design.
3.1 Understand the Challenge

Thinking about How Things Fall

Demonstration

If you drop a book and a piece of paper at the same time, which will hit the ground first? You may have some ideas about the answer to this question. You also may have some ideas about what affects how things fall. To figure out how to make a whirligig fall slowly, it will be necessary to identify what you think you already know about how things fall. You will also need to identify what you might not understand yet. That way, you’ll know what you need to learn to succeed in achieving the challenge.

You are going to observe three short demonstrations. They will help you to figure out what you know and what you need to learn about how things fall. For each demonstration, record your predictions and observations on a Demonstration Notes page. Afterwards, your class will share their predictions and observations. You will record the things you think you know and need to learn on a Project Board. (You will learn more about the Project Board later.)
During each demonstration, you will be asked to do three things:

**Predict** – Your teacher will explain to you what he or she is going to do during the demonstration. You will predict what you think will happen. Record your prediction on your Demonstration Notes page.

**Observe** – You will observe the demonstration and record your observations.

**Compare** – After the demonstration, you will compare your predictions to what you observed. Note what you predicted well and what surprised you.

**Conference**

Share your predictions and observations with your group members. Make sure everybody has a chance to share. Your predictions and observations probably don’t match exactly. As a group, see if you understand why the dropped objects behaved the way they did. Discuss what you think you know and what you thought you knew. Discuss what you think you still need to learn to fully understand your observations. Jot down notes so that you will remember what you discussed when you share again with the class. You will have about five minutes, so get started quickly.

**Introducing the Project Board**

When you work on a project, it is useful to keep track of your progress and what you still need to do. You will use a Project Board to do that. It gives you a place to keep track of your scientific understanding as you make your way through a Unit. It is designed to help your class organize its questions, investigations, results, and conclusions. The Project Board will also help you to decide what you are going to do next. During classroom discussions, you will record the class’s ideas on a class Project Board. At the same time, you will keep track of what’s been discussed on your own Project Board page.

The Project Board has space for answering five guiding questions:

- What do we think we know?
- What do we need to investigate?
- What are we learning?
- What is our evidence?
- What does it mean for the challenge or question?
Each time you use the Project Board, you will record as much as you can in each column. As you work through a Unit, you will return over and over again to the Project Board. You will add more information and revise what you’ve recorded. Everything you record in the columns will be based on what you know or what you have explored. In addition to text, you will sometimes want to put pictures or data on the board.

Create the Project Board

To get started on this Project Board, identify the important science question you need to answer. To design a better whirligig, you need to understand the answer to this question: What affects how an object falls toward Earth? Write this question on your Project Board.

The demonstrations you just watched were meant to help you remember what you understand about how things fall. They also helped you think about what you don’t understand well enough yet. These are exactly the things that you will record in the first two columns of the Project Board.

<table>
<thead>
<tr>
<th>The Whirligig Challenge</th>
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<tbody>
<tr>
<td>What do we think we know?</td>
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</table>

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</tr>
</tbody>
</table>
What do we think we know?

In this column of the Project Board, you will record what you think you know. As you just experienced, some things you think you know are not true. Some things are not completely accurate. It is important to record those things anyway for two reasons:

• When you look at the board later, you will be able to see how much you have learned.

• Discussion with the class about what you think you know will help you figure out what you need to investigate.

What do we need to investigate?

In this column, you will record the things you need to learn more about. During your group conference, you probably came up with questions about how to explain what happened in the demos. You might have figured out some things you are confused about too. And you might have found that you and others in your group disagreed about your predictions. This second column is designed to help you keep track of things that are confusing. Record what you don’t understand well yet, and that you disagree about. These are the things you will need to investigate. They will be important for achieving your challenge (designing a better whirligig).

Sometimes you are unsure about something but don’t know how to word it as a question. One of the things your class will do together around the Project Board is to turn the things you are curious about into questions that you can investigate.

Later in this Unit, you will return to the Project Board. For now, work as a class and begin filling in the first two columns.

Be a Scientist

Messing About

Messing About is an exploratory activity. It gives you a chance to become familiar with the materials you will be using. It also lets you figure out how a product you will be designing should work. At this stage, you aren’t ready to do a formal investigation or test. When you mess about, you explore in a way that will help you do that later.
Mess About with the Whirligig

To help you think about how to achieve your challenge, you will begin by **messing about** with the whirligig. You will use the basic whirligig that now appears on the back of the cereal boxes.

You will get a template (pattern) of a whirligig. It will look like the one shown below. The whirligig has several parts: blades, paper clips, and a stem. If you call them by those names when you talk about the whirligig, everyone will know what you are talking about.

Cut out the template. To form the whirligig, fold the cutout template. Attach two paper clips to the stem.

As you Mess About with the whirligig, explore how it works. Think about what it is capable of doing. While Messing About, see if you can answer the questions below. This will help you identify more about what you still need to learn and help you figure out what investigations to do.

- What is the **structure** of the item I’m working with? (Structure means the way the parts are put together.)
- What are its **mechanisms**? (Mechanism refers to how the different parts connect to each other or move with each other to make the object behave the way it does.)
- How is this item supposed to behave? What might I change in the item to affect that behavior?
You will have about five minutes to construct and drop your whirligig several times. Watch it carefully. Try dropping it in different ways. Try changing some of the parts. Notice the effect these changes seem to have on the whirligig’s fall. Discuss the observations you make with your group. Use Messing-About Observations pages to record your observations, ideas, and questions.

### Messing-About Observations

<table>
<thead>
<tr>
<th>Name:</th>
<th>Date:</th>
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<table>
<thead>
<tr>
<th>Top view</th>
<th>Description (structure, behavior, mechanism)</th>
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<table>
<thead>
<tr>
<th>Side view</th>
<th>What happened?</th>
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### Update the Project Board

After you complete a small-group activity, your class will get together to review what you found out and what you were thinking about. This time, you will discuss the behavior of the whirligigs. Update the What do we think we know? and What do we need to investigate? columns based on your Messing About experience.
What’s the Point?

In your previous challenge, you identified the criteria and constraints to help you understand the challenge. In this challenge, you were given the criteria and constraints. To help you understand this challenge, you tried to find out what you need to learn more about to be successful.

You made some predictions and observations about several demos. Then you compared your observations with your predictions. You may have found some surprises.

You started a Project Board to help track what you understand. You also added questions about how things fall. The Project Board is a space to help the class work together to understand and solve problems. Using it will help you have good science discussions as you work on a project.

You Messed About with a basic whirligig. You became familiar with how a whirligig moves and acts. This led to identifying more investigations you might do.
3.2 Plan

**Whirligig Experiment**

You’ve identified what you need to learn more about to be able to design a better whirligig. Some of the questions you came up with are about how different parts of the whirligig affect how fast it falls. It is time now to design and run experiments to answer some of those questions. You probably raised a lot of questions on the Project Board. Unfortunately, there is not time right now to investigate all of them. For now, you will focus on only two of them.

- How does the length of a whirligig’s blades affect the time it takes the whirligig to fall to the ground?
- How does the number of paper clips on a whirligig’s stem affect the time it takes the whirligig to fall to the ground?

To answer these questions, you will design and run experiments. Your group will investigate the effect of either the blade length or the number of paper clips on how long it takes the whirligig to fall to the ground. Then you will examine your results. You will try to draw some conclusions from these results to answer the questions. You can use a stopwatch for timing whirligig drops.

**Materials**
- whirligig template
- stopwatch
- paper clips

**Variables and Designing Experiments**

When you investigate a **phenomenon**, you want to learn about the factors that influence it. In science, these factors are called **variables**. For the whirligig, the phenomenon you are studying is what affects the time it takes a whirligig to fall. The point of most experiments is to understand how one variable will affect the phenomenon you are investigating.

**Design Your Experiment**

Half of the class will study how the variable “blade length” affects the time it takes a whirligig to fall. The other half of the class will study how the variable “number of paper clips” affects the time it takes the whirligig to fall.
With your group, plan and design an experiment to answer the question that has been assigned to your group. Remember to discuss and record the following aspects of your experiment’s design:

**Question**
What question are you investigating and answering with this experiment?

**Prediction**
What do you think the answer is, and why do you think that?

**Variable Identification**
- Which part of the whirligig will you be changing in your experiment?
- Which variable will you manipulate (change) in your experiment to test the effects of that whirligig part?
- What conditions and procedures will you keep the same (hold constant or control) in your experiment?
- What will you measure?
- How many trials will you do for each value of your manipulated variable?

**Procedure and Data**
Write detailed instructions for how to conduct the experiment. Include the following:
- how you will set up the whirligig
- how you drop it
- how you measure its performance
- how you record the data
- how many trials you will do

Make sure you can explain to the class why you think they will be able to trust your data.

Use a *Whirligig Experiment Planning Guide* page to plan your experiment. You will have about 15 minutes to plan. Use the hints on the planning page as a guide. Be sure to write enough in each section so that you will be able to present your experiment design to the class. The class will want to know that you’ve thought through all of the parts of your plan.
Communicate

To help you as you learn to design experiments, you will share your experiment plan with the class. Others in the class have planned experiments to answer the same questions you are answering. You will probably see differences and similarities across these plans. In the class discussion, compare plans to each other. Notice similarities and differences. Identify the strengths of each plan. Think about what might need to be improved in each.

Revise Your Plan

With your group, revise your experiment plan based on the discussion you just had in class.
What’s the Point?

You’ve just designed an experiment to investigate the effect of a variable on the time it takes a whirligig to fall. In the past, you probably followed written steps to run an experiment. Here, you are designing the experiment yourself. Your big challenge is to discover how scientists work together to solve problems. One thing scientists do is collect data and use it as evidence. By designing your own experiment, you will have a better understanding of how scientists do this.
3.3 Investigate

Experiment with a Whirligig

Run Your Experiment

It is time to run your whirligig experiment. Use the materials given in the list. You will run the experiment, analyze your data, and then report your results to other groups.

Recording Your Work

As you do the experiment, record your results on your Whirligig Experiment Results Guide page. These pages have guidelines on them. They will help you with each task you need to do. Look at the guidelines for hints.

**Materials**
- cutout whirligigs
- stopwatch
- paper clips

**Materials**

- cutout whirligigs
- stopwatch
- paper clips

**Date**

- Record the results for each trial in a table to keep it organized.
- Analyze the data to look for a trend between the variable you changed and the variable you measured. **Hint:** Calculating an average mean or finding the median are two common ways to analyze data.

**Quality of Experiment**

- How well did your procedure test the effects of the variable you manipulated?
- How well did you control the variables you needed to hold constant?
- How consistently did you follow your procedure each time you ran it?
- How much variation does your data show for each value of your manipulated variable?

If you think you could have done better at any of these, you might need to redesign or re-do your experiment.

**Meaning of Experiment**

Based on your data analysis, write a statement that could be read or spoken as an answer to your research question. Use the trends you see in the data to show how the variable you changed affected the variable you measured. Also, use any science knowledge you have to support or explain the answer to your research question.

© It's About Time
Interpret Your Results

Finding Trends and Making Claims

You’ve collected data about how your variable affects the time it takes a whirligig to fall. It is time now to interpret those results. To interpret means to figure out what something means. Interpreting results of an experiment means identifying what happens as a result of changing a variable. What happened as you added paper clips? What happened as you lengthened or shortened the whirligig’s blades? Did the time it took the whirligig to fall increase or decrease as the value of your variable increased?

You’ll do two things to interpret your results. First, you’ll identify trends in your results. Then you’ll state a claim based on those trends. A trend is a pattern that you can see over several examples. A claim is your statement about what those trends mean. For example, suppose you varied the width of the whirligig’s blades. You would find that the whirligig takes less time to fall, as the blades get narrower. This is a trend. Your claim would be your statement: “When the blades are narrower, the whirligig takes less time to fall.”

Every time a scientist makes a claim, other scientists look for the evidence the scientist has for that claim. One kind of evidence is data collected in an experiment and the trends in that data. You’ll spend a lot of time in PBIS Units making claims and supporting them with evidence. You’ll learn more about that in other Units. For now, make sure that the data you collected matches your claim.

Make sure to record on your Whirligig Experiment Results Guide page the trends you see in your data. Also include any claims you think you can make so that you can share them with your classmates.

Communicate Your Results

Investigation Expo

You will share what you’ve found with the class in an Investigation Expo. Remember, no groups in the class investigated both variables. Therefore, others will need your results to complete the challenge. They will rely on your report to design a better whirligig.
Introducing an Investigation Expo

An Investigation Expo is like other presentations you’ve done. However, it is specially designed to help you present results of an investigation. You will include your procedure, results, and interpretations of results.

Scientists present results of investigations to other scientists. This lets the other scientists build on what was learned. You will do the same thing.

There are several things scientists usually want to know about investigations. These include the following:

- questions you were trying to answer in your investigation
- your predictions
- the procedure and what makes it a fair test
- your results and how confident you are about them
- your interpretation of the results and how confident you are of it.

To prepare for an Investigation Expo, make a poster that includes all of the five items listed above. Present them in a way that will make it easy for someone to look at your poster. Others should be able to identify what you’ve done and what you found out. If you don’t think you ran a fair test as you had planned, your poster should also have a report on how you would change your procedure if you had a chance to run the experiment again.

Sometimes scientists make posters when they present their investigations and results. They set up their poster in a large room where other scientists have also set up their posters. Then other scientists walk around the room. They look at the posters and talk to the scientists who did the investigations. Another way scientists share results is by making presentations. For presentations, they stand in front of a room of scientists. They talk about their investigations and results. They usually include visuals (pictures) showing all the important parts of their procedures and results. They talk while they show the visuals. Then other scientists ask them questions.

Your Investigation Expos will combine these practices. Sometimes, each group will formally present their results to the class. Sometimes, each group will put their poster on the wall for everyone to walk around and read. In this Expo, because you investigated only two variables, every group will put their posters on the wall. The class will look at all the posters. Then two groups will make presentations to the class. One will present for each variable investigated.
There are two parts to an Investigation Expo: presentations and discussions. As you look at posters and listen to other groups present their work, look for answers to the following questions. Make sure you can answer this set of questions about each investigation:

- What was the group trying to find out?
- What variables did they control as they did their procedure?
- Is their data scattered, or is it fairly consistent?
- Did they measure the time it took the whirligig to drop in a consistent way?
- Did their procedure cause them to run a poor, uncontrolled experiment?
- What did they learn?
- What conclusions do their results suggest?
- Do you trust their results? Why or why not?

When looking at posters and listening to presentations, you should ask questions if you can’t identify a clear answer to any of the questions above. Ask questions that you need answered to understand results and to satisfy yourself that the results and conclusions others have drawn are trustworthy. Be sure that you trust the results that other groups report.
Different Kinds of Variables

As you designed and ran your experiment, there were several kinds of variables you worked with:

- One you changed or varied in your experiment. This is called the independent variable (or manipulated variable).
- Some were ones you worked hard to keep the same (constant) during every trial. These are called control variables.
- Some were ones that you measured in response to changing the manipulated variable. These are called dependent variables (or responding variables). Their value is dependent on the value of the independent or manipulated variable.

Experiments are a very important part of science. When scientists design experiments, they think about the things that might have an effect on what could happen. Then they identify the one thing they want to find out more about. They choose this thing as their independent (manipulated) variable. This is the one they change to see what happens. They must keep everything else in the procedure the same. The variables they keep the same, or hold constant, are control variables. Finally, there is a set of things that they measure. This is the dependent (responding) variable. If they have designed a fair test, then they can assume that changes in the dependent (responding) variables result from changes made to the independent (manipulated) variable.

When you ran your whirligig experiments to find out the effects of the number of paper clips on how a whirligig falls, your independent (manipulated) variable was the number of paper clips attached to the stem. Your dependent (responding) variable was the time it took a whirligig to fall. Everything else, including the shape of the blades, the length of the stem, the height from which the whirligig was dropped, and the way the time to the ground was measured were the control variables. To be sure that what was measured (the dependent or responding variable) was dependent on what was changed (the independent or manipulated variable), it was important to keep the controlled variables exactly the same every time the whirligig was dropped.
Reflect

Answer the following questions. Then discuss your answers and how they may help you better achieve the Whirligig Challenge with your class.

1. What variable were you investigating in your experiment? What were you investigating about that variable? How did you vary it to determine its effects?

2. List all of the variables you tried to hold constant in your experiment.

3. How many trials did you perform? Explain why you performed that number of trials. Was this a good number of trials?

4. How consistent was your set of data? Why is consistency in repeated trials important in an experiment?

5. Do you think that the data set you collected was useful in determining the effect your variable had on the fall of the whirligig? Explain why or why not.

6. What do you think you now know about how things fall that would allow you to design a better whirligig than the one you started with? Do you know enough to explain your results?

What’s the Point?

You have just investigated how a variable affects the time it takes a whirligig to fall to the ground. You then presented your results in an Investigation Expo. In your experiment, you only investigated one possible variable. You needed to rely on other groups to get the data you needed for the other variable. This is the way scientists work. Presenting results of investigations to other scientists is one of the most important things they do. This lets other scientists build on what they learned.

You interpreted the data from your investigation. The trends you found and the claim you made will help you in achieving the Whirligig Challenge.