SECTION 2.3 INTRODUCTION

2.3 Redesign Your Investigation

Getting to a Better Procedure

t *1 class period**

Overview

Students first identify factors in their investigation that lead to inconsistent results, and then design a new, more precise class procedure to control these factors. They design a class procedure that is specific and replicable, controlling each of the factors they identified. Finally, students reflect on their new procedure by comparing it to their original, varied procedures to see how their ability to plan an investigation has improved.

Targeted Concepts, Skills, and Nature of Science	Performance Expectations
Identifying factors that lead to variation is an important part of scientific investigations.	Students identify factors that can affect the results of an investigation.
Scientific investigations and measurements are considered reliable if the results are repeatable by other scientists using the same procedures.	Students describe how investigations and measurements are considered reliable if they can be repeated by following the same procedures. Supporting reasons should include observations from the previous section, such as when groups used different results, they all came up with different answers and they couldn't decide which answer was correct.
Scientists often work together and then share their findings. Sharing findings makes new information becomes available and helps scientists refine their ideas and build on others' ideas. When another person's or group's idea is used, credit needs to be given.	Students consult their peers in planning, and they share their results with their peers.

Materials

1	per class	media for creating class procedures (e.g., butcher block paper, overhead)
1	per class	list of criteria and constraints for the class

*A class period is considered to be one 40 to 50 minute class.

Homework Options

Reflection

- **Science Content:** Scientists in City A spent two hours one evening catching fish in a stream using an experimental new bait and caught five fish, while scientists in City B spent three hours one morning catching fish in a lake using the same bait and caught two fish. They could not reach any conclusion about how many fish a person can catch using the bait. What are the factors that led to the different results? What are some practical ways the scientists could reduce the variation? *(Check to see if the answer addresses the differences between the studies: in this case, a difference in settings — stream vs. lake — and a difference in time.)*
- **Science Process:** Think about the criteria and constraints you listed for your first investigation with the penny and water drops. Identify some additional criteria and constraints that will guide your next investigation with the penny and water drops. *(Answers may include: criteria — a set of procedures that everyone can follow; constraints —number of trials.)*
- **Nature of Science:** Describe the reasons for creating a clear, standard procedure. *(Answers should point out the need for other researchers to be able to run the same procedure and get similar results. Otherwise the results are not considered reliable.)*

Preparation for 2.4

- **Science Content:** If everyone in class follows the class procedure, what do you expect the line plot of the results will look like? Draw a picture to illustrate your answer. *(Answers should say something about the data being more clustered. The picture should depict a line plot with tightly clustered data.)*

SECTION 2.3 IMPLEMENTATION

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.

repeatable: when someone follows the reported procedure, they get similar results.

replicate: to run a 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

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DIVING INTO SCIENCE

t 1 class period

Getting to a Better Procedure

15 min.

Now that students have seen how unreliable their data are due to lack of uniform procedures, have them design a standard class procedure to get a smaller distribution of data.

Engage

Now that students have thought about why their results were inconsistent, ask them if they can design a procedure that would get them better results.

TEACHER TALK

"So you've thought about what made your results different. Do you think you can design a procedure that will get all groups the same results?"

△ Guide

Begin by reminding students of the differences in procedures and materials they identified and some of students' ideas for getting more trustworthy results.

Then lead the class in identifying all the things they will need to pay attention to when revising their procedure.

TEACHER TALK

"Let's think about all the factors that need to be the same from trial to trial—things we need to think about in our new procedure.

"Did anybody's procedures say what a drop is? How big is a drop? You could probably squeeze out a pretty small drop if you tried, and you could also squeeze out a pretty big drop. That's something to specify in the procedure."

As students identify factors in their investigations and ways their procedures were not uniform, list these factors on the board or an overhead so that students can reference this list when they revise their procedure in the next step.

Many of the factors will involve inconsistencies with measurement. Discuss how measurements can be precise — how they can address how students place the penny, how they measure a drop of water, and how they determine when there is as much water as possible without overflow. Emphasize that a standard procedure will need to describe how each of these factors will be measured and controlled.

NOTES

trial: one time through a procedure.

precision: how close together the measured values are.

range: the zone between the largest and smallest solution results.

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 better controlling in the new procedure?
3. What effect do you think this new procedure will have on the **range** of results across groups?

Revise Your Procedure

15 min.

Lead the class in deciding upon a standard procedure for the investigation.

△ Guide

Next, lead students in designing a new procedure, as a class, that will give them a more reliable answer. They will need to make sure that all factors are accounted for and that they describe how the factors will be kept the same. Remind students that every group should be able to do the procedure exactly the same and, thus, get very similar results.

One way to lead students in designing a new procedure is to model your thinking as you focus on one factor at a time. For instance, you might want to talk about the penny first.

META NOTES

Modeling thinking by verbalizing your thoughts helps students see how to think about designing a procedure. Modeling is helpful here since this is the first time students have designed a procedure. This will help them think through a procedure that controls variables the next time they do an investigation to answer a question.

META NOTES

Designing a procedure is a good opportunity to assess students' ideas about controlling factors. In this case, students should be thinking about how to measure all the things that might affect the number of water drops on a penny.

TEACHER TALK

"Let's start with the penny. What should we do with the penny? Each side is different; maybe one side holds more drops than the other. So, we would want to make sure the same side of the penny is always up. What if it were slanted? That might make the water run off sooner. Well, we don't want that to happen, so I am going to make sure the penny is sitting on a flat or level surface."

As you think through the procedure out loud with students, record the steps and decisions on the board or overhead so that students will be able to evaluate the procedure and use it to run their investigations.

Next, use the bulleted list to help the class assess their procedure for replicability.

☐ Assess

As you develop the procedure, listen to students' ideas about how to measure consistently and precisely and how to control factors in investigations.

Reflect

10 min.

Now it is time to lead students in comparing the old and new procedures.

...ew 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 better controlling in the new procedure?
3. What effect do you think this new procedure will have on the **range** of results across groups?

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△ Guide

When the procedure is complete, review it with your students. You can use the *Reflect* questions to assess students' understanding of what they have done and why. You might have students write their answers to the *Reflect* questions, and then lead a discussion of students' responses. Alternatively, you might want to lead a discussion of the questions without having students answer them first.

Help student answer the *Reflect* questions.

1. Student responses should reflect an understanding of what was important about their revisions. The key changes will probably be in the steps where there were differences between groups' procedures.

2. The factors in the student lists should generally correspond to the key revisions to the procedure. In this discussion, emphasize changes that were made in the steps where there were differences between groups' procedures and where factors were not specified.
3. The new procedure should reduce the range of the results.

NOTES

What's the Point?

5 min.

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.

variation: a spread of data.

The reflection discussion you just had will sum up most of what is in this segment. The one remaining thing is to introduce the word "variation," which is the word that scientists use when they discuss how wide-ranging the data are.

As you finish the reflection discussion, listen for students recognizing the importance of using uniform procedures to get repeatable or consistent results. Uniform procedures should reduce variation.

Assessment Options

Targeted Concepts, Skills, and Nature of Science	How do I know if students got it?
Identifying factors that lead to variation is an important part of scientific investigations.	**ASK:** What are some of the reasons why you might get inconsistent results from an investigation? **LISTEN:** Students should recount some of the things that happened during their investigations that led to variation. **ASK:** What should the class graph look like when the investigation results are more consistent? **LISTEN:** The class graph should be more clustered.
Scientific investigations and measurements are considered reliable if the results are repeatable by other scientists using the same procedures.	**ASK:** How can you verify that another researcher's results are reliable? **LISTEN:** Students should know that if results are reliable, a researcher should be able to get similar results by following the same procedure. **ASK:** How can changing your procedure from trial to trial affect your results? Give an example. **LISTEN:** Students should link changing procedures to varied results and use examples from their investigation.
Scientists often work together and then share their findings. Sharing findings makes new information becomes available and helps scientists refine their ideas and build on others' ideas. When another person's or group's idea is used, credit needs to be given.	**ASK:** Why is it important for researchers to have carefully controlled procedures? **LISTEN:** Students should recognize that a researcher needs to have results verified by peers, and that a researcher needs to establish procedures that peers can replicate.

Teacher Reflection Questions

- What evidence do you have that students understand the need for a clear procedure that can be replicated and the need for repeatable results?
- Have you observed different attitudes toward success and mistakes among students? For example, did some students compete for the best results in either investigation? Have you observed any changes in these attitudes?
- What did you do to model appropriate language during discussions? What ideas do you have for next time?

NOTES

SECTION 2.4 INTRODUCTION

t 1 class period*

2.4 Investigate

How Many Drops of Water Fit on a Penny?

Overview

Students run their revised procedure and collect data, which they share on a class line plot. Using the spread of the data to evaluate their new procedure, the class identifies ways that the procedure is still not precise enough. Students once again revise their procedures and share their data. This time their results are much more consistent, providing evidence that a precise, standard procedure ensures consistent results.

Targeted Concepts, Skills, and Nature of Science	Performance Expectations
Scientists often work together and then share their findings. Sharing findings makes new information becomes available and helps scientists refine their ideas and build on others' ideas. When another person's or group's idea is used, credit needs to be given.	Students consult their peers in planning and they share their results with their peers.
Scientific investigations and measurements are considered reliable if the results are repeatable by other scientists using the same procedures.	Students follow the same procedure, analyze the data from the class, and describe, based on their experiences, why scientists consider results reliable if they are repeatable.

Materials

1 per pair	pipettes
5 per pair	pennies
1 cup per pair	water
1 per pair	paper towels
1 per class	class procedure
1 per class	class graph
1 per student	graph paper

*A class period is considered to be one 40 to 50 minute class.

Watch for water spills.

Activity Setup and Preparation

Decide how you want to arrange the classroom. Keep in mind that students will be working in pairs and with water.

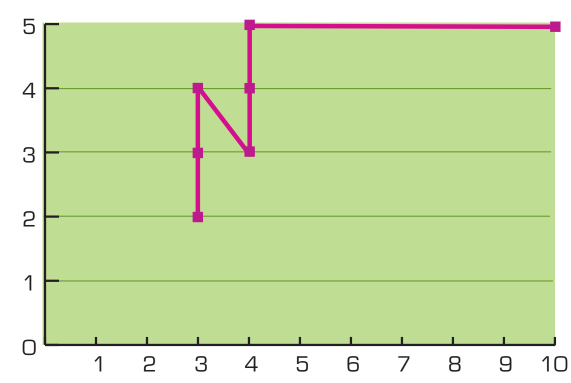
Have supplies ready to distribute. Consider creating a materials station for investigations after the different pipettes have been identified, placing the pipettes for this investigation with the materials. You can put one of the other pipettes on display so that students can remember the last investigation and see one of the factors that caused a difference in their results.

Homework Options

Reflection

- **Science Content:** Based on the results of your last investigation, what could you say about the results that other researchers using your procedure would get? Why? *(Look for students to link the reliability or unreliability of the results with their usefulness for saying what results other researchers might get.)*

Trial	Time (s)
1	14.5
2	15.1
3	15.3
4	21.3
5	14.9



- **Science Content:** Look at the graph above. What are some possible reasons that one data point is far away from the rest? Can you use these data even though one data point is far away from the rest? (*Look for students to explain that outliers can often be excluded from analysis, since they are often due to accident*.)
- **Science Content:** Above is a set of measurements of the time it takes a pendulum to swing back and forth 10 times. Make a line plot for these results. Do you think all the trial values are reliable? Why or why not? Can you reliably say how long it takes the pendulum to swing back and forth 10 times? If so, how long? *(Check to see if students identify the outlier at trial 4, and if they exclude the trial from analysis.)*

SECTION 2.4 IMPLEMENTATION

2.4 Investigate

How Many Drops of Water Fit on a Penny?

Materials
- dropping pipette
- penny
- cup of water
- paper towel

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?

*1 class period**

2.4 Investigate

How Many Drops of Water Fit on a Penny?

Run Your New Procedure

10 min.

Guide students to run an investigation with the new procedure that the class designed in Section 2.3.

*A class period is considered to be one 40 to 50 minute class.

△ Guide

With the class, check to see if the list of criteria and constraints from *Section 2.1* needs to be updated for this investigation. The criteria and constraints should include specific requirements for reliable results, such as: groups need to follow the chosen procedure carefully and they need to ensure that they are all using the same materials.

⬡ Get Going

Next, distribute the materials or have students get them from a materials station. Make sure that only one size of pipettes is available; the others should be wrapped in a rubber band and set aside.

Then get students going with their investigation, emphasizing that pairs should record their results on the same sheet of paper where they wrote their procedure. One student can record results while the other drops water on the penny, as they did in their first investigation. Make sure students know how long they have (10 or 15 minutes) and how many times to repeat the procedure. Pairs should run five trials if your class is large and 10 if your class is small. This ensures that the class will generate enough data (you should shoot for at least 70 trials total).

☐ Assess

While students are running their investigations, you can observe how closely groups are following their procedure. If any group is doing anything differently from the rest of the class, note the difference as something to discuss later. Also, look at their data to get an idea of how consistent they are. Listen for students' ideas about carefully following a procedure or recording data.

Communicate Your Results

10 min.

When all groups have finished running their investigations, have student pairs share their results with the class to create a graph of everyone's 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.

△ Guide

First, make sure that all students have graph paper. Then, briefly review how to use graphs to share data and, with a fresh graph transparency on the projector, ask each pair how many drops they recorded for each trial. For each result, put an X on the graph. Remind students to record the results of the class on their own graphs.

TEACHER TALK

"We're going to plot your data on a graph just like we did last time. Remember, each of the columns on the line plot represents a number of drops that might fit on a penny. If a group got 17, I'll put an X over the 17 on the graph. You should also do this on your graph. When we are finished, I will allow you some time to check your graph against the class graph."

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?

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Analyze Your Data

15 min.

Using the class graph, lead students through an evaluation of their data for evidence that their procedure is refined enough to reduce the range of the results. If the data are still scattered, students will need to revise their procedure once again.

△ Guide

Lead students to examine their graphed data and critique their new procedure. Begin by looking at the spread of data and then the precision of the procedures. The goal is to evaluate whether the procedure must be refined and repeated once again to get a result reliable enough to report to the cookie company. The answers to the first three questions in the student text will provide evidence for discussion about the trustworthiness of these new data (question 4). Use the questions to guide the discussion.

1. If students have effectively redesigned their procedure, they should find that the results of the second investigation are more consistent, with data points clustered together on the line plot.
2. This is a good place to discuss outliers. If a pair of students has one or two trials that are very different from their other trials, then perhaps that value is an outlier. Outliers are almost always caused by blunders, and show that trials should be redone if time permits. They should always be presented and discussed, but may be omitted from the analysis if you know they are blunders.
3. It is likely that the class will have a few outliers. You may be able to connect these with mistakes or accidents of some kind that happened during the investigation. You might also discuss the fact that no measurement is ever exact. There is always some range of values that the measurement may fall within.
4. Students may say that results that are more consistent can be repeated, and results that can be repeated are more reliable.

META NOTES

Groups may still be straying from the standard procedure, causing varied results. If you observed any groups straying, you can lead students to this source of variation. If groups are following the standard procedure and still finding different ways of doing things, then the procedure needs to be more precise, and you can lead them to this.

As students evaluate the results of the investigation, discuss whether the results are good enough to send to the cookie company. Guide students in deciding to revise their procedures and run the investigation again.

TEACHER TALK

"Would the cookie company trust your results, based on the data we just looked at? What would the data have to look like for the cookie company to trust your results? Should we revise our procedure once more?"

If the class decides that the investigation needs to be run again, discuss ways in which the procedure can be improved.

TEACHER TALK

"Were there any things other groups were doing differently? Could your procedures have been more precise? What else could you do to get more consistent results?"

NOTES

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 fixes 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.

Revise Your Procedure

up to 10 min.

If the class has decided that the results are still unreliable, lead the class in revising their procedure once more.

△ Guide

Guide students to think about the features and problematic differences they identified as you lead the class in designing a new procedure. Since this is possibly the third time students have worked on this procedure, focus on refining or adjusting the current procedure rather than starting from scratch.

TEACHER TALK

"So there's still something that we can do better in this procedure. Are there any places where the procedure could be more specific? Were there any groups that got very different answers from other groups? What were they doing differently?"

META NOTES

If you observed any groups doing anything differently from the rest of the class, you can guide students to this source of inconsistent results here.

As students specify steps, record the new procedure on the board.

Once the class has revised their procedure, have students run their investigations. (If there is not enough time to do this in class, students can run their procedures at home and bring the results to class.) Graph the new data on a line plot with the class, and help them analyze the data and evaluate the results.

Reflect

15 min.

Now that students have two or three iterations of their investigation, lead a class discussion comparing the procedures and resulting graphs across the investigations.

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*.

△ Guide

To get students thinking about the importance of precise and uniform procedures, have students look again at the graphed data from each iteration of their investigation.

If students have three graphs, first focus on comparing the graphs and procedures. If they did only two, then they've made the comparison already.

Focus students' attention on the spread of the data and remind them of the changes they made in their procedures that led to the improvements in the reliability of the data.

TEACHER TALK

"So how has the spread of the data changed? What changes in your procedures could have changed the spread of the data?"

Listen for the following students' answers and guide the class toward these responses if necessary. Try to always help students make a connection between their responses and how it will help them better achieve the challenge.

1. Students' responses should demonstrate an evaluation of the data, and an understanding of what the distribution of a data set indicates. For example, if students say the data are clustered tightly around a number, they should use this as evidence that the lab has used

precise procedures. If the students say the data are still scattered, they should use this as evidence that the lab's procedure still isn't precise enough. In order to achieve the challenge, they need to have results that are trustworthy. The results are more trustworthy when their data are more clustered.

TEACHER TALK

"How would you describe the data on the new graph? Are the data more or less clustered than the data in the last graph?

What were the most important changes you made to your procedure? Is the new procedure more or less precise than the last procedure? Did all groups follow the procedure?

How does this information help you to solve the challenge?"

2. Students' responses should be based on the evidence of the procedures that they have run. Students have probably made their procedures much more precise, and gotten their data much more clustered, but some variation probably remains. From this, they can conclude that it is unlikely that they could ever get an exact answer with the materials and conditions in the classroom.
3. Students might say that finer equipment, such as more precise tools to measure out water drops of more uniform size, and a level to ensure that the pennies are level, would get an exact answer. They should recognize, however, that all tools have limited precision, and thus no measurement is ever exact. Students should realize that there is no "exact" value, but that they can still have trustworthy results if, when following the same procedures under the same conditions, their results are repeatable.

META NOTES

An example of limited precision is a digital stopwatch. The stopwatch will give you measurements in increments of hundredths of seconds, but there is still some uncertainty in the thousandths of seconds range. At the very best, the stopwatch has an uncertainty of $\frac{1}{2}$ its smallest increment.

What's the Point?

5 min.

Sandw... ...nge.

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.

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META NOTES

Continue on to *Back to the Big Challenge.*

◇ Evaluate

As students reflect on their investigations, make sure they make the link between precise procedures and more reliable and trustworthy results.

TEACHER TALK

"The first time we graphed our results, it turned out that everybody had a different answer. So you made your procedure more precise, and then the answers people came up with were closer together. It makes sense that making your procedure as precise as possible, and making sure everybody is using the same procedure, is going to help you get an answer that's pretty close to everyone else's."

NOTES

Assessment Options

Targeted Concepts, Skills, and Nature of Science	How do I know if students got it?
Scientists often work together and then share their findings. Sharing findings makes new information becomes available and helps scientists refine their ideas and build on others' ideas. When another person's or group's idea is used, credit needs to be given.	**ASK:** How would your conclusions be different if you had run all of the trials by yourself, without your classmates? **LISTEN:** Students may suspect that their trials would have been consistent, but they should recognize that they would not have been able to verify that other researchers would get similar results.
Scientific investigations and measurements are considered reliable if the results are repeatable by other scientists using the same procedures.	**ASK:** How do you know if measurements are reliable? **LISTEN:** If they can be repeated by using the same procedures of measurement, then they are reliable.

Teacher Reflection

- How did students make progress in graphing and analyzing data from the beginning of this *Learning Set* to this section? What evidence do you have that students understand the need for repeatable results?
- Did students stay focused on the goal of the investigations? What can you do to encourage this?
- What observations did you make during the class discussions that students were leading the discussions? What did you do to encourage this?

Back to the Big Challenge

10 min.

Now that the class has completed the Sandwich-Cookie Challenge, *have students reflect on what they have learned and how it connects to the* Big Challenge *of the* Launcher Unit: *How do scientists work together to solve problems?*

META NOTES

Students should say that, like scientists, they designed standard procedures and worked towards repeatable results. During the investigations, they should have made their procedures more specific and ensured that everyone was using the same procedures. And scientists consult with each other, share their results, and revise their investigations.

BACK TO THE BIG CHALLENGE IMPLEMENTATION

Learning Set 2

Back to the Big Challenge

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.

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△ Guide

Use the student text to help students connect their experiences in this *Learning Set* to the *Big Challenge* of the Unit, highlighting the three likely sources of inconsistent data. Pose questions to connect their experiences with the sandwich-cookie problem to the *Big Challenge*.

TEACHER TALK

"What did we do in these investigations that helped us to get to a better answer? How did the way you worked together change during your investigations? What were you doing in these investigations that might be like what scientists do?"