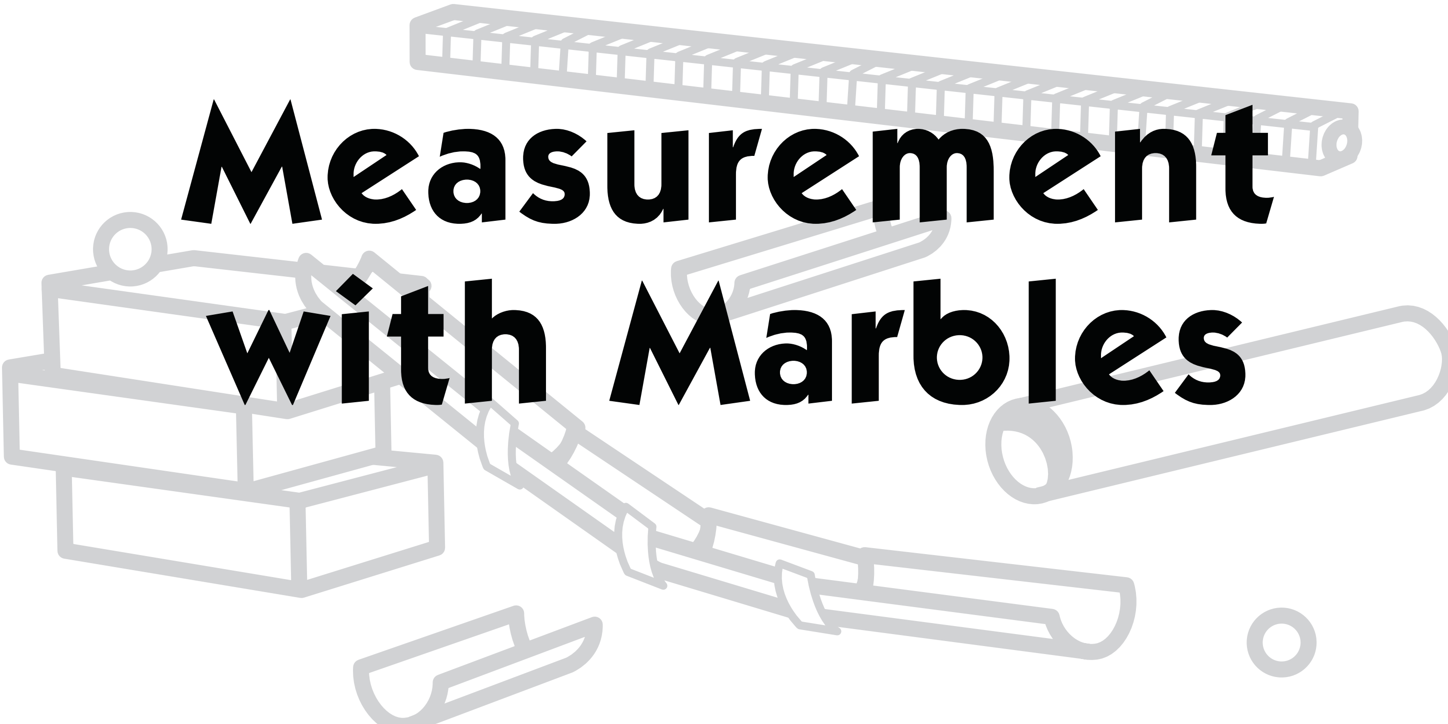
Measurement with Marbles



HANDS-ON MATH FOR HOMESCHOOLERS

Excerpts from Bridges in Mathematics

Measurement with Marbles
Hands-On Math for Homeschoolers

A Math Learning Center Publication

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Measurement with Marbles

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What's Going to Happen in This Unit?

This project gives children an opportunity to use mathematics in the context of scientific research. In this unit, students make cardboard ramps of different kinds to investigate some of the factors that cause marbles to roll farther and faster. Once they've had a bit of time to "mess around," they measure the distances their marbles roll as they change the ramp heights, the ramp lengths, and marble masses. Finally, they apply the understandings they've gained through informal and formal experimentation to planning and building mega-marble rolls—pathways designed to get the marbles to do a series of specified tasks.

You'll start by giving students the basic ingredients—marbles, cardboard tubes, masking tape, and building blocks—and asking them to use these materials to get the marbles rolling.

Midway through the first session, rollways of various sorts will be sprouting from chairs, shelves, and tables, and the marbles themselves will be moving. (We're not saying that there will be complete chaos, but the activity level will be pretty high.) As you draw students into a discussion circle at the end of this session, there may be reports of getting the marbles to roll all the way across the floor, around corners, and even up and down like roller coaster cars.

After you introduce longer cardboard tubes the second day, you'll probably hear children hypothesize about ramp length and height. Around the room, there may be murmurs of: "The longer the ramp is, the faster the marble goes. Look how fast it just came out of that tube!" "We can get ours to roll across the room if we use our longest tube." "If you put the tube up higher and make it like a steeper hill, you can get your marble to go even faster!" On the third day, when you add wooden beads and steel ball bearings to the glass cat's-eye marbles the children have already been using, you may hear hypotheses about the effects of mass too. "The heavier marble goes faster." "I think our lighter one is going faster—the heavy one gets dragged down—it's too heavy!" "No it's not! Look at it go!"

The informal experimentation that goes on during Sessions 1 through 3 is essential for several reasons. One is to familiarize children with the materials. Another is to establish a few ground rules. The third and most important reason for providing some "discovery time" is that children's questions and hypotheses will evolve from their free play with the marbles. Questions that make for good math and good science must connect with firsthand experience.

After this initial period of informal experimentation, students conduct more formal investigations of ramp height, marble mass, and ramp length. These three variables are tested, outcomes measured, averaged, graphed, and discussed with interest.

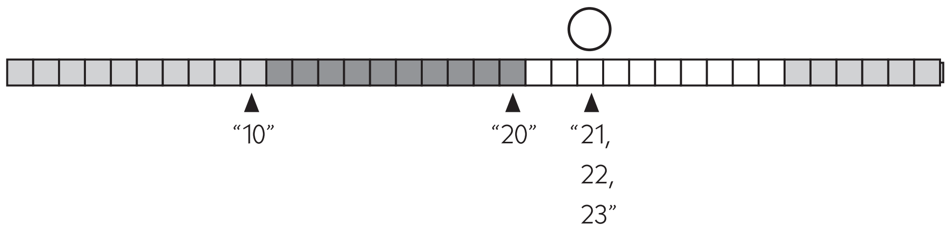
The final phase of the unit, in which they're asked to apply what they've learned, is probably the most exciting to children. During Sessions 11 and 12, they use the basic materials (cardboard tubes, masking tape, building blocks, and furniture) to design and build complex ramps that enable marbles to roll up and down, turn corners, jump into cups, knock over targets, and traverse more than one table. The work proceeds from 2-dimensional drawings to 3-dimensional constructions as students first draw their plans on paper, attempt to build what they've drawn, and then modify their structures as needed to get the marbles to perform the assigned feats. (Talk about a task that encourages children to stick with a challenging problem!) Because their final creations often bear little resemblance to the original plans, students are asked to make drawings of their marble rolls before they're disassembled. (We even splurge sometimes and take photos of these final marble rolls. The children are so proud of their hard work.)

As a very last step, children review the unit's activities and reflect on what they've learned. They also complete a paper-and-pencil assessment that includes such tasks as measuring length with nonstandard units, counting by 10's and 1's, reading and interpreting a bar graph, and finding the average of three quantities. Finally, they write about their favorite activities, describe the parts of the unit that were hard for them, and make any suggestions they may have for making the unit better.

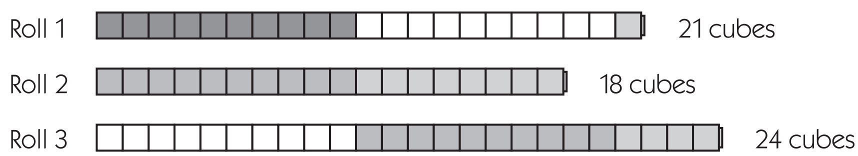
Although the unit works fine with one child, two or more children will be able to share ideas and discoveries with one another. We find the unit especially effective with a small co-op group.

What's the Big Idea? Connecting Math and Science

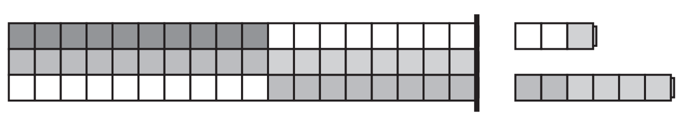
One of the reasons we designed an applied math unit around marbles is because many of the variables that influence the speed and distance with which things roll, including ramp height and object mass, can be quantified. As students investigate these variables, they can easily measure the distances rolled. (Speed can also be quantified, but we've decided to focus on distance alone.) Rather than reading the numbers from a ruler or a tape, however, the children construct their own measuring tools with Unifix cubes and count by 10's and 1's to determine the distances.



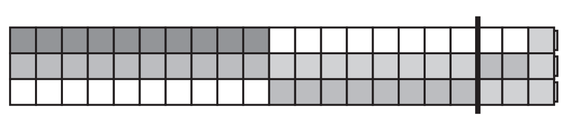
Working with Unifix cubes snapped into trains of 10 not only reinforces place value counting, it also enables youngsters to determine average distances in a very concrete manner.



"We set our ramp at 1 block high. Then we rolled the marble down 3 times. The first time, it rolled 21 cubes. The second time, it rolled 18 cubes. The third time, it was 24."

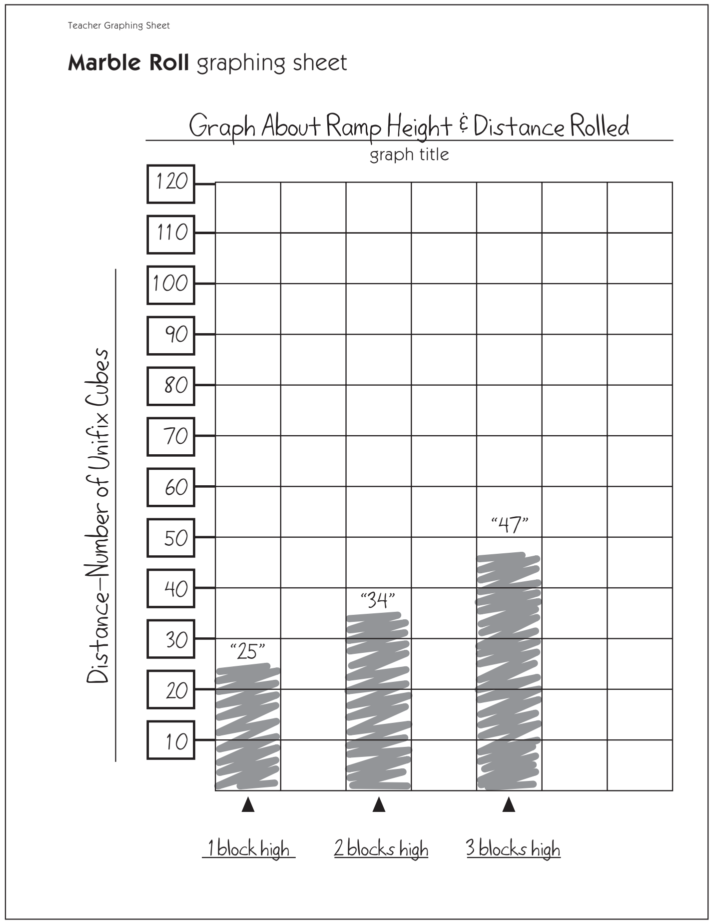


"To find the average distance, we can break off the extra cubes and put them back on so each train gets the same amount. It's like leveling off."



"See? The average distance for a marble rolling down a ramp 1 block high is 21 Unifix cubes!"

The averages can then be graphed and the graphs studied to draw conclusions and make predictions.



Ali *Wow! You can really see how much difference it makes to have the ramp set up higher and higher. The marble went 25, then 34, then 47 cubes. If I set up a ramp that was 4 blocks high, the marble would probably roll somewhere in the 50's!*

Suzanne *If I could launch my marble off a ramp that started as high as a desk, I could really get it to roll far!*

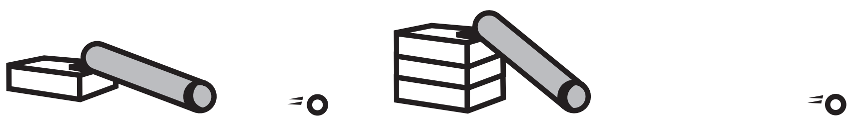
Gavin *It's kind of like when I ride a bike. If I start at the top of a really high, steep hill like the one by the park, I'm flying by the time I get to the bottom!*

Because science is involved in this unit—more specifically, some very basic physics—we went to Lowell Herr and Paul Dickinson, both of whom teach upper division physics at Catlin Gabel School, for advice. We explained that while we were trying to design a good math study, we didn't want children to develop any serious misconceptions about physics along the way. Here are some of the things they told us:

1. Children are correct in identifying speed and distance as variables to watch when marbles roll. The speed and distance a marble rolls are closely connected because speed equals the distance a marble rolls divided by the time

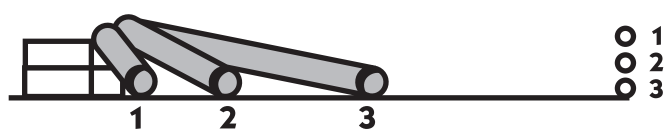
it takes to roll that distance ($s = d \div t$). Conversely, distance equals speed multiplied by time ($d = s \times t$). In other words, the distance a marble travels depends on how long it rolls at a particular speed. (The faster the marble is going when it comes off the ramp, the farther it's going to roll along the floor. Of course, if it meets lots of friction on the floor surface, like a carpet instead of linoleum, it may slow down quickly.) When children equate speed and distance in the course of this investigation, which they do almost continually, they're not that far off. We can't measure the speed with which the marbles are rolling, but we can certainly measure the distances they roll.

2. As children will readily observe, the height at which the top of a ramp is set influences the speed with which the marble rolls, as well as the distance it travels once it hits the floor.



"Watch! If I set one end of this paper towel tube on 1 block, my marble rolls pretty far, but if I set the end of the tube up on 3 blocks, the marble goes really far!"

Note that it's the height from which the marble descends rather than the angle that influences its speed. No matter how the ramp is angled, a marble will hit the ground traveling at the same speed if it starts at the same height each time.



"The marbles from all 3 of these ramps traveled the same distance."

3. Because the end of a long tube can be set at a greater height than that of a short tube, many students will hypothesize that ramp length influences the speed with which a marble rolls. If we are careful to set all our ramps at exactly the same height, though, their length makes no difference. In fact, the friction created as a marble rolls through a long tube may cause it to slow down a bit and travel a shorter distance than a marble rolling from the same height through a shorter tube.

4. Although children will observe that the mass of a marble influences the speed with which it comes off the ramp and distance it rolls, technically, mass shouldn't make any difference. Lowell explained that mass should have no effect on how an object rolls down an incline, but there will be an observed difference, even between two marbles of the same size, because of

how the mass is positioned within the two marbles. Friction plays some part in this also. He said that it's okay to let our students believe their eyes in this case and record what actually happens with marbles of different masses.

5. Force is a word we're better off not using. Lowell explained that a force is a push or a pull and involves the change in speed divided by the change in time. The increased speed afforded a marble by a ramp set up high at one end does allow the marble to roll farther or even knock down a line of dominoes or a building block, that's true, but the phenomenon the children are observing isn't quite the same as force. Paul suggested that we might refer to it as "push" or "push power" instead.

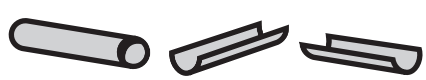
How Do I Sequence My Instruction For This Unit?

There are 13 sessions in this unit. None of these should take much more than a single, 1-hour math period, except for the second to the last, in which students build their "mega-marble rolls." This lesson might take up to 2 hours for some children, with another half hour for sharing and discussion.

Preparation Notes

A glass marble, steel ball bearing, wooden bead, and a set of Unifix cubes are included in the unit, but you'll have to furnish the cardboard tubes and building blocks for this unit. Specifically, you'll need 3 blocks, roughly 3″ wide, 6″ long, and 2″ high, for every two students. If you don't have your own, you may be able to borrow them.

You'll also need 17 full toilet paper tubes, 1–2 paper towel tubes, and 1 gift wrap tube for every 2 students. If you let friends and family know that you're after tubes, you'll probably have what you need within several days. As the toilet paper tubes start to come in, slit about 10 of them in half lengthwise to form small open curved ramps, as shown below. Leave the rest of the tubes whole.



Finally, this unit depends on friction. If you don't have an area of short carpet (such as indoor/outdoor carpet), you'll need to use a large bath towel after the first three days. If marbles come off ramps with much speed at all, they'll absolutely sail across linoleum floors. This won't make too much difference in the first three days of exploration (unless marbles shooting all over the place are likely to drive you nuts). But once students begin to test variables and measure distances rolled, you'll want some additional friction to make the lengths manageable.

General Information

Student Groupings/Ages

The lessons may be used with one child or an entire classroom. While the unit works with one child, two or more children will be able to share ideas and discoveries with one another. We found the unit especially effective with a small co-op group.

Although the lessons are designed for grades 1–4, homeschooling families with a variety of ages may choose to include everyone as they make and test predictions; during this unit, the two adults in our co-op were forming hypotheses right alongside the children. Older children's assistance will also make it possible to construct more elaborate "mega-marble rolls."

Time Frame

The marble unit contains 13 sessions. None of these should take much more than one hour except for the second to the last in which students build their "mega-marble rolls." Move through the lessons at your child's pace.

Reproducing Curriculum

The student pages may be reproduced as needed for your own children.

Planning Guide

SESSION 1	SESSION 2	SESSION 3	SESSION 4	SESSION 5
Exploring Marbles & Ramps	Exploring Marbles & Ramps: Introducing Longer Tubes	Exploring Marbles & Ramps: Introducing Marbles That Differ in Mass	Measuring Distances with Unifix Cubes	Marble Roll Experiment 1: What Happens If You Set the Top of the Ramp Higher?

SESSION 6	SESSION 7	SESSION 8	SESSION 9	SESSION 10
Marble Roll Experiment 2: What Happens If You Use Marbles of Different Mass?	Marble Roll Experiment 3: What Happens If You Make the Ramp Longer?	Another Look at Averaging	Finding Average Distances	Graphing the Data

SESSION 11	SESSION 12	SESSION 13
Designing Mega-Marble Rolls	Building Mega-Marble Rolls	**Assessment** Thinking Back About Marble Rolls: What Have We Learned?

Session 1

PROBLEMS & INVESTIGATIONS

Exploring Marbles & Ramps

Overview

During this session, the teacher introduces the materials and the basic problem: Using blocks, tape, and cardboard tubes, can you get a marble to move without pushing it? Children work alone or with partners to tape the tubes together to form simple ramps and rollways for their marbles. As they work, youngsters begin to develop some skill at building with these very limited materials. They also begin to generate hypotheses about some of the variables that influence speed and distance. The teacher may pose additional challenges as the work proceeds: Can you get the marble to turn a corner without flying off the ramp; speed past a hole you cut in one of the tubes; move up and down? After taking some time at the end of the period to view and discuss everyone's work, the children take their creations apart and pack the pieces back in their baskets for use the next day.

Each PAIR of children will need

★ a basket, shoe box, or sack to keep their materials in

★ a glass cat's-eye marble

★ 3 blocks (The ideal size block for these lessons is the one that's roughly 3″ × 6″ × 2″.)

★ a roll of masking tape

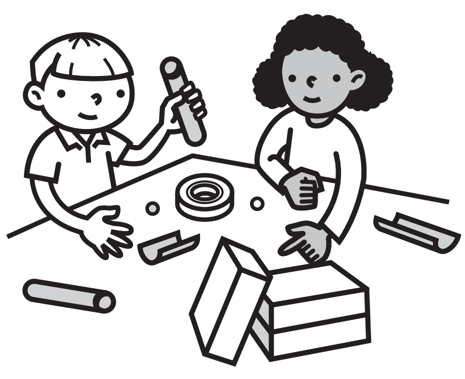
★ a collection of toilet paper and paper towel tubes: 6–7 full toilet paper tubes, 1–2 paper towel tubes, and 16–20 half toilet paper tubes (Slit them lengthwise so you wind up with small open ramps, as shown in the drawing below.)

★ a large bath towel (optional)

Skills

★ predicting, testing, and validating outcomes

★ developing an understanding of the relationship between form and function

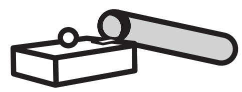


Note *Children will reuse their tubes throughout the unit. If you can, collect extra tubes. You'll find that your students will build with more ease and creativity if they have lots of tubes to work with.*

Session 1 Exploring Marbles & Ramps (cont.)

Begin the session by gathering your students into a discussion circle. After everyone's in a comfortable place and they can all see, bring out one of the baskets of materials. Explain that these are the materials they are going to be using throughout the next math unit. Take out the items one by one—the blocks, the tape, the marble, and the tubes. Ask the children if anyone can think of a way to combine the materials to get the marble to move on its own (without a push or a shove from human hands, feet, or other appendages).

Many of the children will instinctively lunge for the materials—it's so much easier to show than tell—but explain that you'd like someone to *describe* an idea to the group. Choose a volunteer and follow her instructions carefully. More often than not, the first child will have you angle a tube from a block and roll the marble down the tube.



Solicit another idea or two and then tell the children that you are going to send them off to work with these materials. If you have more than one child, pair them up. Explain that you'll be very interested to see what they create and how they get the marble to move without pushing or shoving it.

Before they go out to work, you might want to set a few ground rules. Here are a few things we usually tell children ahead of time:

1. Each pair of children has been given one marble. They'll need to take very good care of it so it doesn't get lost. (It's inevitable that a few marbles will roll under shelves. You might also pose this as a problem to be solved by interested students during break times! Do be sure to have a few extra on hand, though.)

2. The idea of this investigation is to get the marble to move on its own. That means that no one should be pushing, shoving, tossing, or throwing the marbles.

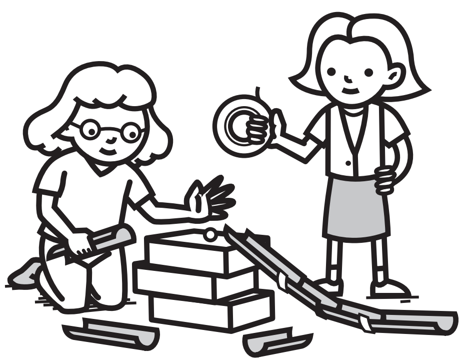
3. Decide ahead of time what you want to do about your floor surface. If you have very short wall-to-wall carpet, there's no problem. If you're surrounded by bare linoleum, you'll need to decide whether you want to have children to start working on towels now or when they get to the stage of measuring marble distances during Session 5. In the years we've had linoleum, we've found the first few days easier and more enjoyable for students if we just let them work on the bare floors and tables.

4. Decide whether or not you want to say anything about the use of furniture ahead of time. If you don't, it will come up almost immediately anyway. Most children will probably be content to use their tubes and 3 blocks for about 5 minutes. We can almost guarantee that within 10 minutes of starting to work,

though, someone will come up and ask if it's okay to tape the top of their ramp to a chair or a table. We always give them permission to do so; it would be impossible to create ramps of much interest at all if we confined them to launching from the top of three stacked blocks. If we had hundreds of building blocks, it might be different, but we don't. You'll probably want to consider this issue beforehand, though. Are there any chairs, tables, or shelves you *don't* want them to use? If so, be sure to tell them right away.

5. It's not going to be quiet during this exploratory period. If you have limits in terms of how much noise you can tolerate, you'll probably want to address the issue up front and even establish some way to signal the children if the din exceeds allowed decibels.

6. Finally, before the children go off to work, you'll want to have them do some thinking about where they want to work. More than likely, each pair will need to find some sort of nook, corner, or alleyway in which to work. It will be impossible to set things up in such a way that everyone's marbles can roll all the way across the classroom, and this might be just as well. After all, who wants to spend all of their time chasing after a marble? Even with discussion and a bit of planning, you'll probably have to do some legislating after children have gone out to work. We ask students to avoid situations where one pair's marble is constantly rolling into the middle of someone else's runway.



Once your students understand the challenge and the basic ground rules, you can send them off individually or in pairs with their baskets of materials. Most of them will be utterly absorbed and will work happily for as long as you let them, trying to get the marble to move farther and faster, through increasingly long and complicated pathways. (It's the rare pair that doesn't almost immediately try to tape every tube together into the longest possible run.)

There may be a few who get bored quickly, though, and you'll need to intervene. With children, "bored" often means uncomfortable or frustrated with a task and, in fact, designing marble rolls won't be easy for every child. You can circumvent some of this by partnering the children carefully. Sometimes it helps to pair a child who's not particularly interested in spatial tasks with one who is. It also helps to be sure that at least one of the children in each

Session 1 Exploring Marbles & Ramps (cont.)

pair has reasonably good fine motor skills and one has good perseverance. You might consider assigning "permanent" partners for at least the first several days of this unit.

Children who quickly build some sort of marble roll path with their tubes and are wondering what to do next can be challenged to get the marble to move in different ways. If they've figured out a way to get it to roll downhill, can they get it to move faster? Can they get it to go so fast that it can roll back uphill a bit before going down again? Can they get it to turn a corner? You'll want to be in constant circulation during this work period, admiring, encouraging, observing, and sometimes nestling in with a pair that might be experiencing difficulty of one sort or another. There are also some children who will do better work by being able to look at the work of others around them. If you see a few "wanderers," watch them carefully for a moment before you ask them to return to their own work. You'll find that some of them will watch or even participate in another pair's work for a few minutes and return to their own work with renewed interest, anxious to try out or modify an idea they saw elsewhere.

About 15 minutes before the end of the period, give students a 3 or 4 minute warning so they can begin to wrap things up for the day. Explain that before they take everything apart, though, you'll lead everyone on a field trip around the room to view the work. If viewing time is allowed in the next two days, many students will work very hard to get something ready to show others by the end of the work period. Also, children get new ideas from one another that they can incorporate into their own work later.

After your class "field trip," have your students take their marble rolls apart and clean up their materials carefully. Some will want to save their work, but unless you have lots of extra space and an enormous supply of tubes, they'll simply have to take things apart. Reassure them that they'll have more opportunities to work and that they may be able to make even more amazing creations tomorrow.

Session 1 Exploring Marbles & Ramps (cont.)

When everything's been disassembled and the baskets safely stowed on shelves or against a wall, gather the group back to your discussion circle and have students briefly share their experiences. What happened today? What worked best? How did they get the marble to move? Did anyone find a way to get the marble to do anything other than roll straight downhill? This is a time when you might want to let children come to the board or the easel to draw as they talk. Sometimes a picture really can communicate much more quickly and effectively than words. In any event, do be sure to allow some time for discussion. As they listen to one another, children will begin thinking about what they want to try tomorrow, and may be inspired to experiment in ways they wouldn't have thought of on their own.

Session 2

PROBLEMS & INVESTIGATIONS

Exploring Marbles & Ramps Introducing Longer Tubes

Overview

The purpose of this session is to introduce a new variable—ramp length—while allowing students more time to build their own marble rolls and develop their own theories.

Skills

★ predicting, testing, and validating outcomes

Each PAIR of children will need

★ a basket, shoe box, or sack to keep their materials in

★ a glass marble

★ 3 blocks

★ a roll of masking tape

★ a collection of toilet paper and paper towel tubes, along with at least 1 longer tube; more if possible

Note These tubes should be significantly longer than paper towel tubes. Gift wrap tubes are fine but can sometimes be a bit flimsy. Mailing tubes or tubes from fabric or furniture stores are great. If you ask ahead of time, you'll find that friends often have long tubes to contribute. We store these longer tubes upright in a box and have children get them as they take their baskets of other materials out to work.

To begin the lesson, gather students into a discussion circle again. Explain that you are going to send them out with the same partners and same materials they had yesterday so they can continue to build fun and fabulous pathways for their marbles. Today, however, you are going to give each pair of children a longer tube (or 2 or 3, depending on how many you've been able to collect).

Spend a little time discussing the new tubes. What might be the effect of using a longer tube? Solicit as many predictions as children are willing and able to give. Some won't be at all sure. Others will be positive that the marble will roll faster or go farther with the additional length. They may even bring in their own experiences to illustrate their predictions.

Session 2 Introducing Longer Tubes (cont.)

Taylor *I get going faster down the big slide.*

Greg *Yeah, when I get to the bottom of the big slide sometimes, I'm really going fast!*

Teacher (sketching a picture of two slides) *You know, this is interesting. Here's a little slide and here's a big one. Which would make you go faster?*

Children *The big one!*
I could go really fast on that one!
We have one even bigger in our park!

Teacher *Do you suppose you would go faster on the big slide because it's longer or higher?*

Children *Longer! You have more time to gather speed.*
Higher! The higher up you start, the faster you go!
Maybe it's both?

You might encourage your students to begin thinking about how to "prove" their hypotheses as they work today. Watching for more speed is one idea; measuring the distance the marble actually rolls each time is another.

Teacher *How could you tell if the marble really is going faster when it comes off a longer ramp? How will you know whether the longer tubes actually make any difference?*

Curran *I'll be able to tell just by looking. I can tell if a marble's going faster or not.*

Teacher *Do you think the distance a marble rolls has anything to do with its speed when it comes off the ramp?*

Cassie *If it's going really fast, it'll go farther?*

Jake *We got our marble to go all the way across the floor yesterday. It was going really fast.*

Teacher *So maybe the distance a marble rolls tells something about its speed? How will you know if a marble rolls farther one time than another?*

Session 2 Introducing Longer Tubes (cont.)

> ***Eric*** *We could use the masking tape to mark how far the marble goes each time. That way, we'll know if it really goes farther sometimes.*

While not all children will follow this discussion, some will, and seeds of experimental design will be planted. Even if they can't say much about what's going on, you'll see children developing and testing new theories, or reconfirming old theories, as they work with the materials. You may hear such comments as, "Wow, look how far the marble went this time!" or "We can really make a steep ramp with this long tube. We got our marble going so fast it could go up this little hill in our marble roll and then back down."

This is an ideal time to watch children's varying abilities to cooperate, compromise, and persevere in the face of challenge. It can take lots and lots of patience and cooperation to get a marble roll to work just the way one wants it to, but the motivation is high and the rewards are great.

Near the end of the period, give a little advance warning and then conduct a viewing trip so that students can see each other's creations. When that's done, have them take things apart and store them in their baskets. Then have them gather to discuss their findings and ideas. Did the longer tubes make any difference? Was anyone able to get the marble to do any "new tricks" today? Allowing children the opportunity to see one another's work and share what happened during this session will help set the stage for tomorrow.

Session 3

PROBLEMS & INVESTIGATIONS

Exploring Marbles & Ramps Introducing Marbles That Differ in Mass

Overview

This is the third and last day of free play. Children continue to create all kinds of marble rolls and pathways for their marbles using the different lengths of tubing, their masking tape, the blocks, and chairs, tables, or shelves as anchor points. By now, many children will be brimming with ideas and may be anxious to get out and try them. Others may feel as if they've played out the possibilities and may not be looking forward to this work. You will introduce two new materials that should spark some new thinking, however. The first is marbles of differing mass. Now, in addition to a "regular" glass marble, each pair of children will have a steel ball bearing the same size as their marble, but of greater mass, and a round wooden bead, again similar in size to the original marble, but of considerably less mass. The second is dominoes, tile, or lightweight blocks that may be set up at the end of marble rollways as "targets" to be knocked over as the marbles speed along.

Each PAIR of children will need

★ a basket, shoe box, or sack to keep their materials in

★ a glass marble

★ a steel ball bearing

★ a spherical wooden bead

★ 3 blocks

★ a roll of masking tape

★ a collection of toilet paper, paper towel, and giftwrap (or other long) tubes

★ dominoes, 1" square colored tile, or other small, lightweight blocks

Skills

★ predicting, testing, and validating outcomes

★ comparing likenesses and differences

★ exploring the concepts of weight and mass

Note You might also want to make a pan balance accessible to the children.

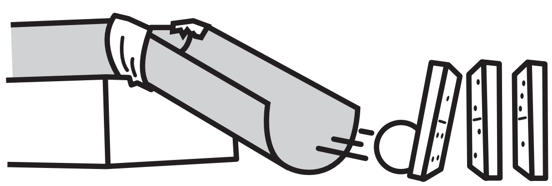
To start the lesson, display a regular marble, a ball bearing, and a wooden bead. What are the likenesses and differences among these three objects? Children may mention size and shape as likenesses; color as a difference. If they suggest that the ball bearing weighs more, ask them how they can find out for sure. This is where the pan balance might come in handy.

Session 3 Introducing Marbles That Differ in Mass (cont.)

Note *Technically, the ball bearing is said to have greater mass and the wooden bead less mass than the glass marble. We're used to speaking about things as being lighter and heavier, but to be scientifically correct, we can talk about finding the mass of objects rather than "weighing" them when we're comparing them against one another in a pan balance or finding their equivalent in standard or nonstandard units. We're used to saying that something weighs 4 tile or 15 grams. We can also say that the mass of the object is equivalent to 4 tile or 15 grams. Be assured that no matter what you say, however, many children will continue to refer to the lighter and the heavier marbles.*

Once the children have determined that the ball bearing does, in fact, have greater mass than the glass marble, and the wooden bead does have less mass, ask them how they think that might affect the roll. Will the ball bearing roll faster than the marble? Slower? What about the wooden bead? If you compare the distance rolled by the marble, the ball bearing, and the bead from the same ramp, will one roll farther than the other? How will you know for sure? Again, solicit speculations and predictions. Some children will be positive the object of greater mass will roll farther and faster, and may say things like, "Gravity will be pulling harder on it—it's got to come down faster," or "It's bigger and stronger—it'll roll farther." Others may think that the marble or the bead, which has less mass, will be lighter as it rolls; less likely to be dragged down. Many students, of course, won't have a clue, but may be excited to try the three different marbles and see what happens.

Before the children go out to work, show the tile, dominoes, and/or small blocks. Suggest that in addition to setting up ramps for their three different marbles today, they might also like to set up some targets. Take a minute here for speculation too. Do they think that one of the marbles might knock over more blocks, tile, or dominoes than the others? Some children will have ideas and predictions but you'll see most of them developing and testing their theories as they work with the materials. In this final day of free play, you'll want to be in circulation, observing, listening, and encouraging children to test their ideas.



If, despite the addition of new materials, you sense that the energy for building and testing marble rolls is low, you may want to call a halt to things early. On the other hand, the possibility of setting up and knocking down targets with three different marbles may really get things going again. In either case, be sure to leave a little time at the end of the work time for viewing if pos-

Session 3 Introducing Marbles That Differ in Mass (cont.)

sible, and discussion for certain. How did the target idea work out? Did the differences in mass make any difference in terms of how the marbles behaved?

Conclude the session by explaining that tomorrow you'll be making devices to measure how far the marbles are rolling, and that in the days to come you'll be setting up more experiments with marbles to test some of the ideas they've developed over the past three days.

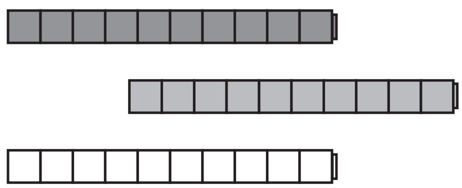
Session 4

PROBLEMS & INVESTIGATIONS

Measuring Distances with Unifix Cubes

Overview

In this session, students make and practice using Unifix cube "measuring sticks" in preparation for the next 3 lessons.



You'll need

★ Unifix cubes snapped into trains of 10 by color (Each train of 10 should only contain 1 color. If you dump out your whole tub of cubes on the floor the day before this lesson and ask the children to help, you'll find that the job will be done before you know it.)

Skills

★ counting by 10's and 1's

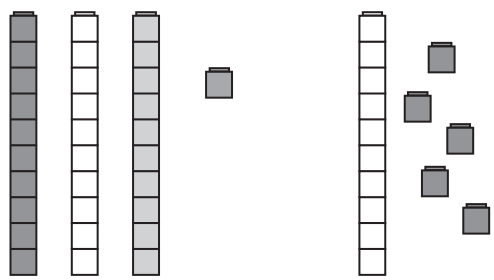
★ measuring length using nonstandard units

Start the session by revisiting the question of how to get a marble to roll farther and faster. By now, children will probably be talking about ramp length, the steepness of the ramp, and maybe even the mass of the marbles as factors that will influence speed and distance. Tell them that you're all going to be doing some experiments over the next few days to test these ideas or "hypotheses." Explain that when scientists set up experiments, one of the things they have to be able to do is to measure their outcomes: sometimes they're measuring speed; sometimes they're measuring mass or volume. In the case of these marbles, where you're trying to find out how to get them to roll farther and faster, what will you be measuring? Distance—how far the marbles are rolling—may be one thing your students will mention. They're less likely to talk about speed, although someone might think to time how long the marbles take to get from the top of a ramp to the finish of their run. This elapsed time is so brief, though, that it's hard to imagine measuring it very accurately, especially in a classroom with young children.

Distance, however, is relatively easy to measure. Children might suggest that you use yardsticks, rulers, or tapes, and all are good proposals. Explain that they're going to make their own measuring devices out of Unifix cubes, partly because there's some real value in counting the distance rolled each time rather than just looking at the number on the yardstick or tape, and partly because Unifix cubes will make the operation of averaging much more accessible to your young students.

Session 4 Measuring Distances with Unifix Cubes (cont.)

Distribute as many trains of 10 as you can to each student. Have them break one of their trains apart into 1's and explain that they'll be hooking their trains together into measuring sticks in a little while, but you're going to take a few minutes just to practice counting in 10's and 1's before they do so. Have them practice setting out different quantities of cubes as you name them: 10, 20, 30, 25, 12, 37, 15, and so on. Many students will be very proficient at counting in 10's and 1's, and you'll probably be able to call out the numbers quite quickly. You can also ask students to describe their transitions from time to time.

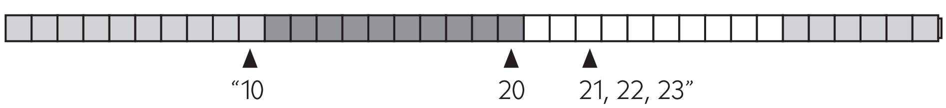


"How did I get from 31 to 15? Simple! I just took away 2 tens and added 4 ones."

After this little warm-up exercise, have your students snap their cubes together into long measuring sticks. Then explain that they'll be using measuring sticks like these to determine how far their marbles are rolling during experiments over the next few days. Have them practice locating various lengths on their measuring sticks as follows:

Teacher Suppose your marble came off the ramp and rolled a distance of 23 cubes. Can you show where on your measuring stick it would come to?

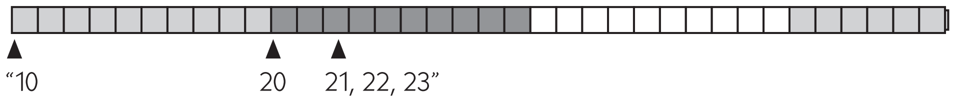
Student 1



Repeat with different numbers, having your students locate each number you name along their measuring sticks. Don't be surprised to see some confusion, even if your students are quite proficient at counting out quantities of cubes using separate stacks of 10's and 1's. We've sometimes seen children make the mistakes shown below when trying to count distances on a train of cubes snapped together:

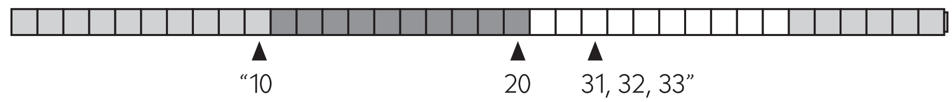
Session 4 Measuring Distances with Unifix Cubes (cont.)

Student 2



or

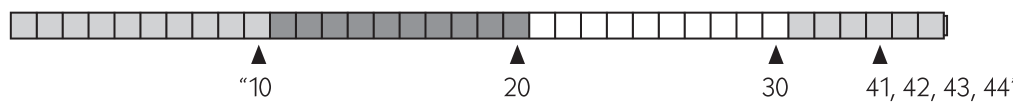
Student 3



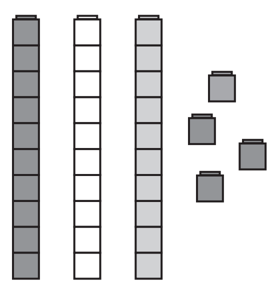
If you see some of these mistakes, try having students break their measuring sticks off at the point where they’re sure they see a particular number and then count their cubes to see if, in fact, they have that many. For example,

> **Teacher** Please show where your marble would land if it rolled a distance of 44 cubes.

Student 4



> **Teacher** Now break your measuring sticks off at that point and count your cubes by 10’s and 1’s to see if you really have 44 cubes.



> **Student** 10, 20, 30, 31, 32, 33, 34. Hey, wait a minute! What’s going on here?

Despite your best efforts, there may be a few children who are still a bit confused. No amount of explanation on your part is likely to change this right now. At this point, it might be best to partner the few who may be confused with children who can count cubes along the measuring stick accurately for the next three days’ worth of experiments.

Session 5

PROBLEMS & INVESTIGATIONS

Marble Roll Experiment 1 What Happens If You Set the Top of the Ramp Higher?

Overview

As students have played around with marble rolls over the past few days, many have hypothesized that ramps set at greater heights ("steeper ramps") influence speed and distance. Today, they test this conjecture in a more formal manner, holding all variables constant except the height at which the top of the ramp is set. After the teacher demonstrates the experimental setup, children work to perform 3 trials for each height and measure the distance the marble rolls each time.

Skills

★ counting by 10's and 1's

★ measuring length using nonstandard units

★ investigating the effect of ramp height on the speed and distance a marble rolls

★ exploring some basic principles of experimental design, including constants, variables, multiple trials, and measuring outcomes

You'll need

★ Marble Roll Experiment 1 record sheet (Blackline 1, run a class set, and 1 for the teacher)

★ clipboards or other hard surfaces on which to write

★ pencils

★ a basket of materials for demonstration purposes (see below)

Each pair of children will need

★ a basket, shoe box, or sack containing the following materials:

- a glass marble
- 3 blocks
- a roll of masking tape
- 1 paper towel tube
- 6 or 7 trains of 10 Unifix cubes (Each train of 10 should be a different color.)

★ a large bath towel if you don't have very short carpeted floors

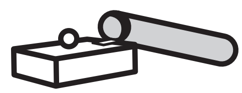
Start this lesson by gathering the children into your discussion circle. As they come to the circle, have them each get a clipboard or other hard writing surface, a pencil, and a copy of the Marble Roll Experiment 1 record sheet.

When everyone has gathered with their materials, explain that today you are going to start a series of experiments to test some of the ideas children generated while they were building marble rolls over the past few days. When scientists observe things happening in the world around them and start to mess around, they often generate questions and hypotheses, which they test experimentally. That's what you'll be doing. Because so many children seem to

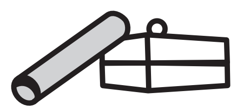
Session 5 Marble Roll Experiment 1 (cont.)

think that changing the height at which the top of the ramp is set influences the distance a marble will roll, that's what you'll test today. (Although many of your students will explain this in terms of steepness, it's not actually the slope of the ramp but the height at which the top of the ramp is set that influences the speed of the marble.)

As the children watch, display the materials in the basket you've set up: 1 glass marble, 3 blocks, a paper towel tube, tape, and Unifix cubes snapped into trains of 10. Tape the tube to the top of one of the blocks to form a ramp.



Explain that children will be working (with a partner if available) to roll a marble three times from a ramp set at this height. Next, set a second block under the first so that the ramp looks like this:

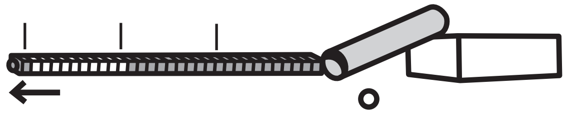


Ask students to describe how the ramp has changed. They'll probably tell you that it's gotten steeper, and that the marble will go farther and faster on this one. (Again, it's the height of the top of the ramp, not its slope, that influences speed and distance. What children observe is true, though—if the ramp length is held constant, it does get "steeper" as you raise the height at one end.)

Next, set a third block under the first two so the top of the ramp is really quite high. As you add each block, point out that the height of the stack of blocks to which you're taping the ramp is the only thing that's changing. Everything else is staying the same. The notion of holding everything constant in an experiment while changing one variable is a "big idea" in science and can be stressed here. If you want to test the effect of setting the ramp higher, the length of the ramp and the mass of the marble should both be held constant.

Another "big idea," scientifically, is that of measuring outcomes. As you're demonstrating how the height of the ramp will increase and children are predicting that the marble will roll farther, you might ask them how they're going to know for sure. How will they keep track of the distance rolled each time? Some will tell you that they'll be able to tell just by looking. Others might propose to mark where the marble lands each time with masking tape or by some other means. Still others, remembering yesterday's session, might suggest using the Unifix cubes to measure distance. After a bit of discussion, connect the trains of Unifix cubes to complete the setup for this experiment.

Session 5 Marble Roll Experiment 1 (cont.)



Teacher *Here is how your whole experimental setup will look. Why is it important to make sure that the Unifix cube measuring stick is set at the very end of the ramp?*

Andrew *Because then it will show how far the marble is rolling.*

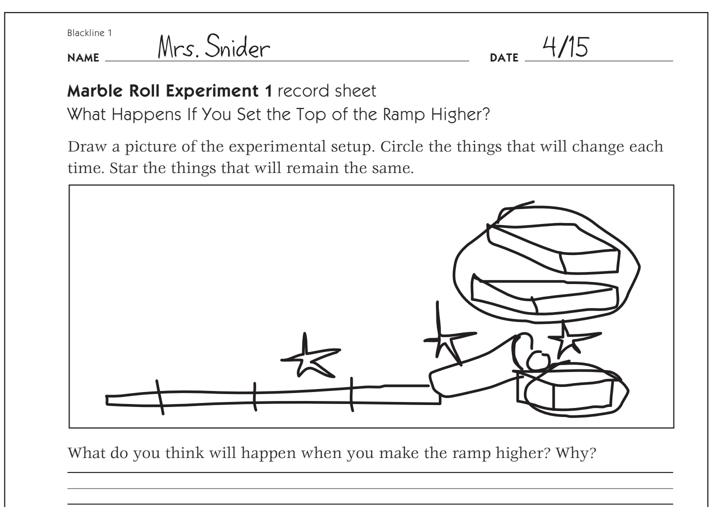
Kaitlin *Because you want to measure how far the marble rolls when it comes out of the tube.*

Ciel *If you push the measuring stick right up to the block, it will show extra. It will show some cubes that the marble didn't roll.*

Teacher *Why is it important to set the measuring stick to the side of the tube?*

Children *So the marble doesn't run right into the measuring stick. If you put the cubes right in front of the tube, you'll block the marble from rolling!*

When everything is ready, have each student sketch the experimental setup at the top of his or her record sheet, as shown below. (You might want to make a sketch on the board for children to refer to as they work.)


Blackline 1
NAME Mrs. Snider DATE 4/15
Marble Roll Experiment 1 record sheet
What Happens If You Set the Top of the Ramp Higher?
Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.
What do you think will happen when you make the ramp higher? Why?

This step helps students remember how to set up the materials when they go to work. It also reminds them that there is only one variable in this experiment—the height of the ramp—while everything else, including the ramp length, the marble mass, and the rolling surface (short carpet or bath towel) is to be held as constant as possible.

Session 5 Marble Roll Experiment 1 (cont.)

After they've sketched the setup, have your students write a prediction about what will happen as the ramp gets steeper, along with an explanation of why. This part isn't easy, but it's very interesting and revealing. We write "because" on the board and explain that their prediction should include this word. If they write something like, "I think the marble will go farther when the ramp gets higher," they'll need to add the word "because" and go on to explain their thinking. As children finish writing their predictions, ask a few volunteers to read theirs aloud.

The last step before sending children out to try this experiment on their own is to model the first three trials. Explain that you are going to roll the marble down the single-block ramp three times and record the results on your own data table, which is on the lower half of the record sheet. The students, of course, won't mark their record sheets because they'll be going out and trying it on their own in a few minutes. Then roll the marble three times, emphasizing the fact that you are *holding it at the top of the ramp and letting it go without pushing, shoving, or adding any extra force from your hand*. Record your results each time on the data table, as shown below:

Data Table

Distance rolled (in Unifix cubes)

Height of Ramp	Trial 1	Trial 2	Trial 3	Average Distance
1 block high	22	24	21	
2 blocks high				
3 blocks high				

When you get to the column that says Average Distance, explain that scientists never stop at one trial. They want to try things at least several times to make sure they're getting an accurate picture of what usually happens. In your three trials, the distance rolled by the marble was a little different each time. What might account for the differences?

(The *average* in this case is the *mean*; the number that would result if you added all the distances and divided by the number of trials. After the students have conducted the experiments in this and the next two sessions, you'll go back and consider some methods for averaging data that may be accessible to young children. In the meantime, it's interesting to consider the variation in distances that occurs even when everything is held constant.

> ***Teacher*** *When I rolled the marble 3 times from the lowest ramp, it rolled 22 cubes, then 24, and then 21. Why didn't it roll exactly the same distance each time?*
>
> ***Evan*** *Maybe you dropped the marble a little differently from the top of the ramp each time.*

Session 5 Marble Roll Experiment 1 (cont.)

Sherwin *Maybe it got a little extra puff of wind when it rolled 24 that time.*

McCall *Maybe the time it only rolled 21 it kind of got caught on the rug.*

Teacher *If I rolled it lots more times, what kinds of numbers do you think I'd get?*

Children *Around the 20's.*
I could get it to roll farther.
But you're not supposed to push it.
I bet I could get it to roll 30 or 40.

Teacher *How?*

Gavin *It would roll that far out in the hall. There's no carpet out there.*

Teacher *I'm glad you mentioned that. Would this experiment be fair if some of us worked out in the hall while others worked here on the carpet?*

Children *No! It would go farther on the floor.*
Yeah! It really goes far on a smooth floor.
We all have to do it the same.

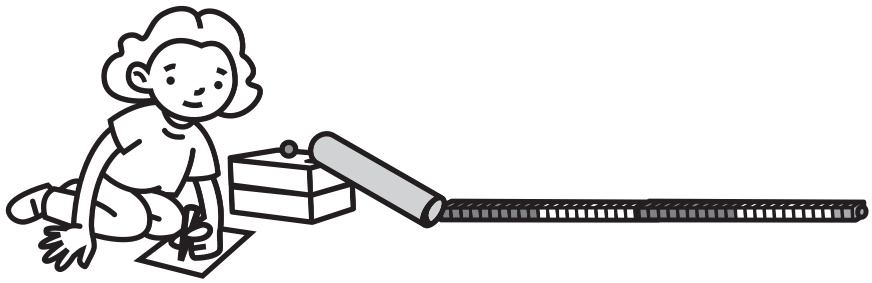
Teacher *If I kept working right here, and I didn't change anything, would I be more likely to get numbers around the 20's or the 50's ?*

Children *The 20's!*
It wouldn't roll 50 unless you made the ramp steeper!

Teacher *I could try it some more times, but there are only 3 spaces on my record sheet, and then a box with the heading "Average Distance." When scientists talk about finding an average, they're thinking of looking at all the numbers they get and finding a number that will give a picture of what* usually *happens. We'll come back to this in a couple of days, though. For now, you don't have to worry about filling in any numbers in the "Average Distance" column.*

Finally, send students off individually or in partners with their baskets and record sheets to try this first experiment. They will have seen and drawn a picture of the experimental setup, written a prediction about what's going to happen and why, and watched you conduct and record the first round of trials. Most will be able to set things up and get right to work easily. You'll want to check that their Unifix cube measuring sticks are set at the ends of their ramps, their tubes are taped at the top so they don't slip around or get pushed up higher on the block by accident, and that they're, in fact, *letting go* of the marbles at the top of their ramps rather than pushing or shoving them down. (If you made a big deal about these things as you modeled the first round of trials, most of your students will be doing fine.)

Session 5 Marble Roll Experiment 1 (cont.)



After they're finished with all nine trials, it is time to stop. They'll be figuring the averages and writing down what "really happened" with this experiment in a couple of days.

NAME ______________________ **DATE** ______________________

Marble Roll Experiment 1 record sheet

What Happens If You Set the Top of the Ramp Higher?

Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.

What do you think will happen when you make the ramp higher? Why?

Data Table

Distance rolled (in Unifix cubes)

Height of Ramp	Trial 1	Trial 2	Trial 3	Average Distance
1 block high				
2 blocks high				
3 blocks high				

Look at your average distances. What really happened when you made the ramp higher?

Session 6

PROBLEMS & INVESTIGATIONS

Marble Roll Experiment 2 What Happens If You Use Marbles of Different Mass?

Overview

This experiment is the second in the set of 3 and is designed to let students test the hypothesis that mass affects the distance a marble will roll.

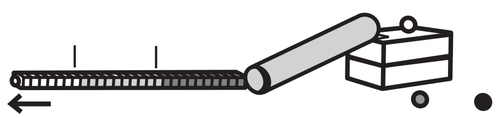
Skills

★ counting by 10's and 1's

★ measuring length using nonstandard units

★ investigating the effect of mass on speed and distance

★ exploring some basic principles of experimental design, including constants, variables, multiple trials, and measuring outcomes



You'll need

★ Marble Roll Experiment 2 record sheet (Blackline 2, run a class set, and 1 for the teacher)

★ clipboards or other hard surfaces on which to write

★ pencils

★ a basket of materials for demonstration purposes (see below)

Each pair of children will need

★ a basket, shoe box, or sack containing the following materials:

- marbles: glass, wood, or steel
- 2 blocks
- a roll of masking tape
- 1 paper towel tube
- 6 or 7 trains of 10 Unifix cubes (Each train of 10 should be a different color.)

★ a bath towel if you don't have carpeted floors

Gather students into your discussion circle. As they come to the circle, have them each get a clipboard or other hard writing surface, a pencil, and a copy of the Marble Roll Experiment 2 record sheet.

Set up the experiment for today as shown below, while students watch. As you set things up, explain that today they'll be testing the idea that mass affects the distance a marble will roll.

Session 6 Marble Roll Experiment 2 (cont.)

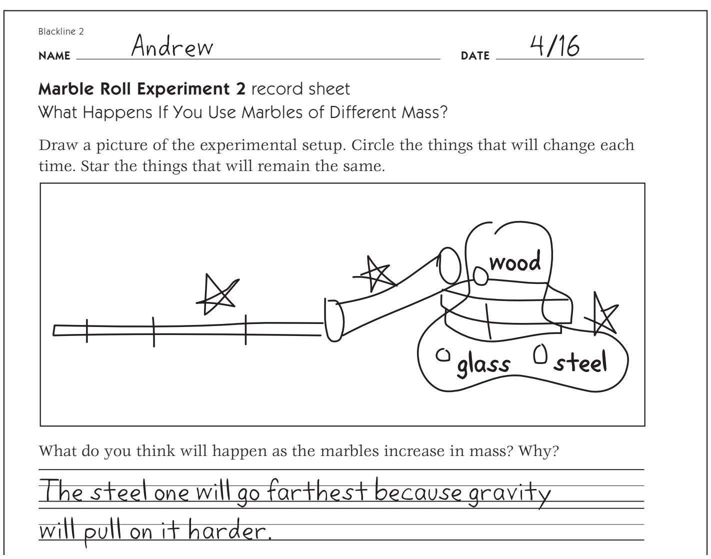
Here are some important things for students to remember when they go out to work:

- The only thing that will be changing today will be the marbles themselves.

- The ramp will always be set at 2 blocks high. The length of everyone's paper towel tube will be the same.

- Hopefully, everyone will make sure that they let the marbles go at the top of the ramp very carefully each time. That way, everything except mass will be held constant so they'll really be able to see the effects of that particular variable.

Once you've explained the experimental setup, have each student sketch it at the top of his or her record sheet. Next, ask children to write predictions about what will happen as the marble mass increases. Remind them to explain their thinking on their papers too.



Blackline 2

NAME Andrew DATE 4/16

Marble Roll Experiment 2 record sheet
What Happens If You Use Marbles of Different Mass?

Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.

What do you think will happen as the marbles increase in mass? Why?

The steel one will go farthest because gravity will pull on it harder.

As students finish writing, take a few minutes to have them read their predictions to one another, especially since their ideas on this particular issue may vary quite a bit. Next, conduct a first round of trials with the wooden bead, recording the information on your own record sheet. (As before, your students won't be recording this information because they'll soon be going out to conduct their own trials.)

Session 6 Marble Roll Experiment 2 (cont.)

Data Table
Distance rolled (in Unifix cubes)

Type of Marble	Trial 1	Trial 2	Trial 3	Average Distance
wood	18	20	16	
glass				
steel				

Teacher *When I rolled the wooden bead, which has the least mass of all the marbles, 3 times, it rolled 18 cubes, then 20, and then 16. Does anyone have any idea why it might have rolled a different distance each time? Why didn't it come out exactly the same?*

Andrew *You may have held the bead a little differently each time you let it go at the top.*

McCall *It may have hit different bumps in the rug each time. That wooden bead is so light that the rug could make a big difference.*

Sherwin *You probably breathed on it the time it went 20. You made it go farther, I bet.*

Teacher *Those are all possibilities. That's exactly why scientists try things more than once. They usually do lots and lots of trials and then find the average, but we're just going to do 3 trials with each marble today.*

David *Could we try more than 3 if we wanted?*

Teacher *Sure, but you won't have enough room on the form to record your extra trials.*

McCall *We could get an extra piece of paper.*

Teacher *That's true. In any case, don't worry about finding the average distances today. We'll handle that together day after tomorrow.*

Finally, send students off individually or in pairs with their baskets and record sheets to do this second experiment. They will have seen and drawn a picture of the experimental setup, written a prediction about what's going to happen and why, and watched you conduct and record the first round of trials. They will also have set up and performed a similar experiment the day before, so things should go pretty smoothly. You'll want to check that their Unifix cube measuring sticks are set at the ends of their ramps, their tubes are taped to the top block so they don't slip, and that they are, in fact, letting the marbles go at the top of their ramps rather than pushing or shoving them down.

Session 6 Marble Roll Experiment 2 (cont.)

Note: *Under favorable conditions, the marble with the greatest mass will travel farthest. In our co-op, however, we noticed that answers vary depending on the surface area. If your students find that the wood or glass marbles travel farthest, discuss the role that surface area plays. In our class, the steel marble quickly sunk in plush carpet; the wooden marble, on the other hand, was light enough to sail across the surface.*

NAME ______________________ **DATE** ______________________

Marble Roll Experiment 2 record sheet
What Happens If You Use Marbles of Different Mass?

Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.

What do you think will happen as the marbles increase in mass? Why?

Data Table
Distance rolled (in Unifix cubes)

Type of Marble	Trial 1	Trial 2	Trial 3	Average Distance
wood				
glass				
steel				

Look at your average distances. What really happened when you used marbles of greater mass?

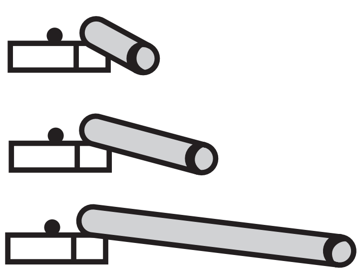
Session 7

PROBLEMS & INVESTIGATIONS

Marble Roll Experiment 3 What Happens If You Make the Ramp Longer?

Overview
This experiment is the last in the set and is designed to have students test the hypothesis that ramp length affects the distance a marble will roll.

Skills
★ counting by 10's and 1's
★ measuring length using nonstandard units
★ Investigating the effect of ramp length on speed and distance
★ exploring some basic principles of experimental design, including constants, variables, multiple trials, and measuring outcomes



You'll need
★ Marble Roll Experiment 3 record sheet (Blackline 3, run a class set, and 1 for the teacher)
★ clipboards or other hard surfaces on which to write
★ pencils
★ a basket of materials for demonstration purposes (see below)

Each pair of children will need
★ a basket, shoe box, or sack containing the following materials:
- a steel marble
- 1 block
- a roll of masking tape
- 3 tubes: short, medium, and long
- 6 or 7 trains of 10 Unifix cubes (Each train of 10 should be a different color.)

★ a bath towel if you don't have carpeted floors

To start, gather the children into your discussion circle. As they come to the circle, have them each get a clipboard or other hard writing surface, a pencil, and a copy of the Marble Roll Experiment 3 record sheet.

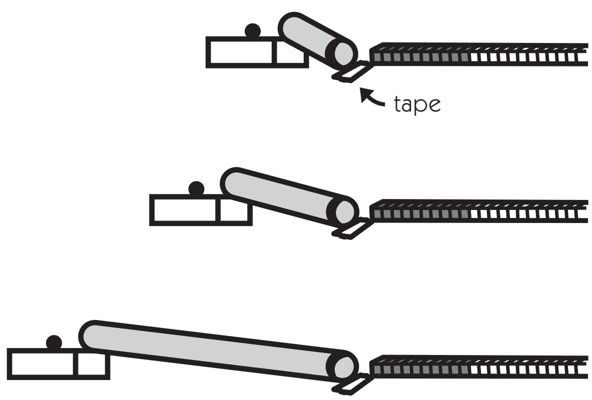
Explain that today they are going to test ramp length as a variable. Here are some reminders to give the children as you work:

- They'll be testing the idea that ramp length affects the distance a marble will roll.
- The only thing that will be changing with each new round of trials will be the length of the ramp.

Session 7 Marble Roll Experiment 3 (cont.)

- Each of the three ramps will be set at one block high and the marble (a steel ball bearing in this case) will be the same every time.

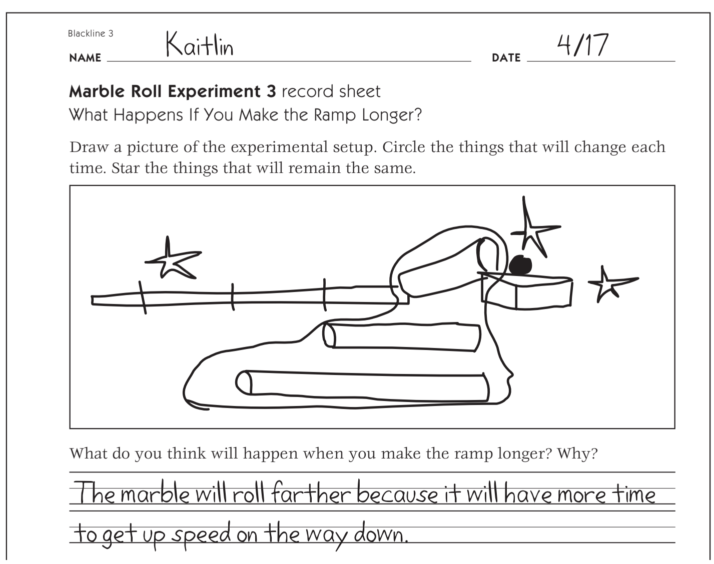
- It will be important for children to measure from the point where the marble comes off the ramp each time. As the ramps get longer, this will mean making some adjustments; either moving their Unifix cubes forward or their block and ramp setups back as the ramp lengths increase. Have students mark the floor at the end of the first ramp with a piece of masking tape to make sure that the other two tubes are placed properly.



"I have to move my block way back for the longest tube"

- Hopefully, everyone will take care to let the marble go at the top of the ramp very carefully each time. That way, everything except ramp length will be held constant so they'll be able to really see the effects of that variable.

Once things are ready, have the children sketch the experimental setup and write their predictions. Then take a few minutes to share and compare hypotheses.



Blackline 3

NAME Kaitlin DATE 4/17

Marble Roll Experiment 3 record sheet
What Happens If You Make the Ramp Longer?

Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.

What do you think will happen when you make the ramp longer? Why?

The marble will roll farther because it will have more time to get up speed on the way down.

Session 7 Marble Roll Experiment 3 (cont.)

Model the first round of trials, letting the marble go from the top of the toilet paper tube and recording the information on your own data table. (As before, your students won't be recording this information because they'll soon be going out to conduct their own trials.) After you've done three trials with the shortest ramp, discuss the fact that your results are all a little different, and reiterate the need for future averaging.

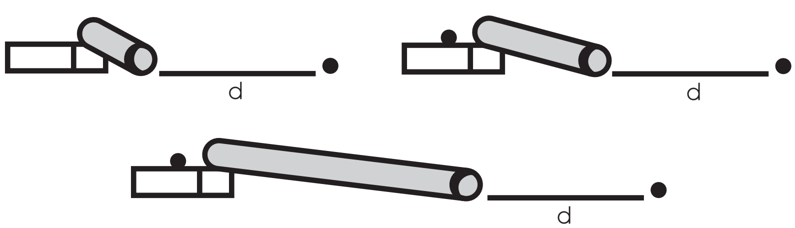
Data Table

Distance rolled (in Unifix cubes)

Ramp Length	Trial 1	Trial 2	Trial 3	Average Distance
short	20	19	21	
medium				
long				

Send students off individually or in partners with their baskets and record sheets to do this third experiment. They'll be figuring the averages and writing down what "really happened" with this experiment during the session after next.

Note *The results of this experiment might be a bit surprising to your students. Although it makes intuitive sense that a longer ramp would cause the marble to roll farther, the truth of the matter is that the marble is descending from the same height each time (from the top of the unit block to the floor). This means that it will be traveling with the same speed when it hits the floor, no matter what the length of the ramp. Thus, the distance traveled on the floor will be about the same, whether the ramp is short, medium, or long.*



(Your students may even find that the marble doesn't travel quite as far when launched from the longest tube as from the other two. This is because the marble encounters more friction while rolling down the longer tube and emerges at a slightly slower speed.)

NAME ______________________ **DATE** ______________________

Marble Roll Experiment 3 record sheet

What Happens If You Make the Ramp Longer?

Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.

What do you think will happen when you make the ramp longer? Why?

Data Table

Distance rolled (in Unifix cubes)

Ramp Length	Trial 1	Trial 2	Trial 3	Average Distance
short				
medium				
long				

Look at your average distances. What really happened when you increased the length of the ramp?

Session 8

PROBLEMS & INVESTIGATIONS

Another Look at Averaging

Overview

Now that your children have had a chance to test some of the hypotheses they developed during the first days of this unit, they're going to take a closer look at the results of their experiments. In this session and the next, they'll look at the idea of averaging and figure the average distances their marbles rolled in the 3 different experiments they just conducted. In the sessions to follow, they'll graph the averages for each experiment and use their graphs to make some generalizations and predictions. Ultimately, the more information students have about what makes marbles roll the greatest distance with the most speed, the easier it will be to plan their "mega-marble rolls" at the end of the unit.

You'll need

★ all your Unifix cubes already snapped into same-color groups of 10 (10 green, 10 red, etc.)

★ Marble Roll Experiment 1, teacher record sheet

Skills

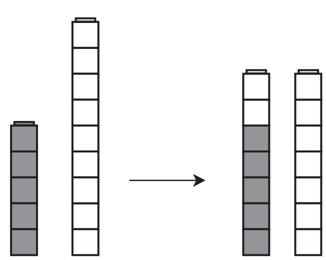
★ counting by 10's and 1's

★ comparing quantities

★ exploring the idea of finding the mean, or the average, of 3 different quantities

★ thinking about why scientists use averages

In today's session, children work with Unifix towers, breaking them apart and redistributing the cubes to create new towers of equal height; literally leveling the quantities to find averages.



"If I want to make these 2 towers the same height, all I have to do is break 2 off of the tall one and give them to the small one. Then they will each have 7 cubes, so I know that the average of 5 and 9 is 7."

To start the lesson, ask if anyone knows what the word "average" means. Show Teacher Record Sheet 1 and ask for comments. Steer the discussion toward the idea of finding average results for each set of trials.

Session 8 Another Look at Averaging (cont.)

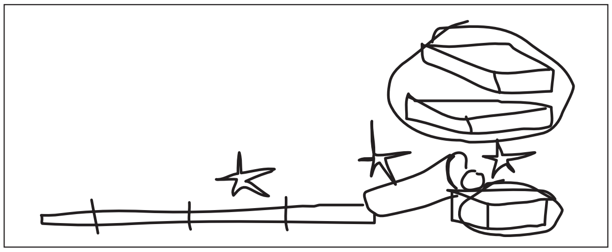
Teacher Record Sheet 1

NAME Marty DATE 4/15

Marble Roll Experiment 1 record sheet

What Happens If You Set the Top of the Ramp Higher?

Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.



What do you think will happen when you make the ramp higher? Why?

The marble will go farther because tall ramps make it go faster.

Data Table

Distance rolled (in Unifix cubes)

Height of Ramp	Trial 1	Trial 2	Trial 3	Average Distance
1 block high	21	24	18	
2 blocks high	30	35	29	
3 blocks high	41	46	38	

Look at your average distances. What really happened when you made the ramp higher?

Teacher *We're going to work today and tomorrow on finding the average distances our marbles rolled when we did the different experiments like making the ramp higher or using marbles with greater mass. Here is a record sheet from another child. What do you notice?*

Children *He was doing the experiment about making the ramp higher.*
He thought the same as me—the marble will go farther with a higher ramp.
46 was his biggest number, and 18 was his smallest.
The marble didn't go very far when the ramp was only 1 block high.
It went pretty far when the ramp was 3 blocks high, but ours went farther.
The numbers get bigger and bigger.

Teacher *Do the numbers* prove *that the marble will roll farther with a higher ramp?*

Children *Kind of.*
They look bigger and bigger, except 38 on the bottom row.
38 isn't all that big.

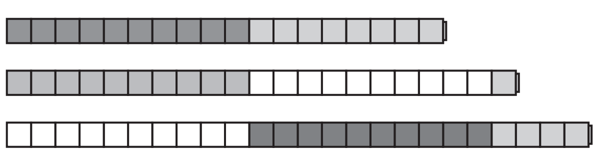
Session 8 Another Look at Averaging (cont.)

> ***Teacher*** *Why are the numbers in each row different? Why didn't Marty get 24 every time he rolled the marble off the lowest ramp? Why did he get different results each time?*
>
> ***Children*** *Because every time you do it, it's a little bit different.*
> *If there's a puff of wind.*
> *Or a bump in the rug.*
> *Or if you hold your hand differently.*
> *You have to give it more than one try.*

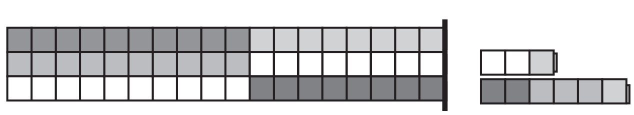
Once children have had a chance to look at the record sheet and make some comments, explain that what scientists often do with data *after* they've collected it is to average the numbers—to level the numbers off as a way to get a sense of what usually happens under a specific set of circumstances. By averaging the numbers in each row on the sample record sheet, the class will be able to determine the *usual*, or *average*, distance Marty's marble rolled from ramps set at heights of 1, 2, and 3 blocks.

As this discussion unfolds, you may lose some of your students. Leveling the quantities themselves is easy compared to understanding what an average really represents and why scientists use the idea in their work. Don't worry. This is a seed-planting time; some children will begin to understand the concept of finding the mean, while others will just have a field day arranging the quantities in 10's and 1's and leveling off the stacks. There is value either way, and children will have more opportunities in the future to comprehend the meanings and applications of averaging.

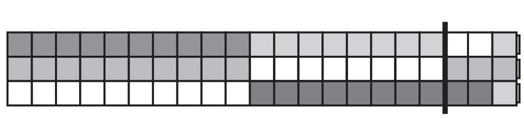
After a bit of discussion, have your students work in partners with Unifix cubes to find the average of the first three distances shown on Teacher Record Sheet 1.



"Here's 18."
"Here's 21."
"Here's 24."



"Now to level them off, we'll just take the extras off the top and then start sharing them out."



"Look! It came out perfect! Each row has 21. I knew it. I knew 21 was going to be in the middle."

After everyone has had a chance to average the first three numbers, bring them back to the circle to discuss their results. Even though they won't all understand perfectly, bring the discussion back to marble rolls for just a

Session 8 Another Look at Averaging (cont.)

minute. Explain that according to the data Marty collected, 21 cubes was the average distance rolled by a marble launched from a ramp 1 block high. His marble rolled a distance that was shorter than that once, and longer than that once, and exactly that amount once. Probably, if he rolled his marble from the same ramp many more times, it would come out somewhere in the neighborhood of 21 each time. (Again, we could be a lot more confident about this if Marty had collected data for 10, 20, or 100 more rolls, but that's just too much data to consider right now.)

If you feel that your children need more practice finding averages together before they tackle their own data, have them work with the other two sets of numbers shown on the sample record sheet. Take time after each set to record the average on the Teacher Record Sheet 1 and discuss the results.

Data Table

Distance rolled (in Unifix cubes)

Height of Ramp	Trial 1	Trial 2	Trial 3	Average Distance
1 block high	21	24	18	21
2 blocks high	30	35	29	31*
3 blocks high	41	46	38	41*

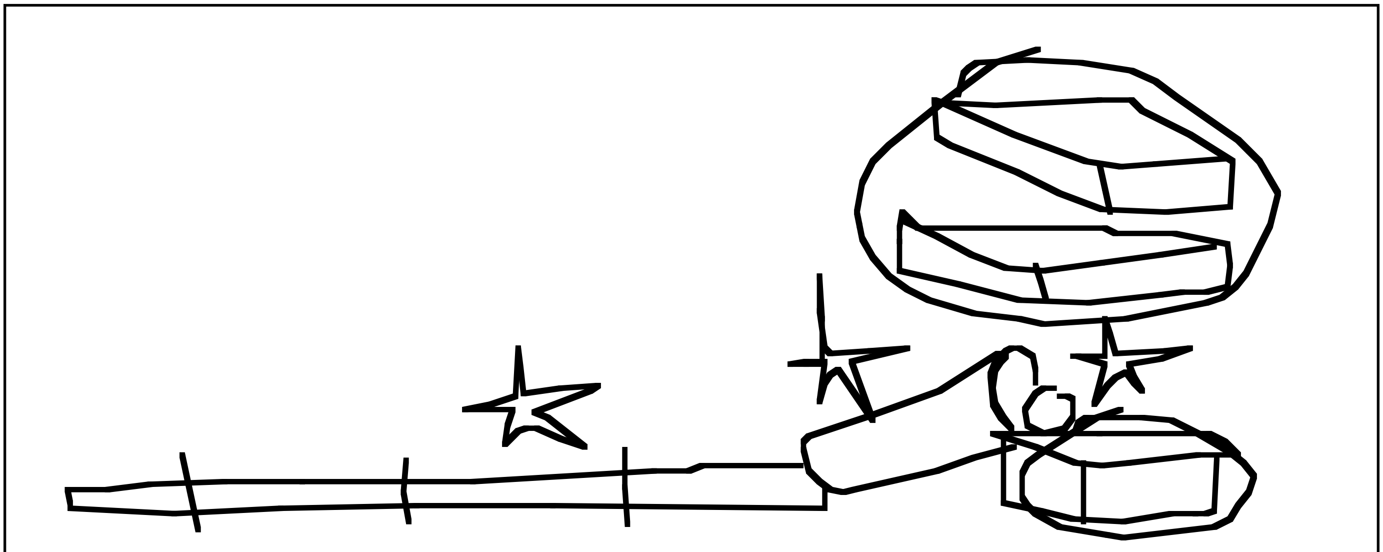
* The last 2 sets of numbers have "leftovers" when averaged. You and your students can decide how you want to deal with these.

NAME Marty DATE 4/15

Marble Roll Experiment 1 record sheet

What Happens If You Set the Top of the Ramp Higher?

Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.



What do you think will happen when you make the ramp higher? Why?

The marble will go farther because tall ramps make it go faster.

Data Table

Distance rolled (in Unifix cubes)

Height of Ramp	Trial 1	Trial 2	Trial 3	Average Distance
1 block high	21	24	18	
2 blocks high	30	35	29	
3 blocks high	41	46	38	

Look at your average distances. What really happened when you made the ramp higher?

Session 9

PROBLEMS & INVESTIGATIONS

Finding Average Distances

Overview
Children look at one more sample set of data together and then go out with partners to average their own experimental data from Sessions 5, 6, and 7.

Skills
★ counting by 10's and 1's
★ comparing quantities
★ finding averages
★ thinking about why scientists use averages

You'll need
★ children's papers for Marble Roll Experiments 1, 2, and 3
★ Marble Roll Experiment 2 teacher record sheet
★ all your Unifix cubes already snapped into same-color groups of 10 (10 green, 10 red, etc.).

Note *It will be important for children to work with the same partners they had when they did the experiments so that they're working with the same data.*

To start the lesson, gather your students into a discussion circle and explain that they are going to work with the data they actually collected from their three experiments. They are going to be finding the averages for each set of data and using the averages to draw some conclusions about the experiments. Next, display Marble Roll Experiment 2 Teacher Record Sheet 2 (see next page).

Explain that this is a sheet done by another child. Give them a minute to look it over and make any observations they can. They might note that the data this child collected was similar to theirs. They may have observations to make about the picture she drew or the distances she got on each trial. If no one mentions it, show them that the average in the last row is missing. Have them look at the numbers in the first 2 rows and the averages and then ask them to tell you what they think the average of the 3 numbers in the last row will be. Some may tell you they think it will be in the neighborhood of 36 or 37. Others may give numbers equal to the lowest or greatest distance rolled, or numbers higher than or lower than those figures, not understanding yet that the average in this case will be something in the middle. (This is a terrific assessment, if you get the chance to note who says what.)

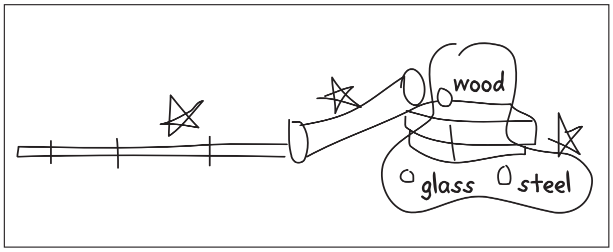
Session 9 Finding Average Distances (cont.)

Teacher Record Sheet 2

NAME K'Sondra DATE 4/16

Marble Roll Experiment 2 record sheet
What Happens If You Use Marbles of Different Mass?

Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.



What do you think will happen as the marbles increase in mass? Why?

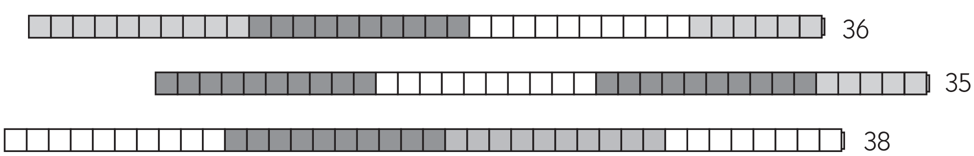
I think the steel marble will roll farther because gravity pulls harder on heavy marbles.

Data Table
Distance rolled (in Unifix cubes)

Type of Marble	Trial 1	Trial 2	Trial 3	Average Distance
wood	18	20	16	18
glass	31	32	31	31
steel	36	35	38	

Look at your average distances. What really happened when you used marbles of greater mass?

Next, ask them to help you find the average of the bottom 3 distances with Unifix cubes. Solicit helpers from around the circle to help you lay out 36, 35, and 38 in 10's and 1's. Once the 3 quantities have been set out, invite your students to make a second estimate. What do they think the results will be when you level the 3 stacks? Again, be prepared for a range of answers. Finally, while they look on and give you advice, level the 3 trains of Unifix cubes.



Teacher *Okay! We have all 3 quantities laid out. We're all set to go.*

Rob *Wait a minute! Before you level them, you have to put them together so the ends all start at the same place.*

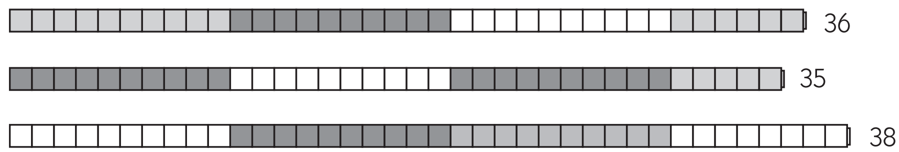
Teacher *Why?*

Rob *Otherwise, you'll get it wrong. You can't compare them unless they all start at the same place.*

Session 9 Finding Average Distances (cont.)

Teacher *Class? What do you think?*

Children *Yeah! Rob's right—put them altogether so they start the same.*



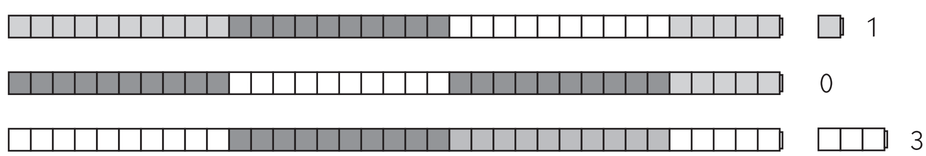
Teacher *Now what?*

Children *Level them off. Let me do it! I know how! I love getting those things level—it's fun breaking them off and putting them back on so they all match.*
Me too!

Teacher *There are probably all kinds of ways to get these 3 trains leveled off. Can someone tell me what to do first?*

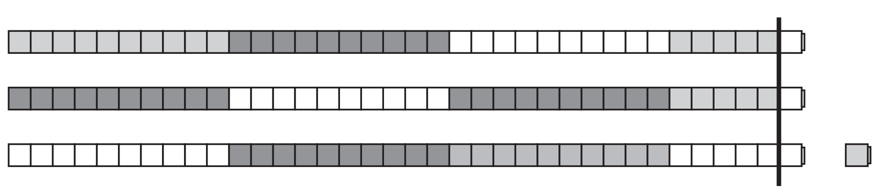
Ciel *Break them all off so they're the same. Then you can share out the extras.*

Teacher *Okay. Now what?*



Joey *Just start sharing out the cubes. This is easy—each tower will get an extra cube.*

Susannah *Wait! There's going to be 1 left over!*



Teacher *What should we do with the extra cube?*

Children *Throw it out!*

Teacher *So what is our average, not counting the extra cube? If the marble rolled 36 cubes, 35 cubes, and 38 cubes, what would the average of these 3 distances be?*

Briana *36. It's 10, 20, 30, then 31, 32, 33, 34, 35, 36.*

Session 9 Finding Average Distances (cont.)

Once you and the children have figured the average of the last 3 distances, enter it on the Teacher Record Sheet 2 and circle the 3 averages on the sheet. Ask students to take a good look at these 3 numbers.

Data Table

Distance rolled (in Unifix cubes)

Type of Marble	Trial 1	Trial 2	Trial 3	Average Distance
wood	18	20	16	18
glass	31	32	31	31
steel	36	35	38	36

Look at your average distances. What really happened when you used marbles of greater mass?

Based on the averages, what can they conclude about this experiment? What was the effect of using marbles of differing mass? (You might mention that scientists generally look at their *averages* when they're trying to draw conclusions. These single numbers, which represent what *usually* happens, are the ones to examine when you want to make generalizations and draw conclusions.)

Teacher *So, now we have our 3 averages. What was the average distance rolled for the round wooden bead?*

Children *18 cubes.*

Teacher *What was the average distance rolled for the glass marble?*

Children *31 cubes.*

Teacher *What about for the steel ball bearing—the marble with the greatest mass?*

Children *36 cubes. Hey! It gets bigger each time.*

Teacher *So what does that tell you about the effect of using marbles with different masses?*

Children *The heavier the marble is, the farther it rolls. I still think that if you had a really heavy marble, it wouldn't roll as far. It would be too heavy!*

Whether or not it comes up in discussion, you might ask your students what would happen with a marble that had a bit more mass than the steel ball bearing.

Teacher *If you had a marble that was a bit heavier than the steel ball bearing, how far do you think it would go, on the average?*

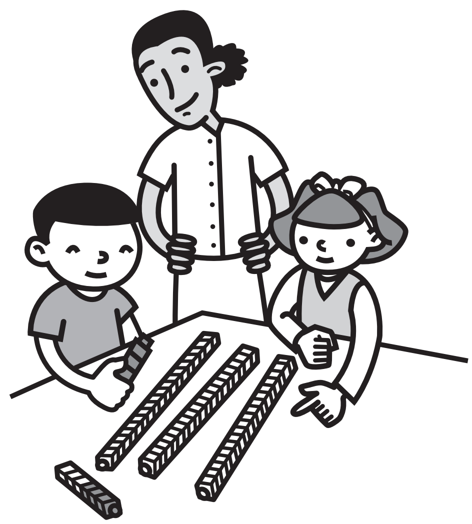
Children *45!*

Session 9 Finding Average Distances (cont.)

In the 40's—it went 18, then 31, then 36; it would go in the 40's next.
28 because the extra weight would slow it down!
64—it might get really lucky and roll really far!

Finally, send them out to work in pairs with their Experiment 1 sheets and their Unifix cubes. Their job is to average the distances in each row, and then go on to average a second sheet if they have time. Let them know that they'll be writing their conclusions about each experiment after they've found averages and constructed graphs—it's not something they need to worry about today.

Note: The surface affects the distance the marbles travel. See Session 6 for additional information.



You'll want to be in continual circulation during this time, giving help where needed and watching the action. If you established partners for the experiments, the children will be able to help each other on this project too. If one child in a pair is pretty thoroughly confused, don't worry too much. Have him or her help set up each quantity in 10's and 1's; hopefully, one out of each pair will be able to do the leveling and help with the recording.

It is fascinating to talk with students as they work. We like to ask them to predict what their averages will be as they work and if the answers they're getting make sense. It is true that you'll have to check the answers for accuracy either during or after this work period. If their averages are off, some children may produce some very skewed graphs. If, in checking through the papers later on, you discover some mistakes, consider the source. Think about whether the children who are doing the work understand the process well enough to benefit from doing some of it over, or would it be better to let it slide and make the corrections yourself?

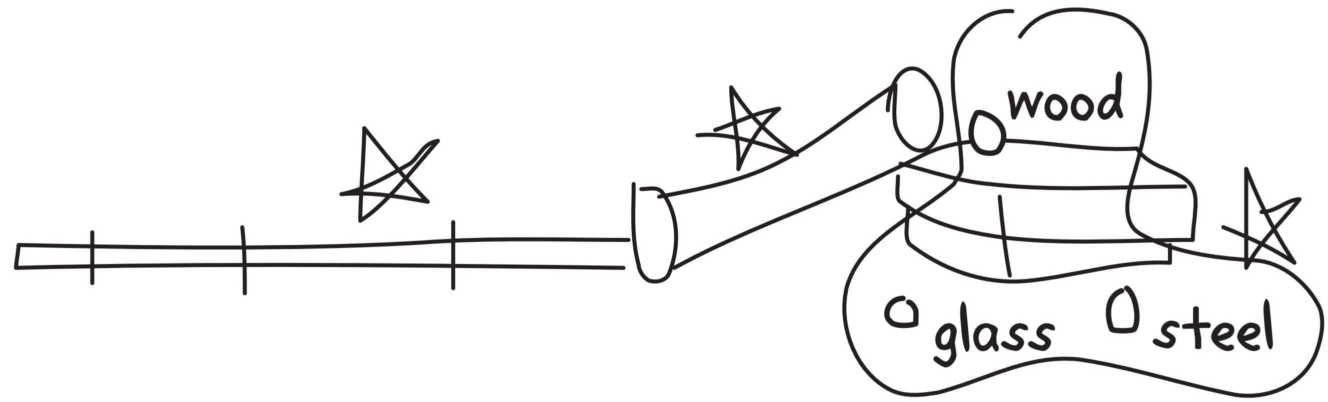
Very few students will get through all three of their papers in one session.

NAME K'Sondra DATE 4/16

Marble Roll Experiment 2 record sheet

What Happens If You Use Marbles of Different Mass?

Draw a picture of the experimental setup. Circle the things that will change each time. Star the things that will remain the same.



What do you think will happen as the marbles increase in mass? Why?

I think the steel marble will roll farther because gravity pulls harder on heavy marbles.

Data Table

Distance rolled (in Unifix cubes)

Type of Marble	Trial 1	Trial 2	Trial 3	Average Distance
wood	18	20	16	18
glass	31	32	31	31
steel	36	35	38	

Look at your average distances. What really happened when you used marbles of greater mass?

Session 10

PROBLEMS & INVESTIGATIONS

Graphing the Data

Overview

The intent of this lesson is to give students practice making and interpreting graphs and also to convey the idea that a picture can be worth a thousand numbers. Looking at averages on a chart or table isn't always as powerful as seeing them on a graph, and we think this idea can be introduced successfully to children.

Skills

★ creating, labeling, and reading bar graphs

★ choosing a reasonable scale for the data collected

★ comparing data

You'll need

★ children's Experiment 1 sheets, with the averages figured and corrected (You will need to go through children's sheets before this lesson and make sure their averages are correct.)

★ any sheets for Experiment 2 and Experiment 3 that have been averaged (Many children will only have found the averages for Experiment 1 during the last session. You can either spend another day having students find averages for their other sheets or have a few of the children who get through their first sheet quickly find the averages for either their second or third experiments as well. In any event, you'll want *some* averaged data for all 3 experiments.)

★ Marble Roll graphing sheet (Teacher Graphing Sheet)

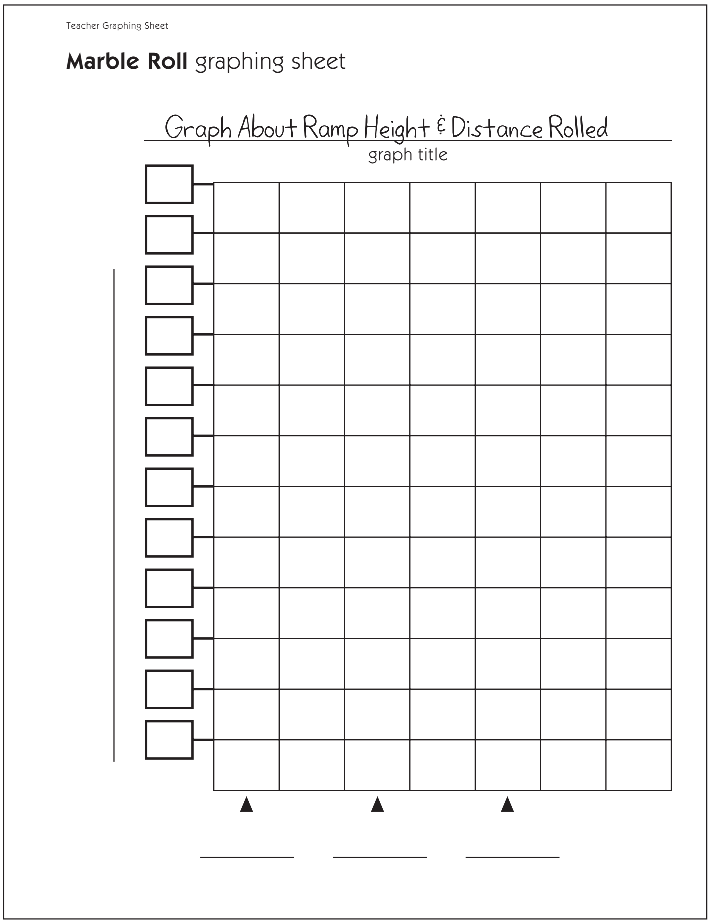
★ Marble Roll graphing sheet (Blackline 4, run a class set and some extras for children who have time to make a second graph.)

Gather your students into a discussion circle where they can easily see the Teacher Graphing Sheet and explain that the class is going to graph the results of the marble roll experiments. Start by distributing their first experiment sheets—the ones that deal with increasing the height of the ramp. Then show the Teacher Graphing Sheet, as shown below, and discuss possible titles.

> ***Andrew*** *This graph should be called "Higher Ramps" because that's what it's about.*
>
> ***Jake*** *I think it should be called "1 Block, 2 Blocks, 3 Blocks."*
>
> ***Eloise*** *How about "Higher and Higher"?*

Session 10 Graphing the Data (cont.)

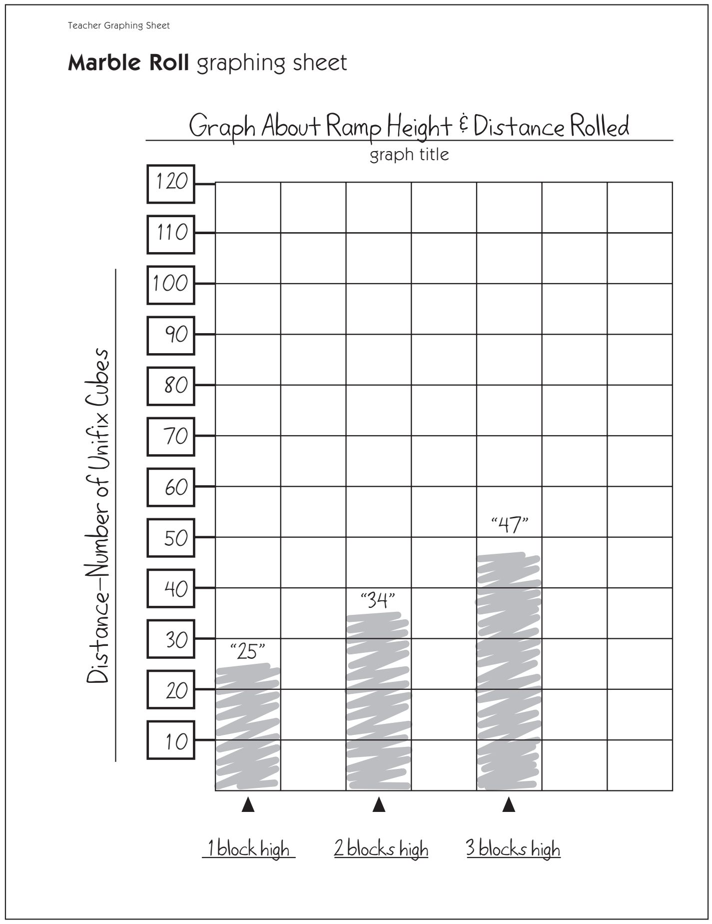
> ***Teacher*** *You can give your graph a title that makes the most sense to you. I think I'll label this one "Graph About Ramp Height and Distance Rolled."*



Next, model the fact that you have to label the columns along the x-axis "1 block high," "2 blocks high," and "3 blocks high." Then count the boxes in one of the columns. There are only 12. Did anyone's marble roll farther than 12 Unifix cubes? Most likely. So, what are you going to do? Discuss the possibilities. Someone will probably suggest using one box to stand for more than one Unifix cube, but if no one does, propose it yourself. Then the question is, how many cubes should each box stand for? Popular ideas are 2's, 5's, and 10's. Which would work best for the numbers your class got? Remind students that if one box stands for more than one cube, *all* the boxes will have to stand for the same number.

Once the class has decided how to calibrate the graph, fill in the numbers up the side on the transparency. Then ask one of the children to give you her 3 averages, the one for the ramp that was 1 block high, 2 blocks high, and 3 blocks high. Work with students to color in the appropriate columns on the transparency.

Session 10 Graphing the Data (cont.)



> ***Teacher*** *Thanks, Susannah, for letting us use your averages. If we were reading this graph for the first time, which column would show us how many Unifix cubes Susannah's marble rolled when the ramp was 1 block high?*
>
> ***Andy*** *The first one.*
>
> ***Teacher*** *And how many Unfix cubes did her marble roll that time, according to the graph?*
>
> ***Jake*** *About 2 and a half! No, wait a minute—I forgot that each box means more than 1.*
>
> ***Danielle*** *It's about 25, because you have 10, 20, and then half a box, which would be 5, so 25 in all.*

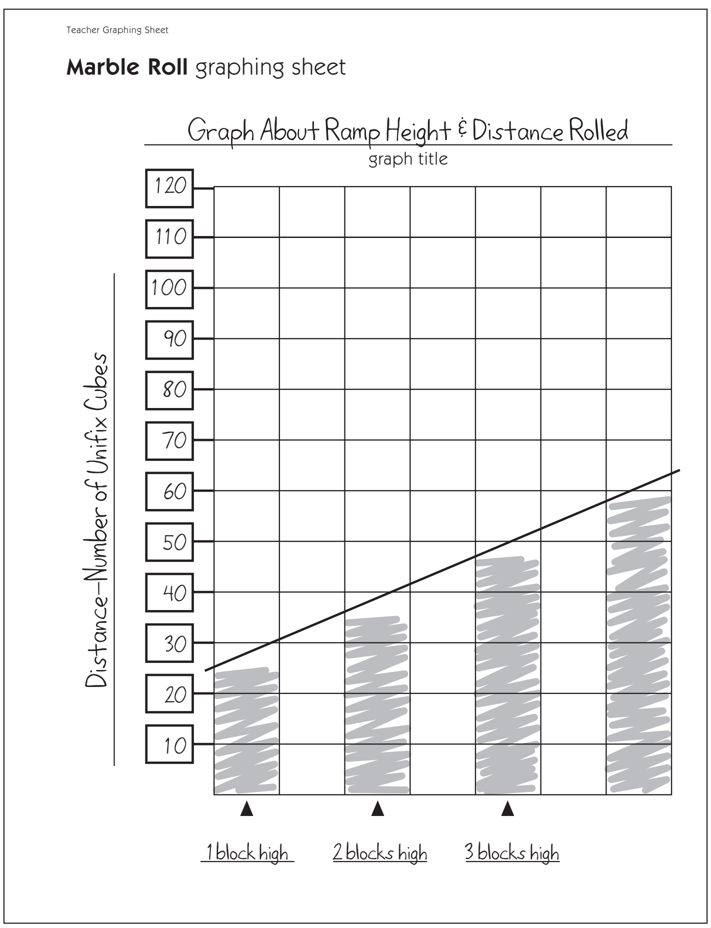
Continue this line of questioning for a minute or two and ask students to share any observations they have about the graph. What does it show about this experiment? As you work, discuss what the children will write on the line that's running vertically beside the boxes—the *y*-axis. What do the boxes along this axis indicate? (The average distance, measured in Unifix cubes.)

Session 10 Graphing the Data (cont.)

When most of your students have the general drift, send them out to work. They'll need their data sheets for Experiment 1 to graph the information. Encourage them to work as neatly and carefully as possible so their graphs will be easy to read. You might have them use crayons or colored pencils to fill in each column. This makes the finished graphs more attractive and easier to read. When they're finished, have them compare their graphs with those of other children and then turn them in.

Children who finish can graph their averages from Experiment 2 or Experiment 3 if they figured them. *You will need graphs from each experiment for Session 12.*

As children start to finish their first graphs, ask them to think about what might happen with a 4-block ramp. It's one thing to try to make such a prediction by looking at averages on a chart, and another to use a graph to help. We set the graphing form up in such a way that it would be possible to imagine a fourth set of trials. Some of our students really get a kick out of connecting the tops of their first three graphed averages and looking at where the fourth lands.



Session 10 Graphing the Data (cont.)

> ***Ele Tasia*** *Hey, look at this. When the ramp was 1 block high, the marble rolled 25 cubes. When it was 2 blocks high, it rolled 34. When it was 3 blocks high, it rolled 47. If I take a ruler and connect the tops of the columns and draw a straight line, I can kind of see where the graph would land for a ramp 4 blocks high. Looks like it would be about 58 or 59. It would be fun to see if a marble would really go that far off a 4-block ramp.*

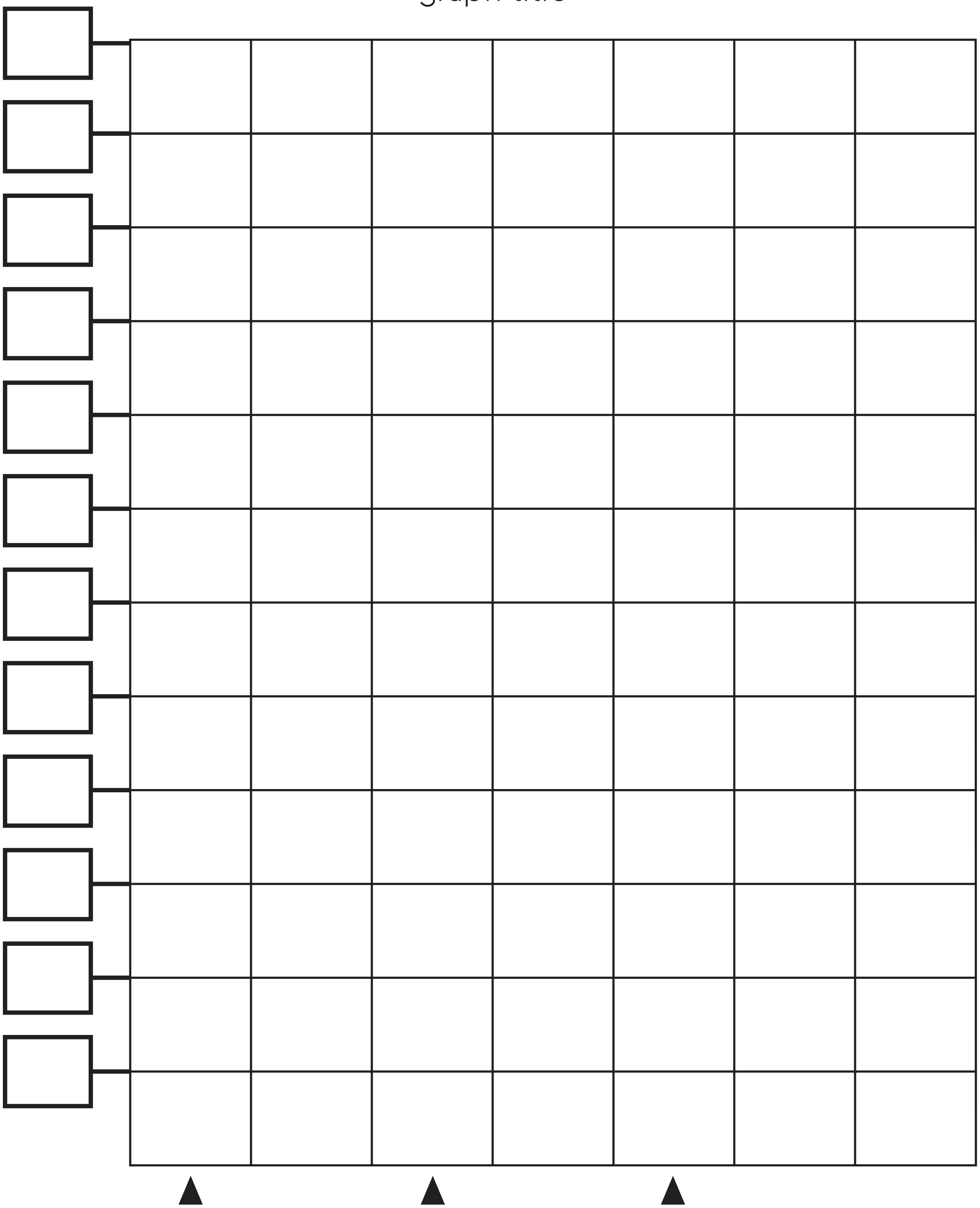
Note *Take some time now or later to have children answer the questions at the bottoms of their three experiment record sheets. By looking at their data tables and the graphs they've constructed, can they summarize what "really did happen" when they used higher ramps, marbles of greater mass, and longer ramps? Did the outcomes of these experiments match their predictions? Were they surprised about any of their results?*

NAME ______________________ **DATE** ______________________

Marble Roll graphing sheet

____

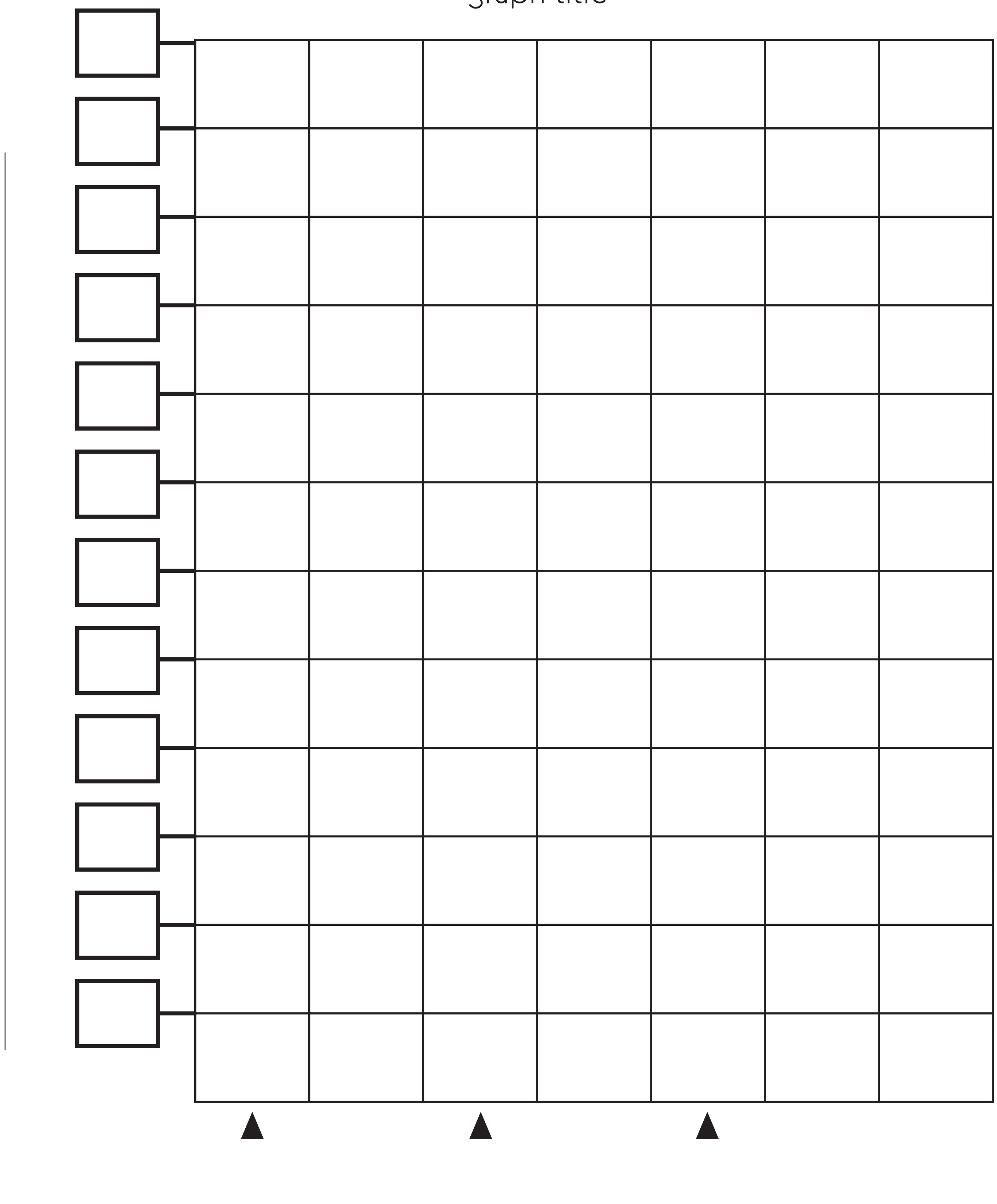
graph title



______________ ______________ ______________

Marble Roll graphing sheet

graph title



Session 11

PROBLEMS & INVESTIGATIONS

Designing Mega-Marble Rolls

Overview

In this session, children apply what they've learned about getting marbles to roll with varying speed and distance to the task of designing marble rolls that perform such "tricks" as getting marbles to roll uphill, turn corners, or knock over targets of various sorts.

Skills

★ reading and interpreting bar graphs

★ comparing data

★ applying learned information to new problems

★ making decisions about the approach, materials, and strategies to use in solving problems

★ drawing plans to solve specific problems

You'll need

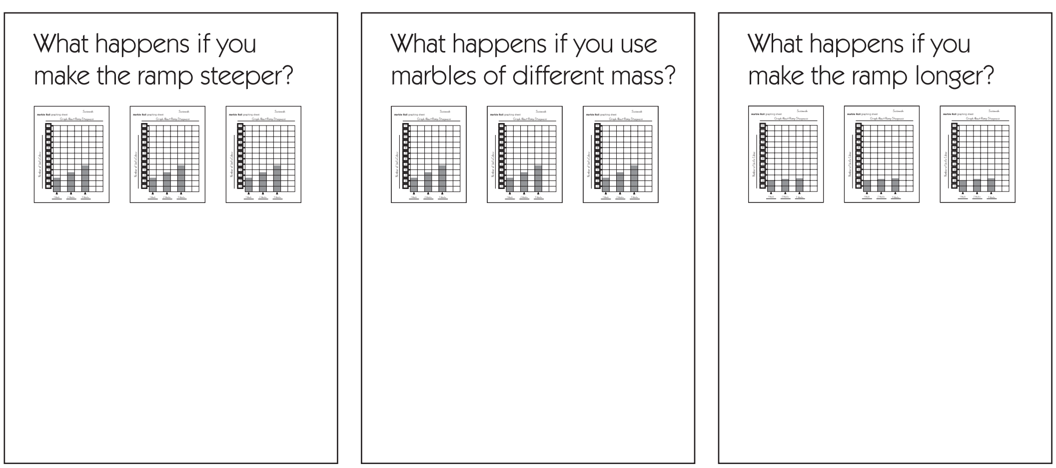
★ all the graphs students made during Session 10 posted where everyone can see them easily (1 for each experiment, as shown below.)

★ a different Marble Roll Problem for students, or pair of students (Blacklines 5–8; run a copy of each sheet and cut the problems apart. If you really want to be dramatic, fold each problem slip and put it in a sealed envelope.)

★ 8½″ × 14″ white copier paper, 1 sheet for every 1–2 children

★ scratch paper

★ gluesticks and pencils



Start this session by explaining to your students that they will now have an opportunity to use everything they've learned about marbles to design some new and specialized marble rolls—"mega-marble rolls." You will give out different problems that require different groups to get their marbles to do such things as roll across two tables, go through a hoop, and drop into a cup; *or* to

Session 11 Designing Mega-Marble Rolls (cont.)

roll downhill, then uphill, then downhill again; *or* to go downhill, turn a corner, go down a ramp, and knock over a target made of at least 25 plastic tile. There will be a need, in these mega-rolls, to control the speed or "push-power" of the marble. Sometimes the marble will need to go fast enough to knock over a target or travel uphill; other times, it will need to go slow enough that it won't fly off the ramp while it's turning a corner.

Take a few minutes to review some of the factors that influence a marble's speed—its push-power. Examine the graphs from all three experiments. What do they tell about the effects of increasing ramp height or ramp length? What are the effects of increasing marble mass? Would there be times when someone might want to make a ramp very long or very short, raise its height at one end or keep it level? Would there be times when one might choose a steel marble over a glass or wooden marble? Would there be times when a wooden marble would be the most advantageous? Children may find these factors and others very important to consider as they try to design marble rolls that will solve the problems they'll be assigned.

After your students have done a final analysis of their experimental results, explain that you are going to hand out different marble roll problems to pairs of children. Demonstrate that each problem has been copied onto a strip of paper by tearing open one of your sealed envelopes.

Marble Roll Problem 11

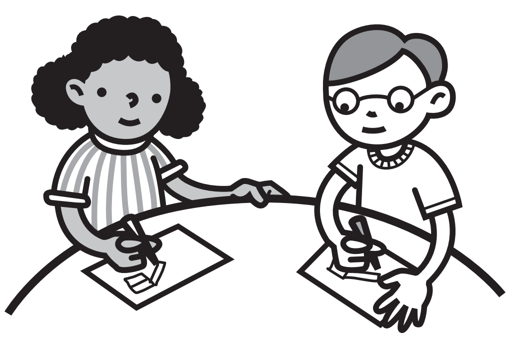
Make a marble roll that gets the marble to make a jump, go around a corner, and land in a cup at the end.

As each student or pair of students gets an envelope from you, they're to:

- Open the envelope and read their marble roll problem.
- Glue the strip to the top of their drawing paper.
- Do some talking about the problem and thinking about how to design a roll that will accomplish the assigned tasks.
- Maybe get some scratch paper to do some preliminary sketches.
- Draw a plan on the drawing paper for their marble roll.
- List the materials they'll need to carry out their plans, including *type of marble, length and number of tubes, tape, blocks, tables or chairs, and any items needed for targets* (*blocks, tile, dominoes*).

Children should also understand that the problem slips only pose the *minimum* requirements for their mega-rolls. This will be their last chance to build marble rolls and they'll really want to make these great. If their problem asks them to build a marble roll that has at least 2 downhill ramps and 2 uphill ramps, they're welcome to make other additions if they want. The pair of children with this particular assignment have to get their marble to go uphill twice and downhill twice, but can also have it turn a corner, make a jump, knock into a target, or drop into a cup. For some students, just developing a design that will accomplish the basic task will be enough, while others will enjoy designing (and actually building) many other twists and turns.

> ***Teacher*** *Evelyn, would you and Jesse like to be the first to come and get a marble-roll problem? Pick an envelope, any envelope!*
>
> ***Evelyn*** *Let's take this one, Jesse. I'll open it.*
>
> ***Jesse*** *What does it say?*
>
> ***Evelyn*** *"Make a marble roll that includes 2 jumps."*
>
> ***Jesse*** *Is that all? That'll be easy!*
>
> ***Evelyn*** *I don't know—you have to get your marble to go pretty fast to make a jump. And this says we have to get it to make 2 jumps, so it'll have to stay on the track after it's made the first jump so it can get to the second jump.*
>
> ***Teacher*** *Don't forget—you can make your marble roll fancier if you want. Two jumps is just the basic problem.*
>
> ***Evelyn*** *Come on, Jess—I'm starting to get some ideas. Let's go glue this strip to the top of our paper and start drawing plans.*
>
> ***Jesse*** *Can we each make a sketch? That way, we can put our ideas together at the end.*
>
> ***Evelyn*** *Okay, that sounds good.*



If you can circulate as children work it's a good time to listen in. While some will work in more intuitive ways, you'll hear others discussing quite seriously the factors they'll need to take into account to solve their problems. There may be a few who work mostly in the realm of fantasy, drawing gadgetry they won't actually be able to build. That's okay, although they'll probably find that they have to modify their plans the following session. It's also interesting to

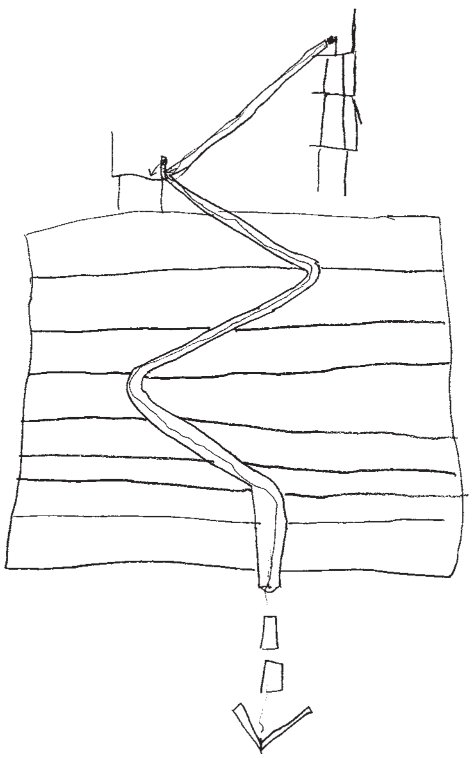
Session 11 Designing Mega-Marble Rolls (cont.)

see how well different children are able to give and take with a partner. Some will be inclined to impose their ideas on their partners, while others will be more able to listen and make compromises.

By the end of the session, students or pair of students will submit a drawing and a list of materials they'll need to build their final roll. Again, their list of materials should include the type of marble they want to use, the length and number of tubes they'll need, tape, blocks, any classroom furniture their structure will require, and any items needed for targets (blocks, tile, dominoes).

Names: Peter & Andrew

7. Make a marble roll that knocks over a target in the middle of the run and then keeps going.



We will need:

4 chars, 3 small lit in wat bloks.

A pis of papr.

4 long tobs 20 ½ tobs.

A stetl marbl

And most of all THE HALL!

Marble Roll Problems sheet 1

Marble Roll Problem 1

Make a marble roll that includes at least:

- 1 downhill ramp
- 1 uphill ramp
- 1 corner
- 1 jump

Marble Roll Problem 2

Make a marble roll that includes at least:

- 2 downhill ramps
- 2 uphill ramps

Marble Roll Problem 3

Make a marble roll that gets the marble to turn at least

1 corner and knock over 2 small square blocks at the end.

Marble Roll Problem 4

Make a marble roll that includes at least:

- 1 downhill ramp
- 1 uphill ramp
- 1 jump

Marble Roll Problems sheet 2

Marble Roll Problem 5
Make a marble roll that gets the marble to go down, then up, then down, then into a target made of 25 dominoes or plastic tile.

Marble Roll Problem 6
Make a marble roll in which the marble turns at least 1 corner, makes a jump, and travels down a ramp with enough speed to knock over some kind of target at the end.

Marble Roll Problem 7
Make a marble roll that knocks over a target in the middle of the run and then keeps going.

Marble Roll Problem 8
Make a marble roll that includes 2 jumps.

Marble Roll Problems sheet 3

Marble Roll Problem 9
Make a marble roll that goes across 2 tables, has the marble go through a paper hoop at some point and land in a cup.

Marble Roll Problem 10
Make a marble roll that gets the marble to roll with enough "push power" to knock over at least 1 building block at the end.

Marble Roll Problem 11
Make a marble roll that gets the marble to make a jump, go around a corner, and land in a cup at the end.

Marble Roll Problem 12
Make a marble roll in which the marble turns at least 3 corners before it stops.

Marble Roll Problems sheet 4

Marble Roll Problem 13

Make a marble roll in which the marble knocks over 2 different targets.

Marble Roll Problem 14

Make a marble roll that gets the marble to go down, then up, then down again, around a corner, and into a cup.

Marble Roll Problem 15

Make a marble roll in which the marble rolls at least half-way across the room and then knocks over some kind of target.

Session 12

PROBLEMS & INVESTIGATIONS

Building Mega-Marble Rolls

Overview
Children build the marble rolls they've designed and test them to see if they work. If modifications are necessary to get the marbles to perform specified "tricks," students make them right on the spot. When they're finished, they make drawings of their final marble rolls. Photographs may be taken to record their final work too.

Skills
★ applying learned information to new problems
★ building structures to solve specific problems
★ thinking flexibly and being willing to persevere in the face of challenge
★ working cooperatively

You'll need
★ a sack for each pair of children containing the materials they requested during Session 11, along with their plans
★ extra supplies—cardboard tubes of all lengths, marbles (cat's eyes, steel ball bearings, and wooden beads), small plastic yogurt or cottage cheese containers, plastic tile, blocks, dominoes
★ scissors and masking tape
★ 8½″ × 11″ white copier paper and pencils
★ camera and film—optional (It's really fun to take a photo of each finished marble roll. These mega-rolls aren't easy to build and can't be left up, so it's great to record the moment.)

This is the big day—the culmination of the Marble Roll unit. During this session, children will build their mega-marble rolls, and hopefully apply the theoretical and practical expertise they've developed over the past two weeks. The lesson itself is simple. You will send each student or pair of students out to work with the materials they requested and the plans they developed during the previous session. They are to work until they have constructed a marble roll that works; that is, performs the tasks specified by their Marble Roll Problem.

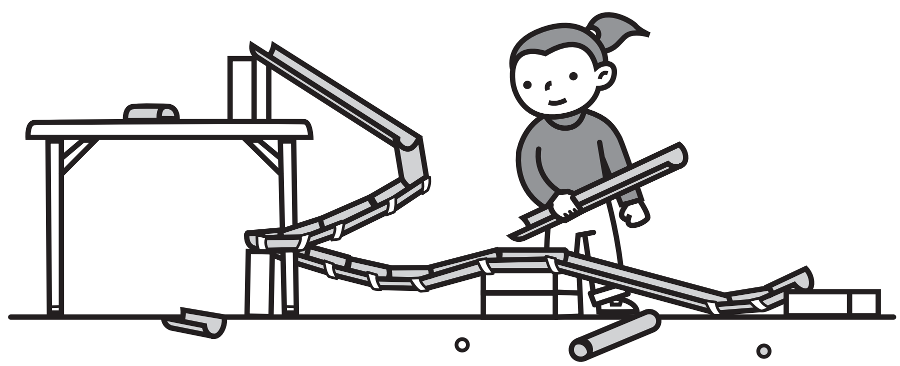
Here are a few tips to help things go more smoothly:

1. *Make sure the children understand that their finished marble roll doesn't have to look like the plan they drew up the day before.* Things might have looked easier, or at least different, on paper than they do in reality. *Their marble roll must, however, do a reasonable job of solving the assigned problem.* If the problem they selected and planned for last session specified that the marble was to make 2 downhill runs and 2 uphill runs, their finished marble roll must accomplish this task (or come as close to it as possible).

Session 12 Building Mega-Marble Rolls (cont.)

Note *If students do change their plans as they work, we don't ask them to redraw their plans. In many cases, children will have to make lots of modifications and adjustments in order to get their marble rolls to work. We do ask them to make a sketch of the completed structure when they're finished, partly so that we (and the children) can see the differences between their plans and the final creations.*

2. Be willing to have children take materials from your "extras" pile. It's quite possible they will have left something essential off their materials list, and once they've looked through their supply bag and discovered their error, they'll still need the tape or the marble they forgot to list. We keep extra marbles, tape, scissors, tubes, and blocks on hand, along with small plastic cups, tile and dominoes for targets, and paper strips to be curled into "hoops."



3. As children finish, have them do some or all of the following tasks:

a. Demonstrate to you that their marble roll works; that it solves the assigned problem.
b. Pose for a photograph with their completed marble roll. (Later, we have two prints made so that each partner can have one.)
c. Each draw a labeled diagram of their finished marble roll that they can compare to their original plan.
d. Leave their marble roll up until everyone has finished.

4. Resist the temptation to step in and help unless things get pretty desperate. We won't claim to be perfect here. In fact, we have intervened nearly every year, sometimes to separate a pair of children who absolutely aren't able to work together; sometimes to offer advice and a helping hand when children have been working for over an hour and aren't making much headway; sometimes to help tie, or tape, or steady a tube when two pairs of hands don't seem to be enough.

For the most part, though, we try to allow lots of time, be very patient, and offer support without stepping in. Children who do manage to get these marble rolls to work on their own are very, very proud of their work, and rightly so.

Session 12 Building Mega-Marble Rolls (cont.)

5. When everyone has finished, take time to have all the students in the class move around to one another's marble rolls. If you have a small group you can have them move together, stopping by each marble roll around the room for a demonstration. If you have a larger group, you might want to have half the children stay stationed at their rolls while the other half roams and visits, and then switch. Students won't see every roll demonstrated this way, but they'll have a chance to show some of their classmates what they've done and to see some of the marble rolls other children have created. One way or another, let each pair explain their assigned problem and show how their marble roll works. This offers some nice closure to the project, and children are excited to show their work to others.

Watching Children in Action

◀ **ASSESSMENT TIPS**

This project provides a wonderful opportunity to take note of children's work habits and social skills. Here are some behaviors you might observe as students work together on their structures:

- Perseverance in the face of challenge and frustration. Ability to stick with the task no matter what.

- Ability to make and follow plans—how closely does the finished product resemble the original plan? Children who are able to draw and execute their plans and actually have them work as expected often have a very high level of spatial intelligence, as well as a lot of drawing and building experience.

- Ability to be flexible if plans aren't working out. What happens when Plan A doesn't work? Can your students think of other ideas or are they stuck?

- Ability to collaborate with others. Are children able to work with their partners in a fairly equal fashion, with plenty of give and take? Are there students who dominate or take over and seem to need to run the show? Are there youngsters who shrink back and defer to others?

- Ability to apply previous experiences. You have to watch and listen closely for this. Some children will be able to verbalize how things ought to work, but they won't have the skills to make everything come together. Others might not be able to tell you much, but if you watch them work, tipping the tubes this way and that to create different angles and lengths, you can tell that they're applying some of the things they've learned over the past two weeks.

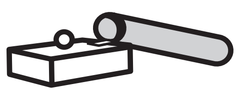
Session 13

ASSESSMENT

Thinking Back About Marble Rolls What Have We Learned?

Overview

Children use the Marble Roll "Picture Menu" shown on the next page to review the work they've done in the last few weeks. Then they complete a paper/pencil assessment that examines their current ability to measure length in nonstandard units, read and interpret a bar graph, and find averages. They also write about the unit, describing their favorite parts, the hardest things for them, and some of the things they learned.



You'll need

★ Marble Roll Picture Menu (Blackline 9, run a class set)

★ Thinking Back About Marble Rolls: What Have We Learned? (Blacklines 10–12, run a class set)

★ Unifix cubes

Skills

★ counting by 10's and 1's

★ measuring length

★ finding the average of 3 quantities

★ reading and interpreting a bar graph

To open the final session, explain that you're going to review what happened over the course of the marble roll unit, and then ask children to write about how it went for them and what they learned. Show the Marble Roll Picture Menu and have students take turns describing what they did at each step. The purpose of this review is to enable children to write more fully about the activities they liked, the parts that were hard for them and the things they learned at various points along the way. Unless you take time for this kind of retrospection, your students may have a hard time remembering much that came before the mega-marble rolls.

After reviewing the Picture Menu together, distribute copies of the Menu and the 3-page assessment to each child. (See opposite page.)

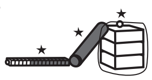
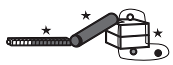
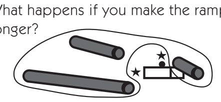
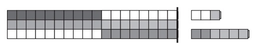
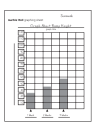
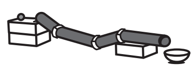
Read through the assessment sheets together and explain that the Picture Menu might help them remember (and see how to spell) some of the things they want to write about. Remind students that they're welcome to use the Unifix cubes to help with the counting and averaging tasks. Then send them off to work quietly by themselves.

Session 13 Thinking Back About Marble Rolls (cont.)

Blackline 9

Marble Roll Picture Menu

Marble Rolls Thinking Back About What We Did

1. Exploring Marbles and Ramps 	**2. Exploring Marbles and Ramps** Introducing Longer Ramps 
3. Exploring Marbles and Ramps: Introducing Marbles That Differ in Mass 	**4. Measuring Distances with Unifix Cubes** 
5. Marble Roll Experiment 1 What happens if you make the ramp higher? 	**6. Marble Roll Experiment 2** What happens if you use marbles of different mass? 
7. Marble Roll Experiment 3 What happens if you make the ramp longer? 	**8. Finding Average Distances** 
9. Graphing the Data 	**10. Designing and Building Mega-Marble Rolls** 

Blackline 10

NAME ______________________ **DATE** ____________

Thinking Back About Marble Rolls What Have We Learned? sheet 1

1 What are some of the things you learned during this math unit?

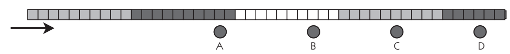
____

____

____

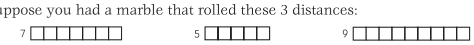
____

2 Tell how far each marble has rolled:



A _____ B _____ C _____ D _____

3 Suppose you had a marble that rolled these 3 distances:



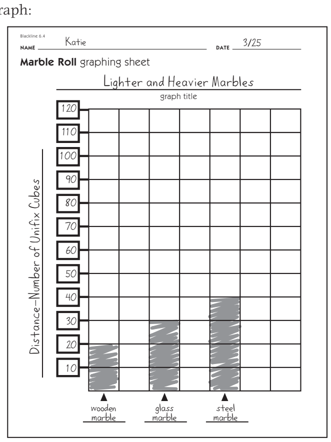
What would the average distance be? Use pictures, words, and/or numbers to show how you got your answer.

Blackline 11

NAME ______________________ **DATE** ____________

Thinking Back About Marble Rolls sheet 2

4 Look at this graph:



What marble rolled the farthest? ______________________

How far did the glass marble roll? ______________________

How much farther did the steel marble roll than the wooden marble? __________

What does this graph show?

____

____

____

Blackline 12

NAME ______________________ **DATE** ____________

Thinking Back About Marble Rolls sheet 3

5 What was your favorite part of the whole unit? Why?

____

____

____

6 Which part of the unit was the hardest for you? Why?

____

____

____

7 What would you change about this unit to make it better?

____

____

____

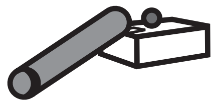
Session 13 Thinking Back About Marble Rolls (cont.)

You might consider saving these assessments in special Marble Roll folders. These folders could include the Marble Roll Picture Menu, all the record sheets from the unit, any graphs a student might have made, a copy of the plan for his or her mega-marble roll, the photo and drawing of the actual marble roll, and the assessment sheets. Such folders give children a nice way to share the unit with others.

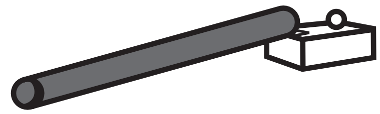
Marble Roll Picture Menu

Marble Rolls Thinking Back About What We Did

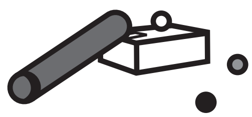
1. Exploring Marbles and Ramps



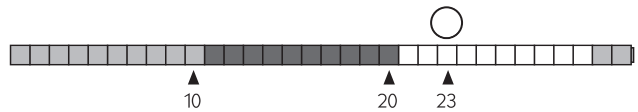
2. Exploring Marbles and Ramps
Introducing Longer Ramps



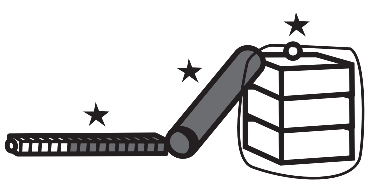
3. Exploring Marbles and Ramps:
Introducing Marbles That Differ in Mass



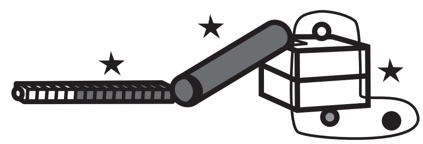
4. Measuring Distances with Unifix Cubes



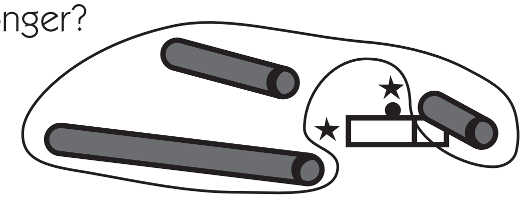
5. Marble Roll Experiment 1
What happens if you make the ramp higher?



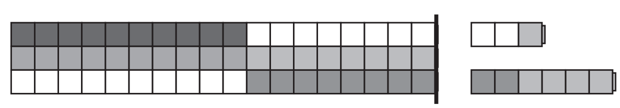
6. Marble Roll Experiment 2
What happens if you use marbles of different mass?



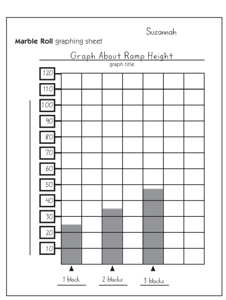
7. Marble Roll Experiment 3
What happens if you make the ramp longer?



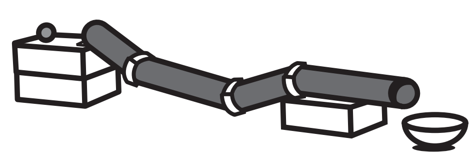
8. Finding Average Distances



9. Graphing the Data



10. Designing and Building Mega-Marble Rolls



NAME ______________________________ DATE ______________________________

Thinking Back About Marble Rolls What Have We Learned? sheet 1

1 What are some of the things you learned during this math unit?

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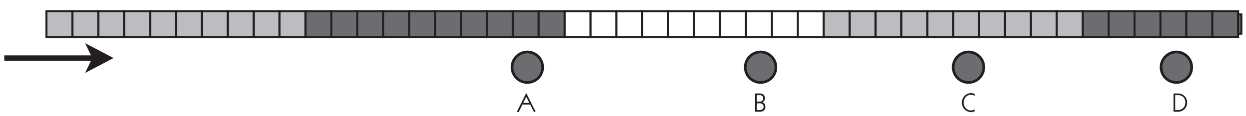
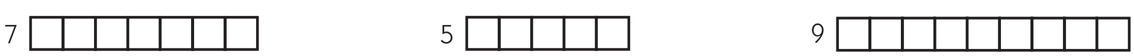
2 Tell how far each marble has rolled:



A ______ B ______ C ______ D ______

3 Suppose you had a marble that rolled these 3 distances:



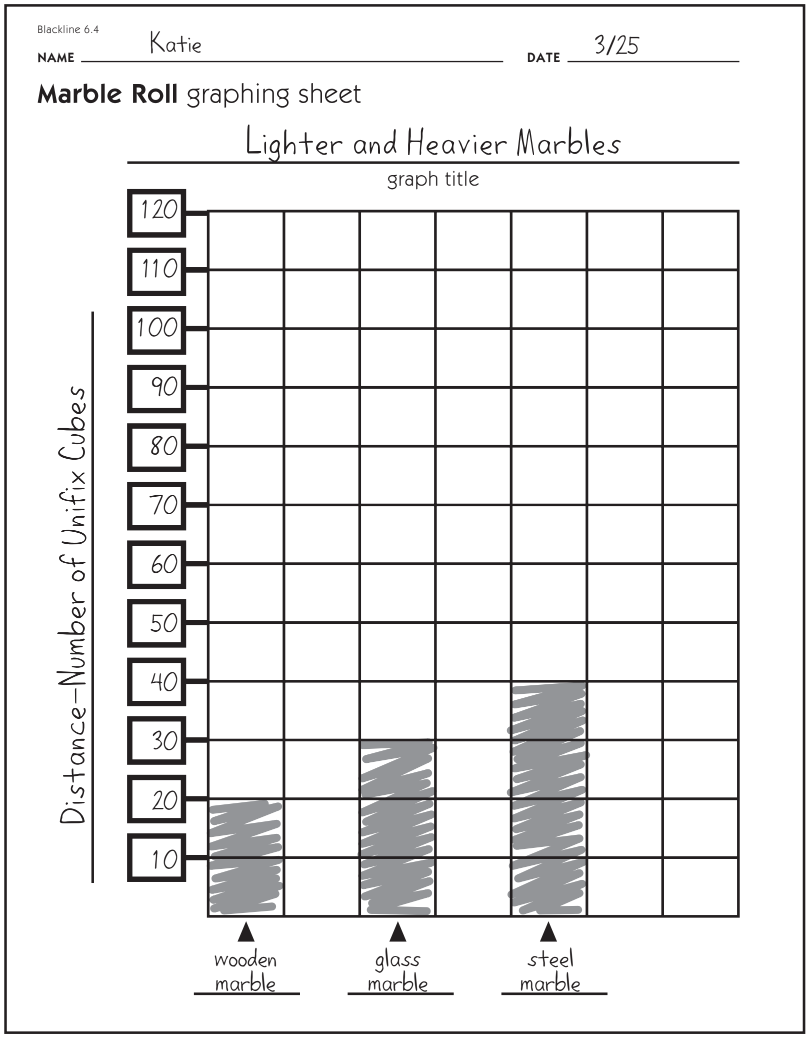
What would the average distance be? Use pictures, words, and/or numbers to show how you got your answer.

Blackline 11

NAME ______________________ **DATE** ______________________

Thinking Back About Marble Rolls sheet 2

4 Look at this graph:



What marble rolled the farthest? ______________________

How far did the glass marble roll? ______________________

How much farther did the steel marble roll than the wooden marble? __________

What does this graph show?

____

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NAME ______________________ DATE ______________________

Thinking Back About Marble Rolls sheet 3

5 What was your favorite part of the whole unit? Why?

6 Which part of the unit was the hardest for you? Why?

7 What would you change about this unit to make it better?