

LOOPS Teacher’s Manual

In the Concord Consortium LOOPS field-test, you will be teaching four related activities about motion and graphing that are described below. We have worked hard to improve the activities and the software system that they run on over previous field trials so that students and teachers find them engaging, easy to use, and well suited to the learning goals. However, the LOOPS project is not just a curriculum and technology development project. It is also a research project that seeks to clarify ideas about how technology may best be applied to classroom teaching and learning. Our main research question is: If teachers have instantaneous access to students’ on-going work through the use of technology, how best can that information be used? We have developed this manual to help you in understanding the goals of the curriculum and using the technology. We also want to provide some insight into “the experiment” that forms the heart of our research and your role in it.

Overview of Research:

Our research goal is to test different teaching patterns using the formative assessment within the LOOPS system. Therefore, we will be asking you to teach somewhat differently in your different classes. Specifically, we want to compare the use of frequent class discussions based on students’ submitted work, tied closely in time to the learning activities, to a pattern where all-class discussions are confined to the start of the class period, leaving more time for students to work individually and teachers to assist students individually.

To run this experiment, you will be acting as your own control. Half of your classes will follow the experimental protocol and half of your classes will follow the control protocol. For our research to be effective, it is very important that you adhere to the research protocol for the experimental and control classes. We do realize that this may be challenging as it may push you out of your most accustomed classroom habits. However, we believe that it will be a beneficial learning experience for us all. The table below is an example of the different patterns we hope to assess in this experiment.

Day	Control	Experiment
1	Full-Class Introduction Students work in groups – teacher follows work on tablets and provides individual instruction.	Full-Class Introduction Students work in groups – teacher follows work on tablets with periodic full-class discussions using student work.
2	Full-Class discussion using student work and introduction of new material. Students work in groups – teacher follows work on tablets and provides individual instruction.	Full-Class discussion using student work and introduction of new material. Students work in groups – teacher follows work on tablets with periodic full-class discussions using student work.
Etc.		

In this manual, we have articulated the curriculum’s learning goals and have indicated places where you can have discussions with your classes designed to achieve these goals. You are free to discuss other questions with your students in addition to the “required” discussions. However, the discussions in your control classes should be limited to the questions that you have discussed in your experimental classes, so that the discussion topics remain the same across both control and experimental classes.

Overview of Activities

These are inquiry activities. Although many definitions of inquiry activities exist, we define our inquiry activities as ones where students discover their own answers. Whenever possible, you should try not to answer your students' questions directly, but rather encourage them to devise experiments to find the answers. We wish to build students' confidence in their ability to discover their own answers.

In the first activity (**Missing Manual**), students explore qualitative aspects of graphing and motion. Using a motion probe students observe the correspondence between the shape of the curve on a position versus time graph and the kinesthetic motion of their bodies that created it. Learning goals are for students to relate the slope of the line to the speed and direction of their motion and the height of the line to their position in front of the probe.

In the second activity (**Modeling Motion**), students explore motion by manipulating a model that is tied to a graph, and also the reverse of this, namely drawing a graph to move a model. This begins the transition from a qualitative description of motion to a quantitative one. Here they begin to understand that graphs tell stories and that motion takes place in a frame of reference. They start to relate positions to actual locations and their numeric representation, explaining what a position-time graph represents. Finally, they start quantitatively comparing speeds by seeing how much distance is covered in a given interval of time.

In the third activity (**Making Measurements**), students return to using the motion probe. This activity emphasizes quantitative measurements made from the graphs of their body motion. After practicing making measurements of distance and duration, students use those skills to calculate speed. Students also formally capture their understanding of the frame of reference by drawing the number line defined by the probe, locating a picture of the probe on it.

In the final activity (**Telling Stories**), students practice interpreting graphs to elucidate the stories being told and drawing graphs from stories. They further practice their ability to turn slopes on graphs into calculated speeds and vice versa.

Learning Goals and Discussion Topics by Activity

Color Code for Activities described in the pages that follow:

Missing Manual

Modeling Motion

Making Measurements

Telling Stories

Missing Manual

Learning Goals:

1. Be able to interpret graphs of position vs. time and describe qualitatively
 - a) position is represented on the y-axis
 - b) time is represented on the x-axis
 - c) positive slope and negative slope relate to direction
 - d) steepness of slope relates to speed
 - e) duration can be measured on the x-axis
 - f) distance can be measured on the y-axis

2. Be able to create and interpret a number line/graph based on a frame of reference. Positions may be on a number line that may include negative numbers.

Try It Out

In this step, students learn about the motion probe. They make a graph of their motion and explain how they moved to make the lines on the graph.

The screenshot shows a web browser window with the title "LOOPS DIY - 39: Motion - Missing Manual - Fall 2011". The main content area is titled "The Missing Manual" and contains a "Try It Out" section. The instructions read: "Experiment with the motion probe. Work in teams. Take turns. One person is the 'computer operator' who starts, stops, and clears the graph. Another person is the 'mover' who stands in front of the probe and moves. Try different motions such as moving forwards and backwards and side-to-side. After you have had some time to experiment, make a graph and describe what you did. Click **Submit** to share what you discovered. You can always submit more than once." Below the text is a "Motion Sensor Graph" with a grid. The y-axis is labeled "Position (m)" and ranges from -1.5 to 2.5. The x-axis is labeled "Time (s)" and ranges from 0.0 to 20.0. Below the graph are buttons for "Start", "Stop", and "Clear". A text input field is labeled "Describe what you did to make this graph." Below the input field are "Submit" and "History" buttons. At the bottom center is a compass icon. A red bar at the bottom right contains the text "User Data Will Not Be Saved".

This is an opportunity to set expectations for students' work. It is not enough for the students to state that they "moved backwards and forwards." They should be looking at their movement and the line on the graph in conjunction; they should be able to define where on the graph they were moving toward the probe and away from the probe.

Does the description match the motion?

Things to Notice:

- 1) The slope of the line refers to the direction of movement and the speed of the movement.
- 2) Horizontal lines refer to no motion toward or away from the probe.
- 3) Some motions may not affect the line on the graph (sideways motions, up and down motions).
- 4) Focus on the qualitative aspects of the graph, not the quantitative aspects.

Draw a Landscape

In this step, students use the motion probe to make a landscape of two mountains on a plain, making qualitative observations about the shape produced. The mountains should be different heights and have different steepnesses.

The screenshot shows a software window titled "The Missing Manual" with a sub-window "Draw a Landscape". The main instruction is: "Use the motion probe to draw a 'picture' on the graph below. Draw a landscape of a flat plain with two mountains of different heights and steepnesses. Share the roles of mover and computer operator with your team. Submit when you are satisfied with your graph." The graph is titled "Two Mountains on a Plain" and has a y-axis labeled "Position (m)" ranging from -1.5 to 2.5 and an x-axis labeled "Time (s)" ranging from 0.0 to 20.0. Below the graph are buttons for "Start", "Stop", and "Clear". A text input field is labeled "Describe how you made this graph." Below that are "Submit" and "History" buttons. At the bottom center is a compass icon. A red bar at the bottom right contains the text "User Data Will Not Be Saved".

This activity is purposely qualitative in order to explore students' misconceptions about what lines on a position vs. time graph represent. Some students may think that the positive slope of the mountains is related to walking uphill, while the negative slope represents walking downhill. In reality, the motion that makes the mountain is the result of students walking away from the probe; the line represents the change in position rather than change in elevation.

Things to Notice:

- 1) Does the description match the motion?
- 2) Does the landscape meet the criteria (two mountains, different heights, different steepnesses, plain)?
- 3) How do you make a taller mountain?
- 4) How do you make a steeper (or more gentle-sloping) mountain?
- 5) Where do you stand to make the plain? (Different plains will be at different positions.)

Draw a Staircase

In this step, students use the motion probe to make a staircase. This is another purposely-qualitative exercise.

The screenshot shows a web browser window with the title "LOOPS DIY - 39: Motion - Missing Manual - Fall 2011". The main content area is titled "The Missing Manual" and contains a section "Draw a Staircase". Below the title, there is a text prompt: "Draw another picture, this time, of a staircase. Try making steep and gentle staircases. Think about how you control the height and width of the stairs. Then answer the question and submit." Below this is a graph titled "Staircase Graph". The graph has a vertical axis labeled "Position (m)" ranging from -1.5 to 2.5 with major ticks every 0.5 units and minor ticks every 0.1 units. The horizontal axis is labeled "Time (s)" ranging from 0.0 to 20.0 with major ticks every 0.5 units and minor ticks every 0.1 units. Below the graph is a control panel with a dashed line icon, a "Start" button, a "Stop" button, and a "Clear" button. Below the control panel is a text input field with the prompt "Describe how you made your staircase graph." At the bottom of the activity area are "Submit" and "History" buttons. At the very bottom of the browser window is a navigation bar with a compass icon and the text "User Data Will Not Be Saved".

Things to Notice:

- 1) What motion controls the height of the riser (height of each step on the graph)?
- 2) What motion controls the length of the tread (horizontal portion of the step)?
- 3) Can you tell by looking at the graph how it was made? Which direction, how fast, how far were the motions?
- 4) What do the axes of the graph show? Start to look at the graph in a more quantitative manner.

Predict Your Motion

In this step, students write a procedure for the motions needed to match the provided graph.

LOOPS DIY - 39: Motion - Missing Manual - Fall 2011

The Missing Manual

Predict Your Motion

We found part of the Missing Manual that contains the graph below, but the instructions for making the graph are missing! Study the graph and write a procedure to make the graph by moving in front of the motion probe.

A Simple Motion

Time (s)	Position (m)
0.0	-1.0
3.0	-1.0
6.0	1.0
9.0	1.0
12.0	0.0
15.0	0.0

Describe in detail the steps necessary to make this graph.

User Data Will Not Be Saved

This is a good place to remind your students that they need to be detailed in their procedures. Ideally, one student would write the procedure and the partner(s) would carry out the instructions exactly as they are written. Stress the importance of including as many details as possible to make the procedure very specific.

Things to Notice:

What do you need to describe in order to write a procedure that will produce a matching graph?

1. starting position
2. duration of motion
3. distance of motion
4. direction of motion
5. speed of motion (encompassed by 2,3, and 4)

Test Your Prediction

In this step, students check their procedure to see if it makes the same graph. Students are asked to reflect on what did not match and how their procedures should be changed to better match the provided graph.

The screenshot shows a software window titled "LOOPS Activity - The Missing Manual - OTrunk Tester". The main content area is titled "The Missing Manual" and contains a section "Test Your Prediction". Below the title, there is a paragraph of instructions: "Now, test your instructions (displayed below) with the motion probe! Follow your instructions carefully to see if you have correctly predicted the motion. If you find that you missed something, return to the previous page and revise your instructions and Submit them." Below this, it says "Your instructions:" followed by a list of controls: "New", "Delete", "Rename", "Prediction" (checked), and "Sensor" (checked). The central feature is a graph titled "Test Your Procedure" with "Position (m)" on the y-axis (ranging from -1.5 to 2.5) and "Time (s)" on the x-axis (ranging from 0.0 to 20.0). The graph shows a red line representing a motion profile: constant at -1.0 m from 0 to 3 s, increasing linearly to 1.0 m at 6 s, constant at 1.0 m until 9 s, decreasing linearly to 0.0 m at 12 s, and constant at 0.0 m until 15 s. Below the graph are "Start", "Stop", and "Clear" buttons. Underneath the graph is a text box with the prompt: "What did you need to revise in your procedure? Describe what you learned by revising your instructions." At the bottom of the interface are "Submit" and "History" buttons, and a directional pad icon.

Students' procedures will be shown in a non-mutable text box above the graph. The line that the students have to match will also be displayed on the "Test Your Procedure" graph.

Things to Notice:

- 1) Was the procedure detailed enough to accurately make the graph?
- 2) Was there enough information to follow? Did you skip any steps?

Modeling Motion

Learning Goals:

1. Be able to create and interpret a number line/graph based on a frame of reference. Positions may be on a number line that may include negative numbers.
2. Be able to interpret graphs of position vs. time and describe qualitatively
 - a) position is represented on the y-axis
 - b) time is represented on the x-axis
 - c) positive slope and negative slope relate to direction
 - d) steepness of slope relates to speed
 - e) duration can be measured on the x-axis
 - f) distance can be measured on the y-axis
3. Be able to interpret graphs of position vs. time and describe quantitatively the motion represented
 - a) measurements/calculations of distance between two positions
 - b) measurements/calculations of duration between two events
4. Be able to create a graph of position vs. time that matches a motion story.
5. Be able to calculate velocity from a position vs time graph.

Dog Walks Make Graphs

In this step, students use a model to create a motion story.

Dog Walks Make Graphs

Chico the Airedale Terrier often gets walks to the park to play with his dog friend Angie, a Chesapeake Bay Retriever. The park is in the center of town. Chico lives five blocks to the East of the park and Angie lives three blocks West of the park. Another popular destination for dogs, the Town Forest, is located five blocks West of the park.

Take Chico for a walk and see how he can make a graph! Click **Walk the Dog** and use your mouse or pen to walk Chico along the road and see how his motion is graphed below. After you have drawn a graph, you may **Play** the walk and **Reset** and **Play** again, then **Clear** it and draw another.

Experiment with the system, making Chico go fast and slow and stand still. Then, write a very simple dog walk story below and make a graph that shows the story and **Submit** your graph and story. Answer the questions that follow.

normal speed

Chico's Position vs. Time

Position (blocks)

Time (mins)

Play | Pause | Reset

One partner should write a very simple story of a dog walk for Chico. Another partner should draw the graph of the story. Then, Submit your graph and story.

User Data Will Not Be Saved

Things to Notice:

- 1) What information is necessary to make a motion story? (position, time, distance, speed)
- 2) Can you tell the motion in the story based only on the graph?

Walking the Dog

In this step, students use a model to create a graph based on a story.

The screenshot shows a simulation window titled "Walking the Dog" with the following components:

- Introduction:** "Chico is hoping to find his dog friend, Angie, and thinks that she may be at the park. Take Chico for the walk described in the story below. Just get as close as you can. Remember that you can always pause between each step."
- Model:** A number line from -5 to 5. A house is at -3 (labeled "Angie's"), and a park is at 0 (labeled "Park"). A dog icon labeled "Chico" is at 4. A "normal speed" slider is at the top.
- Buttons:** "Clear" and "Walk the Dog".
- Instructions:**
 - He leaves his house at 3:00 and dashes 2 minutes to the park.
 - He waits at the park for 2 minutes, then decides to go to Angie's house to look for her.
 - He sprints to Angie's house in 1 minute where he barks loudly, but Angie does not appear.
 - Dejected, he returns immediately to the park in 3 minutes and plays at the park for 4 minutes.
 - Exhausted after his play, he shuffles home, taking 4 minutes.
- Graph:** A graph titled "Chico's Walk - Position vs. Time". The y-axis is "Position (blocks)" from -6 to 6. The x-axis is "Time (mins)" from 0.0 to 20.0.
- Controls:** "Play", "Pause", "Reset", "Submit" (with a green checkmark), and "History".
- Question:** "What time does Chico get home?" with a radio button selected for "3:00".
- Compass:** A compass icon at the bottom center.
- Footer:** "User Data Will Not Be Saved"

What time does Chico get home?

- 3:00
- 3:15
- 3:16
- Not enough information to tell.

Submit

History

How many blocks is it from Chico's house to Angie's house?

- 2
- 7
- 8
- 8

Submit

History

Things to Notice:

- 1) How can you measure distances between positions on the model's number line and a graph?
- 2) How can you measure the duration of an event on a graph?
- 3) Use the multiple-choice item as a diagnostic to see how students have fared with calculating time.

Distractor Analysis for what time Chico gets home:

Choice 1: 3:00

Students who choose this answer may not have read the introduction fully, thinking that 3:00 is the time Chico got home; 3:00 is the time that Chico left home.

Choice 2: 3:15

Students who choose this answer may have missed the time that Chico went to Angie's house.

Choice 3: 3:16

This is the correct answer.

Choice 4: Not enough information to tell.

Students who choose this answer may not have drawn the graph correctly from the story.

- 4) Use the multiple-choice item as a diagnostic to see how students have fared with calculating distance.

Distractor Analysis for distance between Chico's house and Angie's house:

Choice 1: 2 blocks

Students who choose this answer may be subtracting the numbers for the positions.

Choice 2: 7 blocks

Students who choose this answer may be miscounting the intervals between Chico's house and Angie's house.

Choice 3: -8 blocks

Students who choose this answer may think that the distance is negative since one of the positions is negative.

Choice 4: 8 blocks

This is the correct answer.

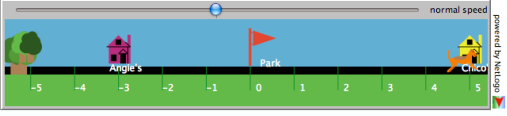
Graphs Make Dog Walks

In this step, students draw a graph to match a story and then check their graph with the model.

LOOPS DIY - 40: Modeling Motion - Fall 2011

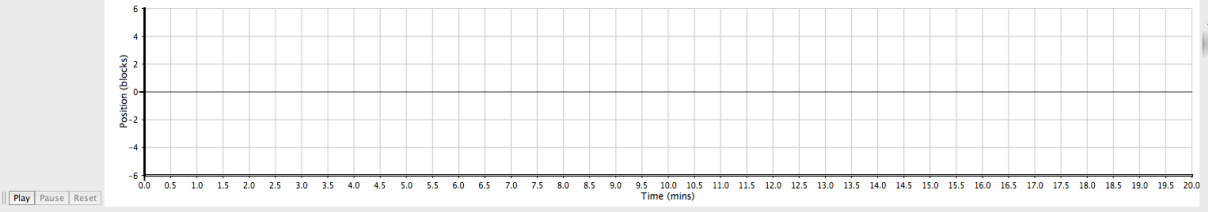
Graphs Make Dog Walks

Now, draw the graph of Chico's walk. The story is repeated below. Play the graph to check that it is accurate.



- He leaves his house at 3:00 and dashes 2 minutes to the park.
- He waits at the park for 2 minutes, then decides to go to Angie's house to look for her.
- He sprints to Angie's house in 1 minute where he barks loudly, but Angie does not appear.
- Dejected, he returns immediately to the park in 3 minutes and plays at the park for 4 minutes.
- Exhausted after his play, he shuffles home, taking 4 minutes.

Graph to Make Chico Walk



Buttons: Play, Pause, Reset, Clear, Submit, History

Where is Chico going the fastest? How can you tell?

Buttons: Submit, History

Where is Chico going the fastest? How can you tell?

Buttons: Submit, History

What was Chico's fastest speed in blocks per minute?

0.33
 0.4
 3.0
 2.5

Buttons: Submit, History

User Data Will Not Be Saved

Things to Notice:

- 1) How can you measure speed on a graph?
- 2) How is speed calculated? What is speed?
- 3) Use the multiple-choice item as a diagnostic to see how students have fared with calculating speed.

Distractor Analysis for Chico's Speed:

Choice 1: 0.33 blocks/minute

Students who choose this answer have transposed the numbers in the speed formula, dividing time by distance rather than distance by time.

Choice 2: 0.4 blocks/minute

Students who choose this answer have chosen the wrong interval (when Chico is going from his house to the park) for the fastest speed as well as transposing the values for time and distance.

Choice 3: 3.0 blocks/minute

This is the correct answer. Students who choose this answer have recognized that Chico is moving the fastest when he goes from Angie's house to the park.

Choice 4: 2.5 blocks/minute

Students who choose this answer have chosen the wrong interval (when Chico is going from his house to the park) for the fastest speed.

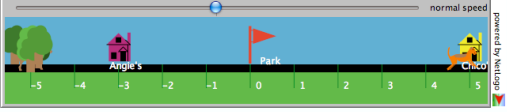
A Happier Ending

In this step, students add another line to the graph to show the story of Angie's journey.

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A Happier Ending

Let's make the story of Chico's walk have a happier ending. The graph you drew of Chico's walk appears below. Add Angie's story to it, and **Replay the graph to see if it is correct. Then submit your graph.**



- At 3:00 Angie was at the Town Forest hunting for squirrels.
- At 3:05 she hears Chico barking and runs to the Park in 3 minutes, meeting Chico just as he gets there.
- Angie and Chico frolic together at the Park for 4 minutes.
- Then, they trot off to their own homes. Angie arrives home in 3 minutes.

Angie's Walk

Position (blocks)

Time (mins)

Chico
Angie

Play Pause Reset

Clear

Submit ✓ History

Who is going faster--Chico going from his house to the park or Angie going from the forest to the park? How can you tell?

Submit History

Who is going faster--Chico going from his house to the park or Angie going from the forest to the park? How can you tell?

Submit History

When the dogs were going home from the park, who was going faster? How can you tell?

Submit History

User Data Will Not Be Saved

Things to Notice:

- 1) How can you tell from a graph which line indicates faster speed?
- 2) What if the directions of motion are opposite?

Making Measurements

Learning Goals:

1. Be able to create and interpret a number line/graph based on a frame of reference. Positions may be on a number line that may include negative numbers.
2. Be able to interpret graphs of position vs. time and describe quantitatively the motion represented
 - a) measurements/calculations of distance between two positions
 - b) measurements/calculations of duration between two events
3. Be able to calculate velocity from a position vs time graph.

The X-Axis: Time

In this step, students use the x-axis to make measurements of the duration between two jumps.

Making Measurements

The X-Axis: Time

The motion probe measures time on the horizontal axis, also known as the X-axis. The length of time between two events is called a duration. To practice measuring time, you will measure the duration between two jumps. Record this motion in front of the probe:

- Stand still and wait a while.
- Make a small jump toward or away from the probe, and wait a while again.
- Then jump back and stand still.

Use your graph to measure the time between the jumps. You can use the Labeling Tool on the right of the graph to help you read the time values.

Submit the graph and the answer the questions below.

Jumping Graph

Position (m)

Time (s)

----- | Start | Stop | Clear

How long was the duration between the two jumps? How did you get your answer?

Submit History

User Data Will Not Be Saved

Things to Notice:

- 1) How did you find the duration between two events?
- 2) How can you be more accurate in your measurements?

The Y-Axis: Position

In this step, students use motion probe to find the location of specific positions.

The screenshot shows a web browser window with the title "LOOPS DIY - 41: Making Measurements - Fall 2011". The main content area is titled "Making Measurements" and contains a sub-section "The Y-Axis: Position".

The text in the sub-section reads: "The motion probe measures position in meters on the vertical axis, also known as the Y-axis. Use the graph to draw a straight line at the indicated position, then answer the questions below. Submit the answers to the questions when you are done. A 1-meter measure is available to help you."

The first graph is titled "Finding Zero". The vertical axis is labeled "Position (m)" and ranges from -2.0 to 2.0 with major grid lines every 0.5 units. The horizontal axis is labeled "Time (s)" and ranges from 0.0 to 20.0 with major grid lines every 0.5 units. A horizontal line is drawn at the 0.0 position. Below the graph is a control panel with a dashed line icon, "Start", "Stop", and "Clear" buttons. Below the control panel is a text input field with the question "How far were you from the probe in meters?". Below the input field are "Submit" and "History" buttons.

The second graph is titled "Finding Negative One". The vertical axis is labeled "Position (m)" and ranges from -2.0 to 2.0 with major grid lines every 0.5 units. The horizontal axis is labeled "Time (s)" and ranges from 0.0 to 20.0 with major grid lines every 0.5 units. A horizontal line is drawn at the -1.0 position. Below the graph is a control panel with a dashed line icon, "Start", "Stop", and "Clear" buttons. Below the control panel is a text input field with the question "How far were you from the probe in meters?". Below the input field are "Submit" and "History" buttons.

At the bottom center of the interface is a compass icon with "N", "S", "E", and "W" labels. At the bottom right corner, there is a red bar with the text "User Data Will Not Be Saved".

Students will find the positions of zero, negative one, and positive one on separate motion graphs.

Things to Notice:

- 1) How can you find the location of specific positions? How did you figure it out?
- 2) Did everyone find the same distance for each position?

Frame of Reference

In this step, students draw a frame of reference on a piece of paper. The LOOPS project will provide paper for the students.

LOOPS Activity - Making Measurements - OTrunk Tester

Making Measurements

Frame of Reference

The number line on which motions occur can be called a frame of reference.

You will receive a piece of paper that has the picture below. Put numbers on the number line to show the position of the probe and the frame of reference that you discovered in the previous step. The interval between ticks is 0.5 meters. Mark positions zero, -1, and 1, and then put numbers at each tick mark.

The diagram shows a horizontal number line with 11 vertical tick marks. A small grey probe icon is positioned at the first tick mark on the left. The rest of the line is empty.

Navigation icons: a left arrow, a compass rose with N, S, E, W, and a right arrow.

User Data Will Not Be Saved!

Things to Notice:

- 1) How far from the probe are you when at position zero?
- 2) What is the motion probe's position?

Calculating Distances from Positions

In this step, students calculate distances between two positions.

Making Measurements

Calculating Distances from Positions

Draw on the graph below the movement described:

- stay still at 2 m for 4 s
- move to 1 m and stay still for 4 s
- move to -1 m and stay still for 4 s
- move to -2 m and stay still for 4 s

and Submit your graph.

Using Your Frame of Reference

Submit History

What is the distance between positions 2 and 1?

1
 2
 3
 4

Submit History

What is the distance between positions 1 and -1?

-2
 0
 1
 2

Submit History

What is the distance between positions -1 and -2?

-3
 -1
 1
 2

Submit History

Things to Notice:

- 1) Use the multiple-choice items as diagnostic devices to measure students' understanding of calculations.
- 2) How can the graph be used to measure distance between two locations?
- 3) Use the multiple-choice item as a diagnostic to see how students have fared with calculating distances from positions.

Distractor Analysis for distance between 2 and 1:

Choice 1: 1

This is the correct answer. The distance between 2 and 1 is 1.

Choice 2: 2

Students who choose this answer may be multiplying or dividing the numbers to find distance.

Choice 3: 3

Students who choose this answer may be adding the numbers to find the distance.

Choice 4: 4

Students who choose this answer may be reading the time intervals between the numbers (as they have drawn the graph).

Distractor Analysis for distance between 1 and -1:

Choice 1: -2

Students who choose this answer may think that since one position is negative the distance must also be negative.

Choice 2: 0

Students who choose this answer may be subtracting 1 from 1, since one of the numbers is negative.

Choice 3: 1

Students who choose this answer may think that distance can be calculated only from positive numbers.

Choice 4: 2

This answer is correct. The distance between 1 and -1 is 2.

Distractor Analysis for distance between -1 and -2:

Choice 1: -3

Students who choose this answer may be adding the numbers to find the distance since both are negative.

Choice 2: -1

Students who choose this answer may think that since both positions are negative, the distance must also be negative.

Choice 3: 1

This is the correct answer. The distance between -1 and -2 is 1.

Choice 4: 2

Students who choose this answer may be multiplying the numbers to find the distance between them.

Position and Distance

In this step, students calculate distances between two positions, using fractional numbers.

Position and Distance

Draw on the graph below the movement described:

- stay still at 1.25 m for 4 s
- move to 0.5 m and stay still for 4 s
- move to -0.5 m and stay still for 4 s
- move to -0.25 m and stay still for 4 s

and Submit your graph.

Measuring Distance between Two Positions

Submit History

What is the distance between position 0.5 to 1.25 meters?

-0.75
 0.5
 0.75
 1.2

Submit History

What is the distance between position 0.5 to -0.5 meters?

-1.0
 -0.25
 0
 1.0

Submit History

What is the distance between position -0.5 to -0.25 meters?

-0.75
 -0.25
 0.2
 0.25

Submit History

Things to Notice:

- 1) Use the multiple-choice items as diagnostic devices to measure students' understanding of calculations.
- 2) How can the graph be used to measure distance between two locations?
- 3) Use the multiple-choice item as a diagnostic to see how students have fared with calculating distances from positions.

Distractor Analysis for distance between 0.5 and 1.25:

Choice 1: -0.75

Students who choose this answer may have subtracted 1.25 from 0.5.

Choice 2: 0.5

Students who choose this answer may have forgotten about the .25 on the 1.25.

Choice 3: 0.75

This is the correct answer. The distance between 0.5 and 1.25 is 0.75.

Choice 4: 1.2

Students who choose this answer may think that the 5s cancel each other so they can be ignored.

Distractor Analysis for distance between 0.5 and -0.5:

Choice 1: -1.0

Students who choose this answer may think that the distance should be negative since one of the positions is negative.

Choice 2: -0.25

Students who choose this answer may be multiplying the numbers to find distance.

Choice 3: 0

Students who choose this answer may be adding the numbers to find the distance.

Choice 4: 1.0

This is the correct answer. The distance between 0.5 and -0.5 is 1.

Distractor Analysis for distance between -0.5 and -0.25:

Choice 1: -0.75

Students who choose this answer may be adding the numbers to find the distance.

Choice 2: -0.25

Students who choose this answer may think that the distance should be negative since both positions are negative.

Choice 3: 0.2

Students who choose this answer may think that the 5s cancel each other so they can be ignored.

Choice 4: 0.25

This is the correct answer. The distance between -0.5 and -0.25 is 0.25.

Measuring Giant Steps

In this step, students calculate the length of one giant step.

The screenshot shows a software window titled "Making Measurements" with a sub-section "Measuring Giant Steps". On the left, there is a photo of a person jumping. To the right of the photo, text instructs the user to use a probe and graph to measure the distance of one giant step. Below the text is a "Giant Step Graph" with a y-axis labeled "Position (m)" ranging from -2.0 to 2.0 and an x-axis labeled "Time (s)" ranging from 0.0 to 20.0. The graph is currently empty. To the left of the graph are buttons for "New", "Delete", "Rename", and a checked "Sensor" option. Below the graph are "Start", "Stop", and "Clear" buttons. At the bottom of the graph area is a text input field with the prompt "How long were each of your team members' giant steps? Describe how you measured these distances." and a "Submit" button. A "History" button is located at the bottom right of the graph area. At the bottom center of the window is a compass icon. The bottom right corner of the window displays the text "User Data Will Not Be Saved".

Things to Notice:

- 1) Do the calculations of step length match what's shown on the graph?
- 2) How did different students make their giant steps?
- 3) Who has the longest giant step?

Measuring Speed

In this step, students calculate the speed of their walking.

The screenshot shows a web application window titled "Making Measurements" with a sub-section "Measuring Speed". The main content area contains the following text:

Can you walk heel-to-toe, heel-to-toe at a uniform speed? Can you find out with the motion probe?

So far, you have measured distance and time. Can you measure speed? **Speed is distance** divided by the **time** it took to go that distance.

Create a graph of heel-to-toe walking. Place labels on your graph to help you make measurements and explain how you got your measurements.

Submit the graph and the answer to the question below.

The graph is titled "Measuring Speed" and has "Position (m)" on the y-axis (ranging from -2.0 to 2.0) and "Time (s)" on the x-axis (ranging from 0.0 to 20.0). To the left of the graph are controls: "New", "Delete", "Rename", and checkboxes for "Jake" and "Pete". Below the graph are "Start", "Stop", and "Clear" buttons. Below the graph is a text input field with the question: "What is the speed of the heel-to-toe walking shown on your graph? How did you find your answer?". At the bottom of the input area are "Submit" and "History" buttons. A compass icon is located at the bottom center of the application window.

Things to Notice:

- 1) Which portion of the graph did you measure? Was that a valid interval to measure speed?
- 2) Did you use the same points to measure time and distance?
- 3) Is this a constant speed (qualitative look at slope)?
- 4) Who was faster? How can you tell?
- 5) In which direction did you walk? Does it make a difference?

Telling Stories

Learning Goals:

1. Be able to create and interpret a number line/graph based on a frame of reference. Positions may be on a number line that may include negative numbers.
2. Be able to interpret graphs of position vs. time and describe quantitatively the motion represented
 - a) measurements/calculations of distance between two positions
 - b) measurements/calculations of duration between two events
3. Be able to create a graph of position vs. time that matches a motion story.
4. Be able to calculate velocity from a position vs. time graph.

A Race! (1)

In this step, students interpret a graph with two lines.

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Telling a Story

A Race! (1)

The graph below tells a story about a race between Isabel and Shanice. Use this graph to help you answer the questions. Remember to submit your answers.

What is the position of the finish line?
 0.6
 2
 20
 22

Submit History

Who won the race?
 Isabel
 Shanice
 tie

Submit History

When did the first finisher cross the finish line?
 2
 6
 20
 22

Submit History

Position Graph

Time (minutes)	Isabel (miles)	Shanice (miles)
0	0.0	0.0
3	0.3	0.6
4	0.4	0.6
5	0.5	0.6
6	0.6	0.6
7	0.7	0.6
8	0.8	0.6
9	0.9	0.6
10	1.0	0.6
11	1.1	0.6
12	1.2	0.6
13	1.3	0.6
14	1.4	0.6
15	1.5	0.6
16	1.6	1.2
17	1.7	1.5
18	1.8	1.8
19	1.9	1.9
20	2.0	2.0
21	2.0	2.0
22	2.0	2.0
23	2.0	2.0
24	2.0	2.0

User Data Will Not Be Saved

Things to Notice:

- 1) Multiple-choice items provide diagnostic opportunities.
- 2) Use the multiple-choice item as a diagnostic to see how students have understood the graph.

Distractor Analysis for position of the finish line:

Choice 1: 0.6

Students who choose this answer may think that the race ends when Shanice stops moving.

Choice 2: 2

This is the correct answer.

Choice 3: 20

Students who choose this answer think that the time that it takes Isabel to run the race is the position of the finish line. Students are looking for position on the wrong (x) axis.

Choice 4: 22

Students who choose this answer think that the time that it takes Shanice to run the race is the position of the finish line. Students are looking for position on the wrong (x) axis.

Distractor Analysis for who won the race:

Choice 1: Isabel

This is the correct answer.

Choice 2: Shanice

Students who choose this answer may think that the race ends at the 0.6 mile position when Shanice stops moving and that the rest of the motion shows the girls' motions after the race has ended.

Distractor Analysis for when the first finisher crossed the finish line:

Choice 1: 2

Students who choose this answer are looking for time on the wrong (y) axis.

Choice 2: 6

Students who choose this answer may think that crossing the finish line is shown when the lines showing Shanice's and Isabel's movements cross at the 6 minute mark.

Choice 3: 20

This is the correct answer.

Choice 4: 22

Students who choose this answer may think that Shanice was the first finisher.

A Race! (2)

In this step, students interpret a graph with two lines.

The screenshot shows a web application window titled "Telling a Story" with a sub-header "A Race! (2)". The main content area contains three questions and a graph. The first question is a multiple-choice item: "How many minutes into the race did Isabel pass Shanice?" with options 0, 6, 20, and 22. The second question is a text input: "How fast did Isabel run? How did you calculate her speed?". The third question is another text input: "What well-known story matches the race?". To the right of the questions is a "Position Graph" with "Position (miles)" on the y-axis (0.0 to 2.0) and "Time (minutes)" on the x-axis (0 to 24). A legend indicates Isabel is represented by a red line with 'x' markers and Shanice by a green line with 'x' markers. Isabel's line starts at (0,0) and increases linearly to (20, 2.0). Shanice's line starts at (0,0), increases to (3, 0.6), stays constant at 0.6 miles until 15 minutes, then increases to (20, 2.0) and stays constant at 2.0 miles until 24 minutes. The lines intersect at (6, 0.6).

How many minutes into the race did Isabel pass Shanice?

0
 6
 20
 22

Submit History

How fast did Isabel run? How did you calculate her speed?

Submit History

What well-known story matches the race?

Submit History

Position Graph

Position (miles)

Time (minutes)

Isabel
Shanice

User Data Will Not Be Saved

Things to Notice:

- 1) Use the multiple-choice item as a diagnostic to see how students have understood the graph.

Distractor Analysis for how many minutes into the race Isabel passed Shanice:

Choice 1: 0

Students who choose this answer may think that Isabel passed Shanice at the start line.

Choice 2: 6

This is the correct answer.

Choice 3: 20

Students who choose this answer think that Isabel passed Shanice when she crossed the finish line.

Choice 4: 22

Students who choose this answer think that Isabel passed Shanice when Shanice crossed the finish line.

- 2) Remind students that speed has units (distance and time). Have them think about the units to remember how to arrange the numbers in the formula.

The Pony Express

In this step, students draw a graph from a story.

The screenshot shows a web application window titled "Telling a Story" with the following content:

Laramie, Wyoming is 50 miles west of Cheyenne. Along the way between them there are two towns. Twenty miles west of Cheyenne is Granite and Buford is 10 miles beyond Granite. On the route, there are mile markers every 10 miles as shown below. The pony express needs to make a delivery from Cheyenne to Laramie. Below is the story of how it traveled. Draw a graph that tells the story of the Pony Express's trip.

Laramie Buford Granite Cheyenne
50 40 30 20 10 0

- The Pony Express travels from Cheyenne to Granite in 2 hours.
- In Granite, the pony and rider take a 1 hour rest.
- Then they leave Granite and reach Buford in 1 hour, but there, the pony throws a shoe.
- To fix the shoe, they have to go back to Granite. The pony has to limp back, so it takes 2 hours.
- In Granite they get a fresh pony, and travel to Laramie at a speed of 15 miles per hour.
- There are no more stops, and the pony and rider arrive without further incident.

Pony Express Trip

Position (miles)

Time (hours)

Clear

Submit

History

How long in hours was the trip from Granite to Laramie?

1

2

3

5

User Data Will Not Be Saved

Things to Notice:

- 1) How did you decide how to draw the last segment of the graph?
- 2) How do you calculate time from a speed and a distance?
- 3) Use the multiple-choice item as a diagnostic to see how students have fared with calculating time.

Distractor Analysis for time of the trip from Granite to Laramie:

Choice 1: 1 hour

Students who choose this answer may think that the time spent resting in Granite is the time for the trip from Granite to Laramie.

Choice 2: 2 hours

This is the correct answer. At a speed of 15 miles per hour, the 30 mile trip between Granite and Laramie would take 2 hours.

Choice 3: 3 hours

Students who choose this answer may be adding the time spent to get to Granite (from Cheyenne) with the rest at Granite, or they may be adding the time it takes to get to Granite via Buford (1 hour plus 2 hours of limping back).

Choice 4: 5 hours

Students who choose this answer may be adding all of the times to get to Granite and Laramie (1 hour to get to Buford from Granite, 2 hours to limp back to Granite, and 2 hours to get from Granite to Laramie).

The Bank Job

In this step, students draw two interlinked stories on the same graph. They can check their graph by playing the model.

The screenshot shows a software interface for a math activity. At the top, it says "Telling a Story" and "The Bank Job". Below this is a map with a coordinate line from -10 to 10. A yellow house is at 5, a bank is at -10, a forest is at 0, and a police station is at 10. A blue car is at -4 and a red car is at 9. Below the map are buttons for "Setup" and "Move Cars".

The text describes two stories:

- Robbers' Story:** Bank robbers leave their yellow house travelling slowly toward the bank at a speed of 3 blocks per minute. They stop in front of the bank, and take 2 minutes to rob the bank. Then they leave the bank and drive at a speed of 5 blocks per minutes until they reach the forest. Then they hear a police siren, get scared, turn around, and drive faster than they have ever driven before. In 1 minute the police overtake them and bring them to a stop.
- Police's Story:** Four minutes after the robbers left their house, the police, who have been at the station, drive to the forest in 4 minutes where they set up a routine speed trap. Shortly, their radar picks up a car headed toward them going too fast, and they turn on their siren. The police see the speeding car turn around, and they chase the car in hot pursuit. In 1 minute they bring the car to a stop, and then find out it's the robbers and arrest them.

Below the text is a "Car Graph Prediction" graph. The y-axis is "Position (km)" from -10 to 10. The x-axis is "Time (minutes)" from 0.0 to 15.0. There are checkboxes for "Police" and "Robbers". Below the graph are buttons for "Play", "Pause", "Reset", "Clear", "Submit", and "History".

Things to Notice:

- 1) Does the graph match the stories?
- 2) How did you draw the robbers' story?

Creating a Story

In this step, students create a story to match a graph.

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Telling a Story

Creating a story

The position of a train traveling between three stations is shown on the graph below. Distances are in miles, and time is in minutes. Station A is at position 0, Station B is at position 10, and Station C is at position 25. Create a story about a train trip that matches the graph. Feel free to invent characters and actions. What might have happened, for example, after 35 minutes?

After you submit your story you'll be able to see some of the class' stories on the next page if your teacher chooses several and releases them for viewing.

Train Story Graph

Time (minutes)	Position (miles)
0	0
10	10
20	10
25	10
30	12
35	15
40	12
45	10
50	5
55	0
60	0
65	0
70	10
75	15
80	20
85	25
90	25
95	25

Station A Station B Station C

Position (miles)

Time (minutes)

User Data Will Not Be Saved

Things to Notice:

- 1) Does the story match the graph?
- 2) Is there enough detail in the story to draw the graph?