Teachers Teaching with Technology™
Professional Development from Texas Instruments

Physics with TI-Nspire™ and TI-Nspire™ Navigator™ – Day 2

I can…	TI-Nspire™ Handheld (HH) Data Collection (DC) TI-Nspire™ Navigator™ (Nav)
Open the TI-Nspire™ CX Navigator™ Teacher Software.	Nav
Use the Documents Workspace.	Nav
Create a class/start class.	Nav
Locate a TI-Nspire™ document on the website.	Nav
Save and identify the components of the activity.	Nav
Send a TI-Nspire™ document to my class in multiple ways.	Nav
Use Class Capture to capture students' screens.	Nav
Use Live Presenter in the classroom setting.	Nav
Show and hide student names in the Class Capture.	Nav
Refresh students' screens in the Class Capture.	Nav
Use the Quick Poll feature of TI-Nspire™ Navigator™.	Nav
Use data aggregation to collect points or lists from the class.	Nav
Linearize data with the Vernier DataQuest™ application	HH/DC
Collect linear data with the CBR 2™ and the Vernier DataQuest™ application.	HH/DC
Find an equation for the linear data using more than one method.	HH/DC

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The TI-Nspire™ CX Navigator™ Science Classroom

TI PROFESSIONAL DEVELOPMENT

Objective

- Perform various TI-Nspire™ CX Navigator™ skills demonstrated in previous activities.

TI-Nspire™ Technology Skills:

- Opening and navigating a TI-Nspire™ document

About the Lesson

- Participants will role-play in this activity as a teacher and/or a student.
- The participant playing the role of the teacher will conduct a directed lesson using the features of the TI-Nspire™ CX Navigator™ System.
- The participant playing the role of the student will perform the tasks of a student for the lesson.
- Participants should then switch roles and repeat the process for another lesson.

Lesson Materials:

Equipment

- Computer with TI-Nspire™ CX Navigator™ Teacher Software (for a pair of participants) with two USB ports
- Two TI-Nspire™ CX learning handhelds per participant
- Standard A to Mini-B USB Cables

TI-Nspire™ Navigator™ Features

- Setting Up a Class
- Sending a Document
- Class Capture
- Live Presenter
- Quick Poll
- Portfolio Workspace
- Student Data

Roles

Working in pairs, assign one role as the teacher and one role as the student. The “teacher” will operate the computer, and the “student” will operate two TI-Nspire™ handhelds. Participants will have an opportunity to switch and experience both roles.

Instructions

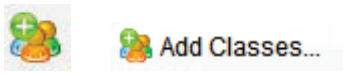
If a step below has **Teacher** in front of it, the participant operating the computer will perform the task. If the instruction has **Student** in front of it, the participant operating the TI-Nspire handhelds will perform the task.

Adding a Class

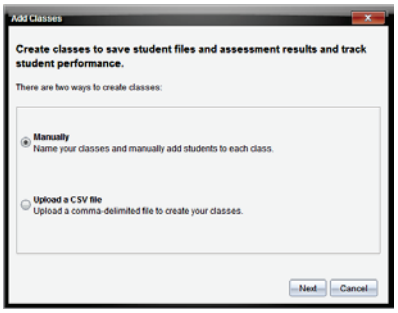
Version	TI-Nspire	CAS
v4.x		
v3.9		

1. **Teacher:** Open the Teacher Software on the computer by double-clicking the Teacher Software icon on the desktop.
    - If necessary, close the Welcome Screen.
2. **Teacher:** If necessary, open the Class workspace by clicking on the **Class** tab.

3. **Teacher:** Select the **Add Classes** icon from the tool bar, or select **Add Classes** from the **Class** menu.

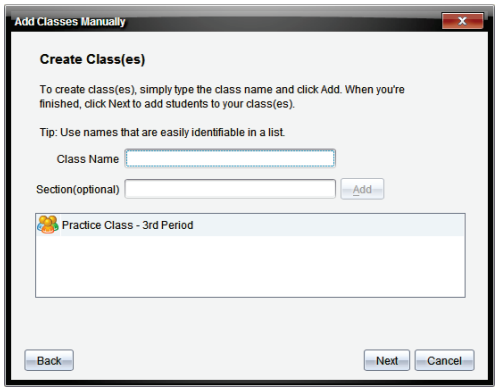


4. **Teacher:** Click on **NEXT** to enter the class and students manually.
    - The process for uploading a CSV file to create classes is located in a tip sheet. It can be discussed at a later time.



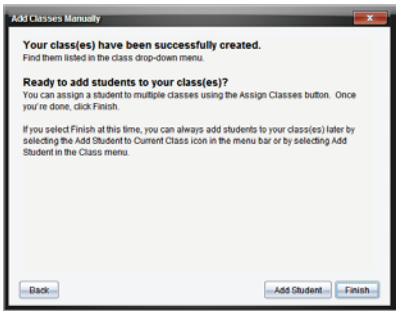
5. **Teacher:** Enter “Practice Class” as the class name and “3rd Period” as the section.
    - It is not necessary to complete the Section field. But it allows teachers to name classes by subject only (e.g. Algebra) and use the section field to distinguish between classes of the same subject (e.g. 3rd Period).

6. **Teacher:** Click on the **Add** button.

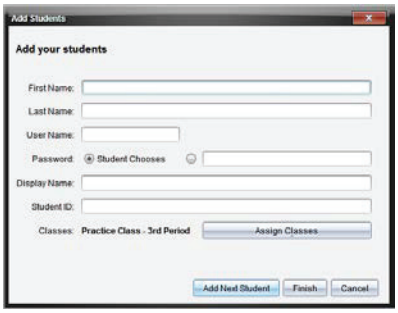


7. **Teacher:** Click **Next**.

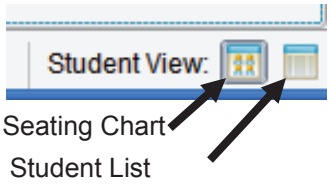
Adding Students



1. **Teacher:** To immediately add students to the class, click the **Add Student** button.
   - If the teacher closes the Class Wizard by clicking **Finish**, select the **Add Student** icon or select **Add Student** from the **Class** menu.

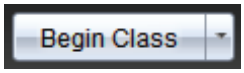


2. **Teacher:** For each student below, enter the first name, last name, and user name into the Add Students window. Select **Add Next Student** to add another student.
   - Jon, Smith, Jon
   - Deb, Jones, Deb
   - Marco, Polo, Marco
   - Sonja, Perez, Sonja
   - Raymone, Tyson, Raymone
3. **Teacher:** You can choose a password for each student, or each student can choose his or her own password when they log in to the class for the first time.
   - This will then be the student's password unless the teacher chooses to reset it.
   - By default, the Display Name is the student's first name. The Display Name can be edited as desired.
   - The Student ID is optional but sometimes important if you want to import grades into grade book software.
4. **Teacher:** After the last student's name is entered, click **Finish**.
5. **Teacher:** To switch the student view between **Seating Chart** and **Student List**, use the Student View icons in the lower right corner of the software.



Log in Students

1. **Teacher:** Begin the class by clicking **Begin Class**.
   - Each student's icon should change from light gray to light blue/yellow.

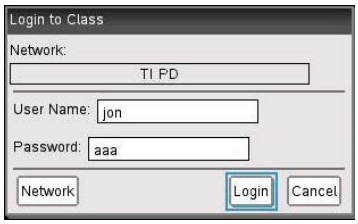


2. **Teacher:** Connect both of the TI-Nspire™ handhelds to your computer using USB cables. One end goes into your computer's USB port and the other into the TI-Nspire™ handheld.

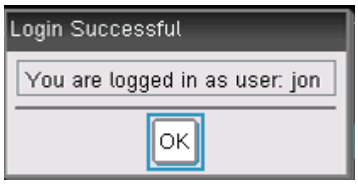
Note: In your classroom, each student's handheld will not be connected to your computer in this way. They will each have their own wireless module that will communicate with your computer.

3. **Student:** Turn on each handheld.

4. **Student:** Log in a student on one of the handhelds.
   - The login window should pop up on the handheld's screen.
   - If it does not, press [on] to access the Home screen, select [5] for Settings and [5] for Login.



5. **Student:** Type **jon** as the username of one handheld, press ▼ on the Touchpad/Clickpad, type **abc** as the password, and press [enter].
   - You will see a message pop up on the handheld stating: "You are logged in as user: jon"



6. **Student:** Press [ctrl] to select the OK button.

Note: The passwords used can be the same for all students or unique to each individual. Some teachers assign everyone the same password so that they do not have to reset any passwords. Some teachers allow students to pick their own passwords.

7. **Student:** Log in as **deb** on the other handheld.
   - If necessary, press [on] to access the Home screen, select [5] for Settings & Status and [5] for Login.
   - **Student:** Type **deb** as the username of another handheld, press ▼ on the Touchpad/Clickpad, type **abc** as her password, and press [enter].
   - You will see a message pop up on the handheld stating: "You are logged in as user: deb"

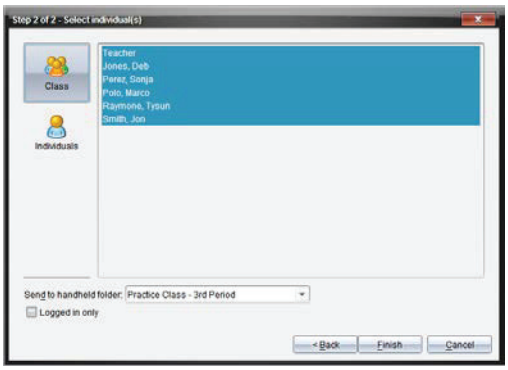
8. **Student:** Press [ctrl] to select the OK button.

Send a Document

1. **Teacher:** Click **Send to Class**.

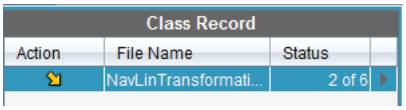
2. **Teacher:** Browse for the TI-Nspire™ document titled *Density_of_Metals.tns* provided for this activity in the location specified by your instructor. Click on the TI-Nspire™ document name so that it is highlighted.
   - Each person, when in the Teacher role, should use *Density_of_Metals.tns*.

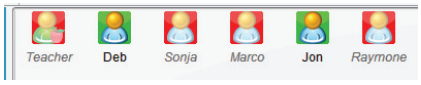
3. **Teacher:** Click **Finish** to send the document to the handhelds.



   - You are able to send a document to specific individuals. However, the default is to send to the entire class. This is advisable because late students automatically get the document after they log in with minimal disruption.
   - You do not have to wait until the students log in before sending a TI-Nspire™ document. Documents can be sent any time after a class has been started.
   - On the handheld, all documents will be sent to a folder with the same name as the class (in this case, the Practice Class – 3rd Period folder).

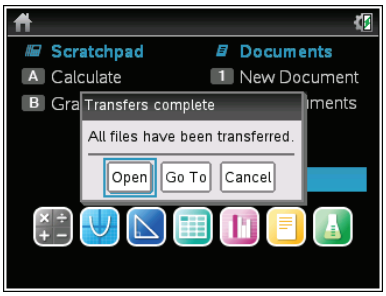
4. **Teacher:** Click on the 1st row in the Class Record. The row will turn blue, and you will see red and green student icons in the Classroom View.





   - A green icon indicates that the student has received the document; a red icon indicates that that student has not received the document.
   - Students with a red icon might be absent, or communication has been disrupted.
   - It is good practice to monitor the transfer of the documents sent to ensure that your students receive them.

5. **Student:** Students know they have received a document based on the "Transfers Complete" pop-up window.

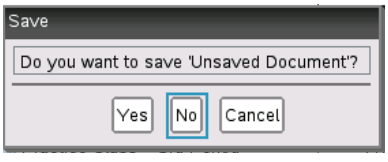


Open the Document

Remember: The participant in the **teacher** role should be looking at the computer screen and not the handhelds. The participant in the **student** role should be looking at the screen of their handheld and not the computer screen. This is to model the classroom experience.

1. **Student:** Pick **one** of the two handhelds and follow the Teacher's instructions in step 2.

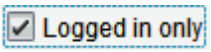
2. **Teacher:** Say: "Open the document that was just sent to your handheld. To do this, Press enter or ☜ del."



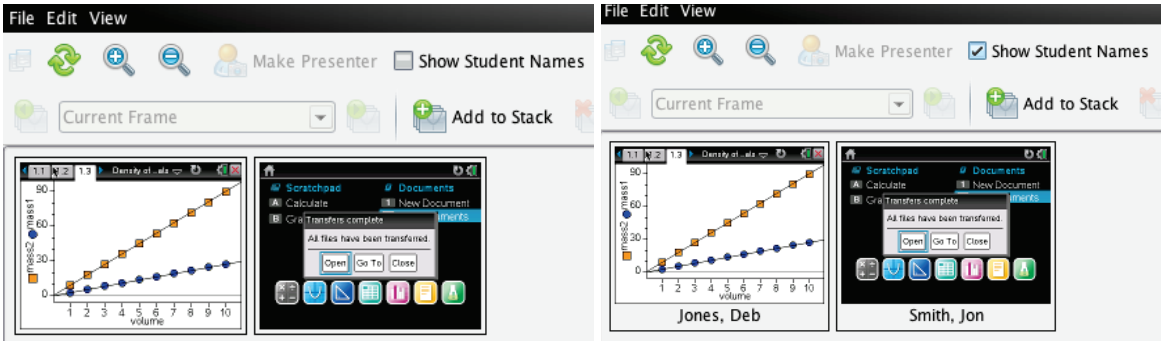
   - If the handheld had a document open prior to opening this one, you would be asked to choose whether to save the prior document. Select No by pressing ▶ ☜.

Class Capture and Live Presenter

1. **Teacher:** Without looking at the student handhelds, press the **Take Screen Capture** icon and select **Class Capture**.



2. **Teacher:** Click on the check box next to "Logged in only" to place a check mark inside. This will show screen captures for only those students that have logged in. Click **OK** to display the screens.
3. **Teacher:** If the student only opened the document on one handheld as requested, the participant playing the role of teacher will notice that one student in the class has not opened the document.
4. **Teacher:** Click on the check box beside Show Student Names, and observe the names appearing under the screenshots.



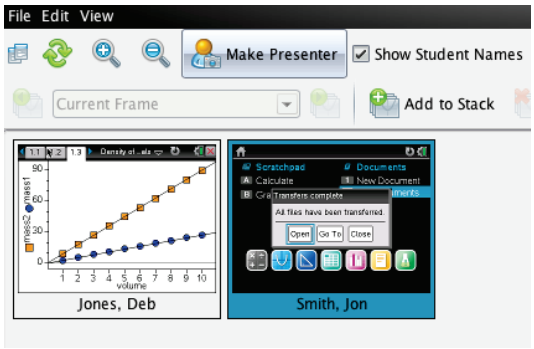
Pause and Think About:

i. Are there scenarios where you want to see the name with the screenshot of each handheld?
ii. Can you think of a scenario where you would not want the names displayed?
iii. If you notice that a student has not yet followed your instructions, how could you get the student back on track?

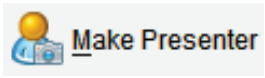
5. **Teacher:** Click on the one screen capture that does not have the first page of the document. It might be Jon's or Deb's handheld.
   - You want all students to properly process your verbal instructions. Class Capture can help you in this regard.

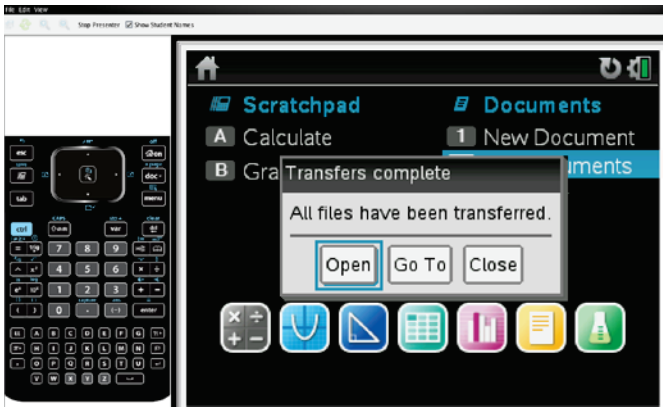
How do you get this student back on track?

- One strategy makes use of the Show Student Names feature within Class Capture to identify students that are having difficulty. Students close to them can help them get back on track.
- Another strategy to get a student back on track is to make the student the Live Presenter and coach the student back. This is the strategy described below.



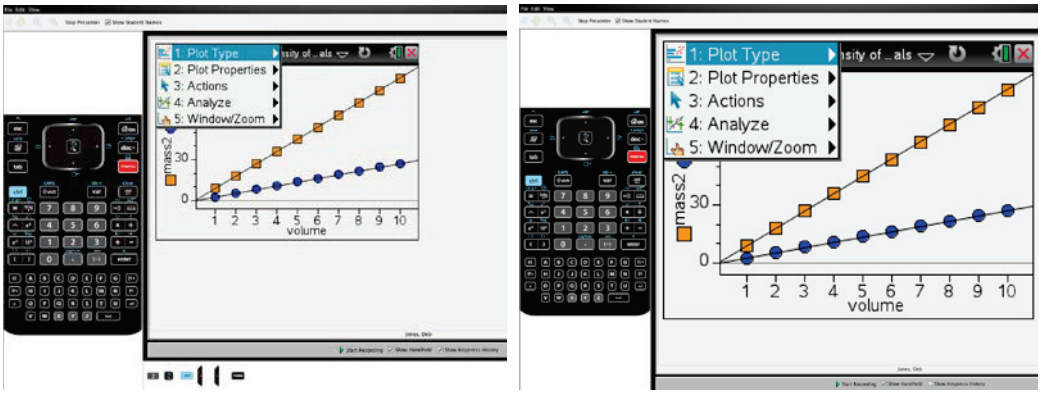
6. **Teacher:** Click on the Screen Capture of the student who is not on the appropriate screen, and click the **Make Presenter** button. You can now view a live feed of the handheld belonging to that student.
   - You will see the student's handheld on your computer screen.
   - The Live Presenter is a tool inside Class Capture that will show what the student is doing in real time. See Below. Note that you will see the handheld type used by the student according to the keypad they are using. This student is using TI-Nspire™ with Touchpad.



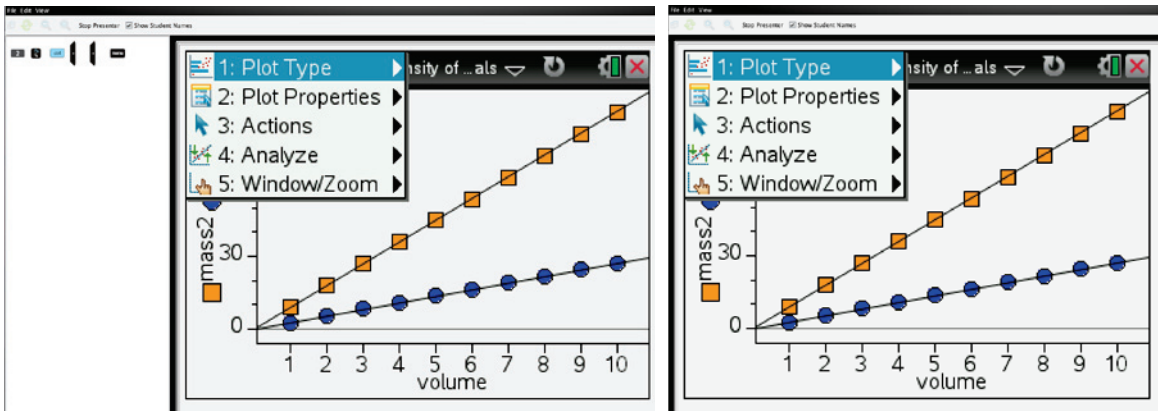


7. **Student:** Pick up the second handheld that has Deb logged into it, and follow the teacher's directions.
8. **Teacher:** Direct the student to press enter or on the handheld to open the document that was sent to the class.

Note: The teacher can customize the layout of the presenter. Currently, the default is to show the Handheld and Key Press History. You can turn off either or both of these views to customize the Live Presenter. You will see the key press history and the screen changing in real time. Notice on your computer software that you will see the specific buttons the student pushes identified by red outlines.

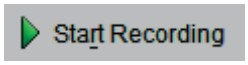


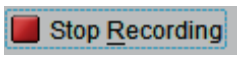
Show Handheld and Key Press History Show Handheld Only

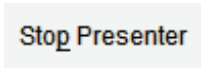


Show Key Press View Only Neither Handheld Nor Key Press History

Note: One other important feature of Live Presenter is the ability to record keystrokes. Pressing **Start Recording** initiates the recording of an .avi video file. When you press **Stop Recording**, you will be prompted to save the .avi file in the Practice Class folder that exists on your computer.







9. **Teacher:** Once this student has opened the document, click on the **Stop Presenter** button.
10. **Teacher:** Direct the student to interact with the document using the accompanying Student Activity handout (if applicable).
11. **Student:** Interact as directed with the TI-Nspire document.
12. **Teacher:** While students are working, monitor their progress with the Class Capture. Refresh manually or set up Auto-Refresh as desired

Pause and Think About:

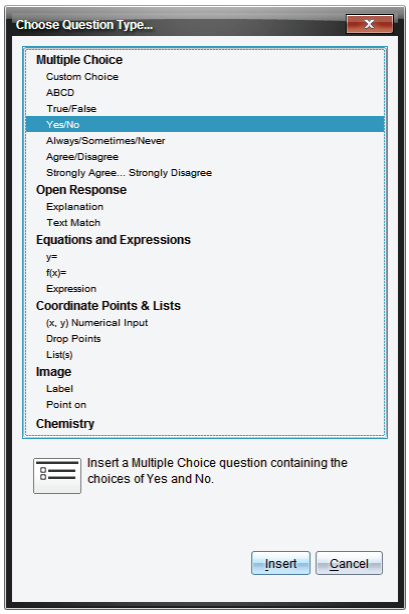
How could the use of Class Capture and Live Presenter change the way you can teach?

Quick Poll

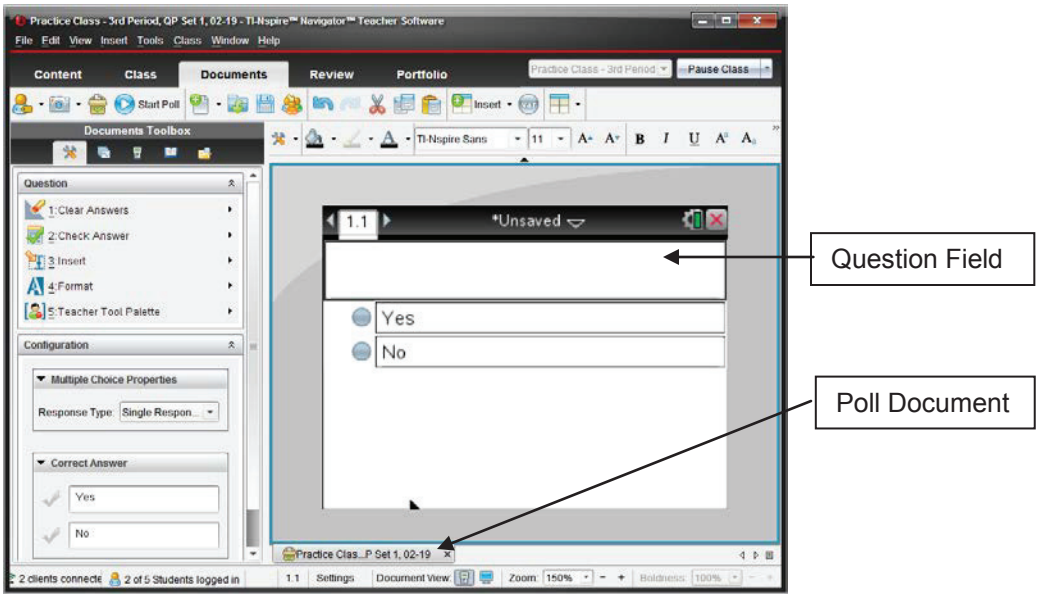
1. **Teacher**: Close the Class Capture feature of the software on your computer.

2. **Teacher**: Now, click the **Quick Poll** icon.

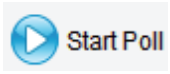
   - The Choose Question Type dialog box appears.
   - There are a variety of question types available:
     - Multiple Choice: Custom Choice, ABCD, True/False, Yes/No, Always/Sometimes/Never, Agree/Disagree, Strongly Agree… Strongly Disagree
     - Open Response: Explanation, Text Match
     - Equations and Expressions: y=, f(x)=, Expression
     - Coordinate Points & Lists: (x,y) Numerical Input, Drop Points, and List(s)
     - Image: Label, Point on
     - Chemistry



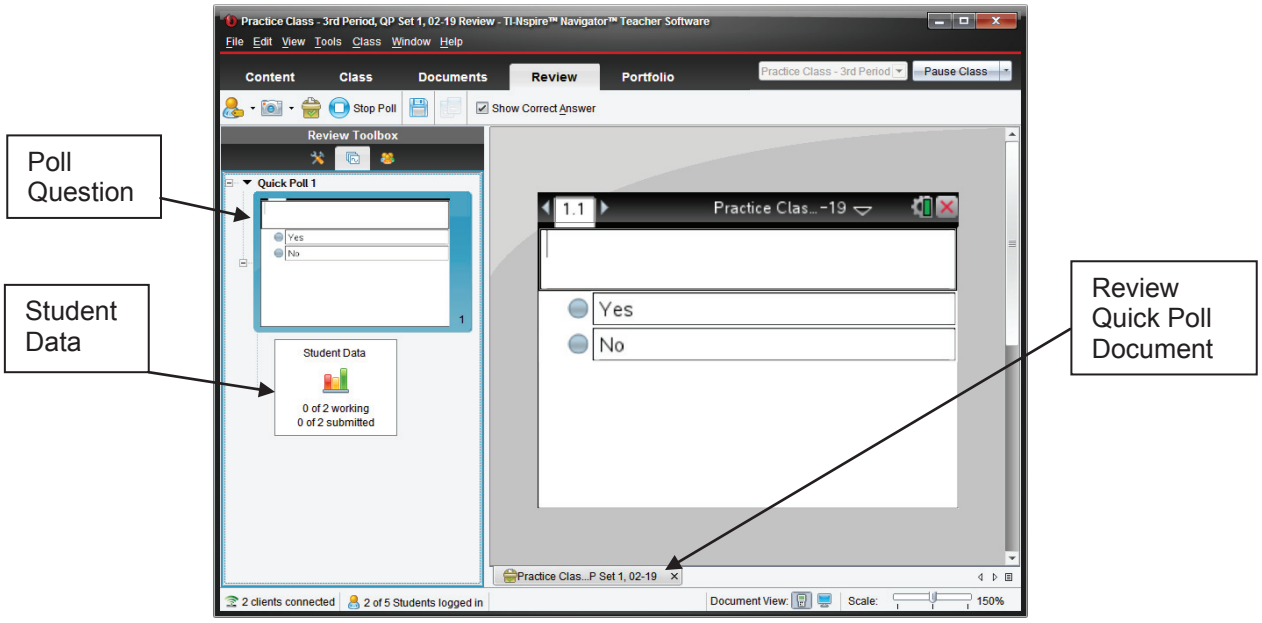
3. **Teacher**: Select the Multiple Choice - Yes/No question type and press **Insert**.
   - A document titled “Practice Class – 3rd Period, QP Set 1, DATE” opens in the Document workspace with a question page.
   - If desired, the question can be entered into the question field or it can be left blank and the question can be asked orally.



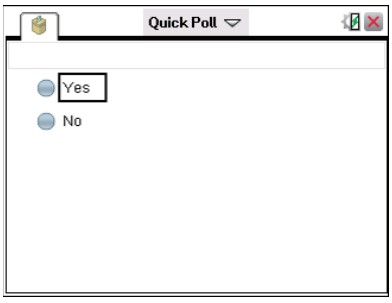
4. **Teacher:** Press the **Start Poll** button.
   - Assume that you are going to ask the following question orally to your class without the need for the question text.
   - Ask the student a yes/no question orally about the activity.



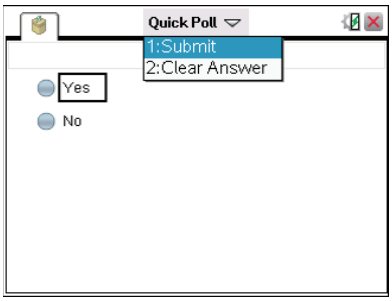
Note: Immediately after pressing the **Start Poll** button, the software opens to the Review workspace and creates a Review Poll document containing the Poll Question and Student Data.



5. **Teacher:** Monitor the number of incoming responses by watching the Student Data.
   - As the students begin to answer the poll, the numbers will change in real-time according to the number of students working on the question and the number of students who have submitted their answer.
   - Shown to the right is what a student sees on his or her handheld. All students have been sent the poll.

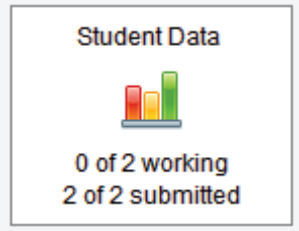


6. **Teacher**: If this is the first time a student has been asked to respond to a poll, you might have to give instructions for answering a poll and submitting an answer. Tell the student:
   - "To answer the question, use the arrow keys to move to the Yes or No answer. Press the click key to "color" in the answer bubble of your choice."
   - "To submit your answer, press the DOC button and select **1:Submit**.

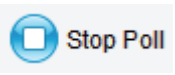


- Alternatively, click on the down arrow to the right of the words **Quick Poll** at the top of the screen. Select **1:Submit**.
- On a Clickpad handheld, press ctrl then the home key to open the Quick Poll pull-down menu.

7. **Student**: Follow the teacher's instructions to send student responses from each handheld to the teacher's computer. On one of the handhelds, send Yes as the answer to the poll. On the other handheld, send No as the answer to the poll.

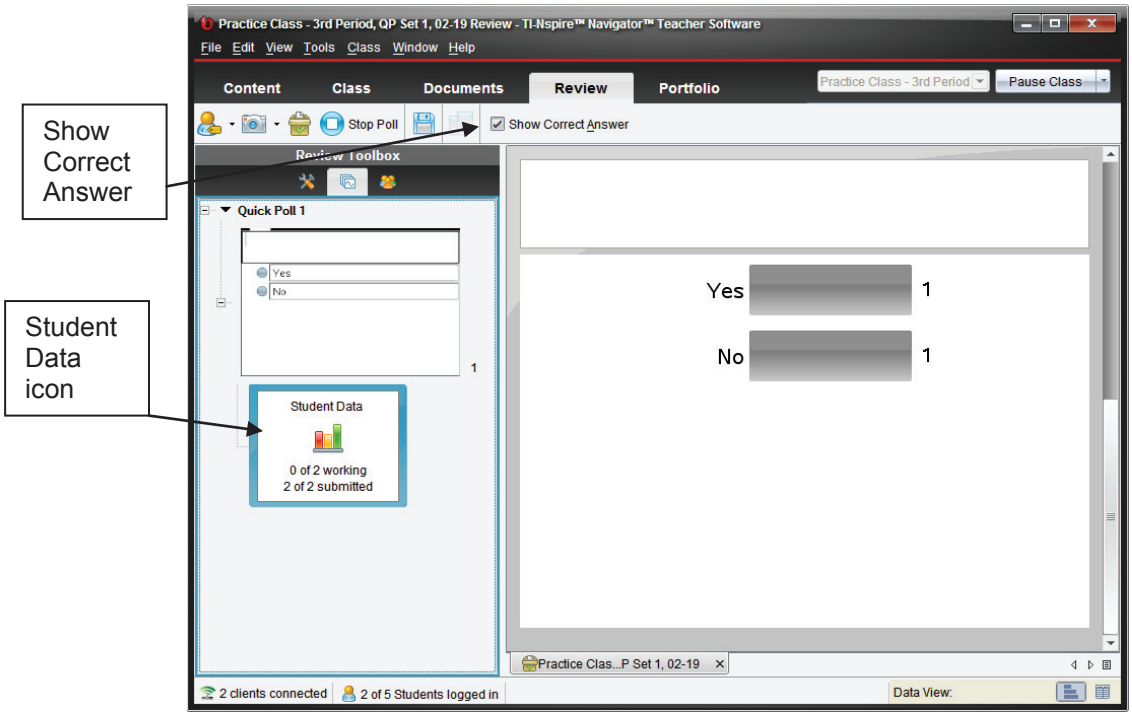


8. **Teacher**: Monitor the Student Data, and click the **Stop Poll** button once you have received an answer from each handheld.

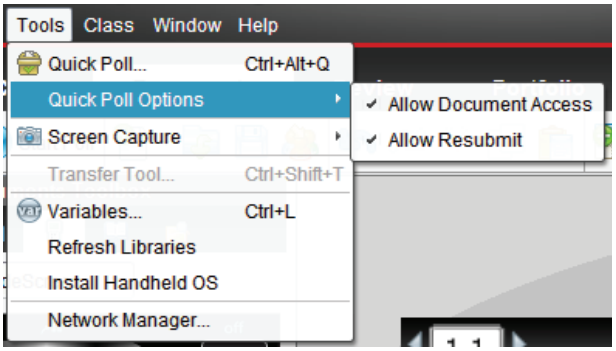


- As the students begin to answer the poll, the numbers will change in real-time according to the number of students working on the question and the number of students who have submitted their answer.

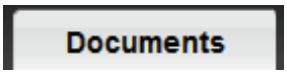
9. **Teacher**: Click the **Student Data** icon, and note that the incoming answers have been collected and organized for you.



Note: By default, the "Allow Resubmit" option is turned off. This option allows students to resubmit their answers until the poll is stopped. When the "Allow Resubmit" option is turned off, then the student has only one chance to respond to the question and the poll will disappear as soon as the student submits an answer.

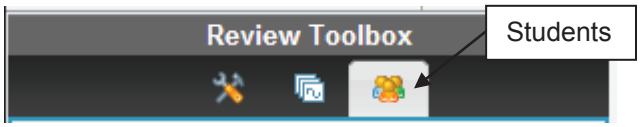


10. **Teacher:** The "Allow Resubmit" option is located in the Documents workspace under the **Tools > Quick Poll Options** menu. Return to the Documents workspace, and select **Allow Resubmit**.

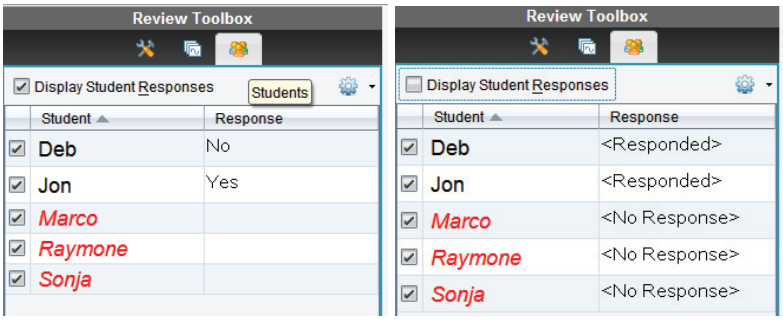


Pause and Think About:
When would you want students to Resubmit answers to a poll?
When would you not want students to Resubmit answers to a poll?

11. **Teacher**: Type the text of another appropriate yes/no question for the activity in the Quick Poll Question page that is already open.
12. **Teacher**: Press the **Start Poll** button.
13. **Student**: Select a response, and submit it for both handhelds.
    - The Quick Poll window remains open on the handhelds since the teacher selected the Allow Resubmit option.
14. **Student:** Change an answer on one handheld and resubmit.
15. **Teacher:** Monitor the Class Results, and click **Stop Poll** once you have received answers from all of your "students."
16. **Teacher**: Click on the **Student Data** icon for Quick Poll 2 to see the student responses.
17. **Teacher**: Click on the **Students** icon under the Review Toolbox to see each student's response. The students' names that are in red have not answered the poll.



18. **Teacher**: Click on the check box beside **Display Student Responses**, and observe what happens. Notice all the responses are hidden, but the teacher knows who has responded.



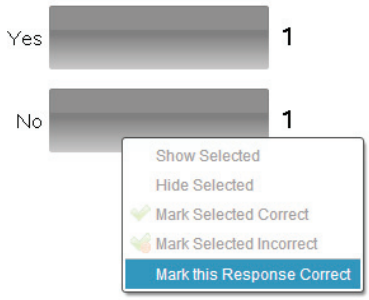
Pause and Think About:

i) How could you use this feature in your classroom?

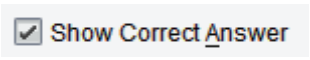
ii) Are there times when you want or don't want your students to see the responses?

iii) Is there pedagogical value in the information provided?

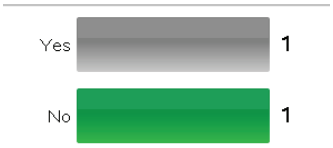
19. **Teacher**: In the Class Results display area, right-click on the bar representing the answer No, and select **Mark this Response Correct**.



- The bar next to the word No will change to green to signify that it has been recorded as the correct answer if **Show Correct Answer** is selected.



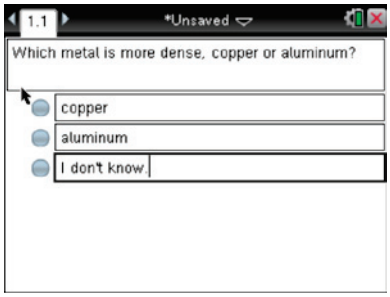
- This will allow the teacher to record and track the correctness of each student's answer to the question posed.
- If the correct answer to a question is never marked, the teacher can still gauge class understanding from the results, but the question will not be included in any scoring when the results are saved into the Student Portfolio.



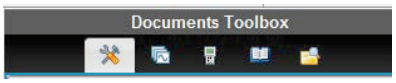
20. **Teacher**: Return to the Document workspace.
21. Turn off the "Allow Resubmit" option by pressing **Tools > Quick Poll Options**.
22. **Teacher:** Click the Quick Poll icon.

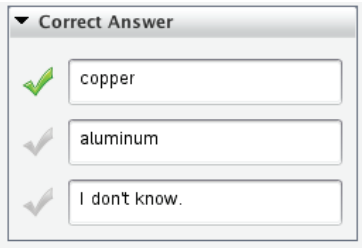
23. **Teacher**: Select the Multiple Choice - Custom Choice type of question, and press **Insert**.
24. **Teacher**: Click in the question field, and type an appropriate question for the activity.
25. **Teacher**: Click in the first answer field, and type the first answer choice.

26. **Teacher:** Using **Tab** or the down arrow, navigate to the second answer field. Type the second answer choice.
27. **Teacher:** Press **Enter** to open an additional answer field, and type in a third answer choice.
    - To remove an empty answer field, click in that field, and press **Backspace**.



Note: If this process is not being completed in front of students, the teacher could mark the correct answer when writing the question. Open the **Document Tools** in the Documents Toolbox and click on the checkmark in front of the correct answer.



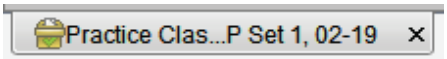


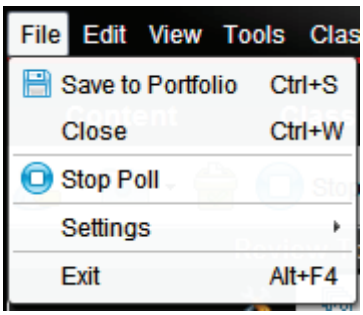
28. **Teacher:** Send the Quick Poll to the class by pressing **Start Poll**.
29. **Student:** Answer the Quick Poll question on both handhelds, and submit the responses.
30. **Teacher:** Monitor the incoming responses. If necessary, repeat instructions on how students submit a Quick Poll response.
31. **Teacher**: Click on the **Stop Poll** button after students have responded to the question.

Saving to the Portfolio

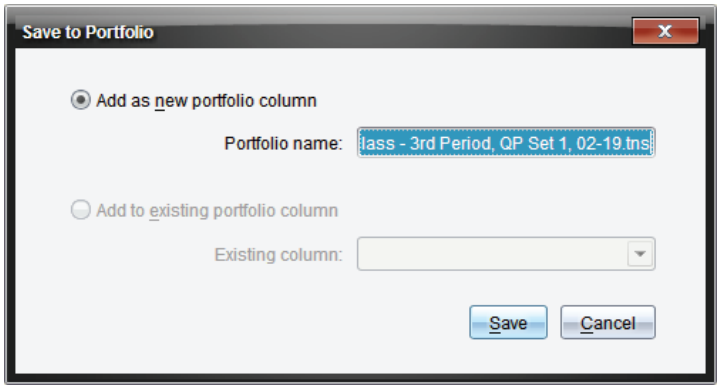
The Quick Poll questions and class results for a class session are compiled into one Review Document for up to 15 Quick Poll questions. If more than 15 Quick Poll questions are sent during a class session, another Review Document will open and compile the next 15 Quick Poll questions and results. These results can be saved into the Portfolio at any time during the class session. Saving the results will help the teacher monitor student progress over time and make diagnostic decisions regarding student performance.

1. **Teacher**: Click on the X to close the Review Document containing the Quick Poll questions and class results, and click **Save**. Alternatively, select **File > Save to Portfolio**.

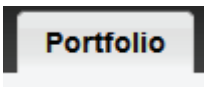




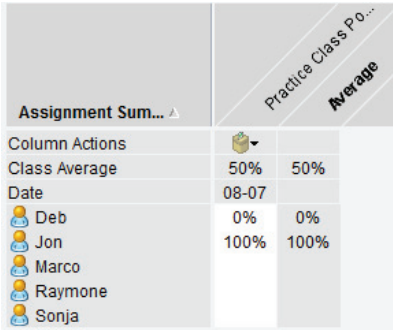
2. **Teacher:** If desired, change the name of the portfolio column, and click **Save**.



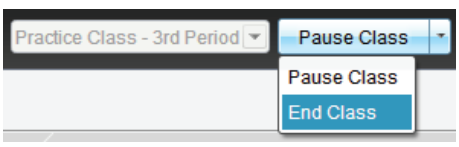
3. **Teacher:** To view the portfolio, go to the Portfolio workspace. The Assignment Summary displays the results in a gradebook type display.

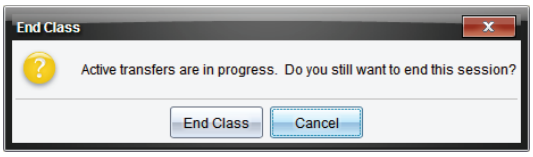


   - The portfolio will be discussed in depth in a later activity in the workshop.



4. **Teacher:** To end the class, select **End Class** from the pull-down menu next to the Class Name.
   - If a pop-up window indicates 'Active transfers are in progress," press **End Class**. The alert indicates that the TI-Nspire document sent to the class is still available for those who have not yet logged in to the class session.





Switch Roles

Now switch roles and repeat the activity. When creating a new class, be sure to use a different class name and select that class name before starting the class.

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Online Resources

TI PROFESSIONAL DEVELOPMENT

Activity Overview

In this activity, you will explore resources available at education.ti.com. You will browse for activities at Math Nspired or Science Nspired. You will search for activities using the Standards Search and Textbook Search, and you will explore additional information regarding professional development.

Materials

- Computer with Internet connection

Step 1:

Go to **education.ti.com > Activities**. Select **Math Nspired** or **Science Nspired**, which can also be accessed directly at mathnspired.com and sciencenspired.com. Select a subject on the left.

Step 2:

Select a unit from the list. When a unit is selected, a table appears with an image from each activity. The table contains links to download, recommend, and save each activity. It also identifies each activity type:

Icon	Type	Description
	Bell Ringer	Bell ringers are short lessons designed to help transition quickly into class after the bell rings.
	Action Consequence Simulation	Interactive, engaging lessons allow students to perform actions on a mathematical object or scientific simulation, observe consequences, and make conjectures. Each lesson contains a pre-made TI-Nspire™ document, a Student Activity, and Teacher Notes.
	Create Your Own	In addition to the Student Activity and Teacher Notes, the lesson also includes step-by-step instructions on how to create the TI-Nspire document.
	Data Collection with Probes	Data Collection Labs give students the opportunity to collect and analyze real-world data with more than 50 data collection sensors from Vernier Software and Technology™.
	TI-Nspire™ Navigator™ Compatible	The Teacher Notes identify opportunities to use the TI-Nspire Navigator System, including opportunities for Quick Polls, Class Captures, and Live Presenter.

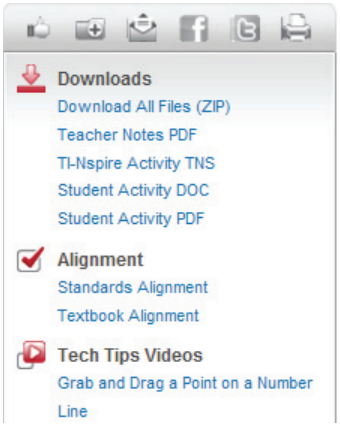
Online Resources

TI PROFESSIONAL DEVELOPMENT

Step 3:

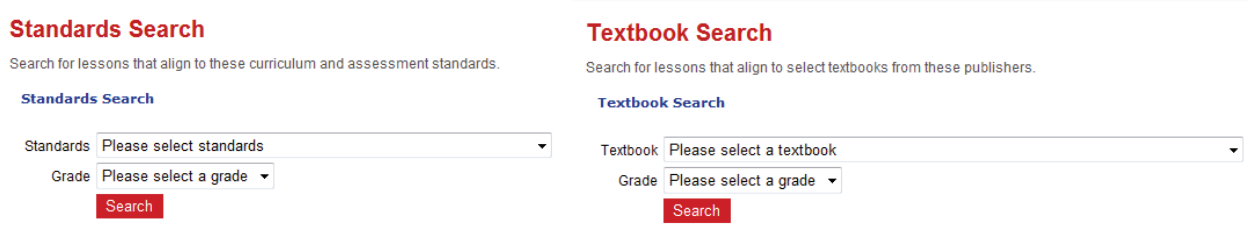
Select an activity from the list. The activity page shows objectives, relevant vocabulary, and additional information. A video offers a preview of the lesson, and related lessons are recommended below.

Icons above the Downloads section allow you to recommend, save, email, and print an activity. Links to Facebook® and Twitter® are also available. The Downloads section contains links to activity files. Links for Standards Alignment, Textbook Alignment, and relevant Tech Tip Videos are also available.



Step 4:

Explore the Standards and Textbook Search channels on the left. Select a set of standards or a textbook from the drop-down box, select a grade, and click **Search**.



Step 6:

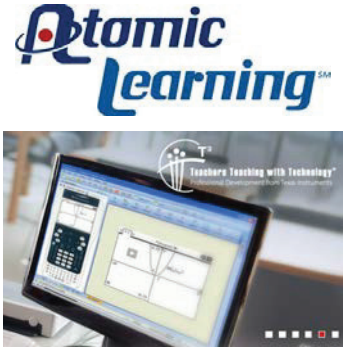
Click the **Solutions** tab and select Common Core State Standards or Science Tools. Content and activities, technology resources, and information on professional development opportunities are provided.

Step 7:

Go to **Professional Development > Online Learning**.

The Tutorials page contains link to free Atomic Learning[SM] video tutorials. There are video tutorials for the TI-Nspire™ handheld, the TI-Nspire™ software, the TI-Nspire™ Navigator™ System, and the TI-Nspire™ Apps for iPad®.

The Upcoming page contains links to upcoming, free PD webinars. The On-Demand page contains recordings of past webinars, and associated webinar documents are available for download.



Step 8:

Explore each of the following pages by clicking the appropriate tab: Products, Downloads, Activities, Professional Development, Solutions, Support, and Where to buy.

Data Aggregation in the Science Classroom

TI PROFESSIONAL DEVELOPMENT

Objective

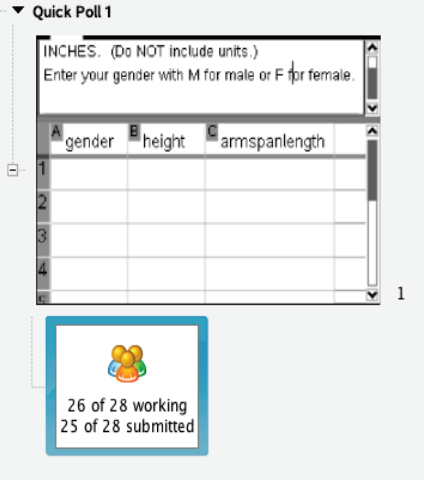
- Become familiar with the data aggregation with lists technique using the TI-Nspire™ CX Navigator™ System.

About the Lesson

- Two activities will be conducted to explore the data aggregation technique.
- The first activity will be instructor-led. The second will be hands-on with participants playing teacher and student roles.

TI-Nspire™ CX Navigator™ Features

- Quick Poll
- Class Results
- Lists & Spreadsheet



TI-Nspire™ Technology Skills:

- Answering questions related to length data
- Submitting a Quick Poll response

Tech Tips:

- Data aggregation is accomplished by collecting data through a question page.
- Aggregated data is sent back to the students through a document.

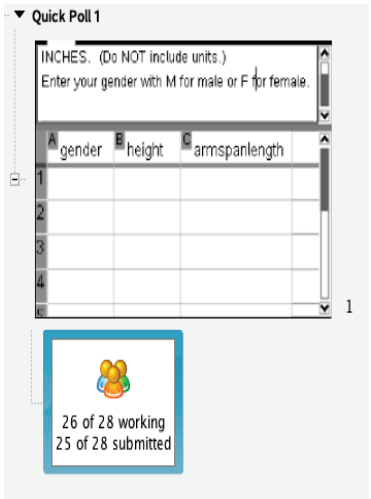
Lesson Materials:

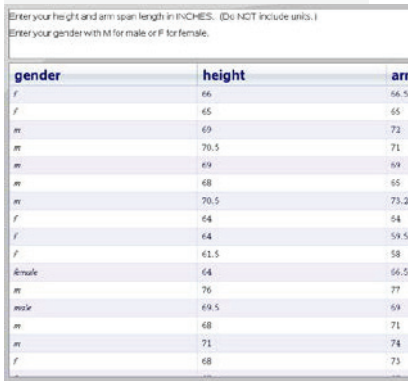
- Computer with TI-Nspire™ CX Navigator™ Teacher Software
- TI-Nspire™ CX Navigator access point
- One TI-Nspire™ CX handheld per participant
- One meter stick / tape measure for every 2-4 participants
- *Data_Aggregation.tns*

Part 1 Activity

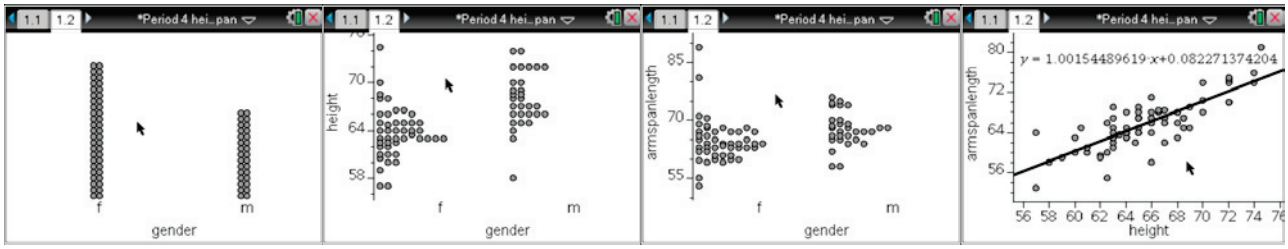
The instructor will demonstrate how to use a TI-Nspire™ CX Navigator™ technique to collect, aggregate, and disseminate data. **These directions are written from the instructor's viewpoint as the 'teacher'.**

1. Open the document *Data_Aggregation.tns*.
   - This file contains a LIST question that asks participants to record their gender, height (in inches), and arm span length (in inches) in Row 1.
   - Be sure to have enough meter sticks and/or tape measures for participants to use to measure their arm span length from the longest finger on their left hand to the longest finger on their right hand.
2. Click START POLL.
3. Click on the "working/submitted" box in the REVIEW tab to show the data table.
4. Click STOP POLL. Right-click on the data table, and select "Copy Entire Table".
5. In the DOCUMENT tab, open a new TI-Nspire document, and add a spreadsheet.
6. With box A1 highlighted, paste your data into the spreadsheet.
7. Label the columns with appropriate names. Clean up the spreadsheet. (Remove rows with dashes. Make sure that data is correct and uniform.)
8. Save the document.
9. Send the document to the students. Now they have a full set of class data ready to be analyzed!
10. Instruct participants to add a Data & Statistics page to the document just sent to them and lead a discussion of trends in the data comparing different sets of variables.



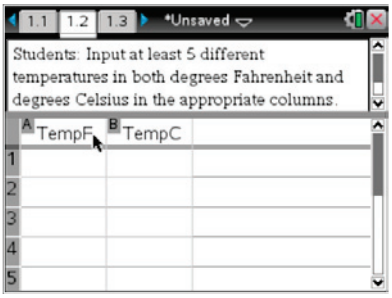


The following graphs are examples of ones that can be created and used for discussion:



Part 2 Activity

Participants should work in pairs. One participant will act as 'Teacher' and the other one will act as 'Student' using temperature data. The Student will operate two different handhelds connected to the Teacher's computer.



1. **Teacher:** Start the class. Create a poll question in which you ask the students to enter data in two columns labeled **TempF** and **TempC**. Send them the Quick Poll question.
2. **Student:** Connect two different handhelds to the Teacher's computer and log in. Enter the data below. Submit your data when you are finished entering it by pressing the DOC button on the handheld.

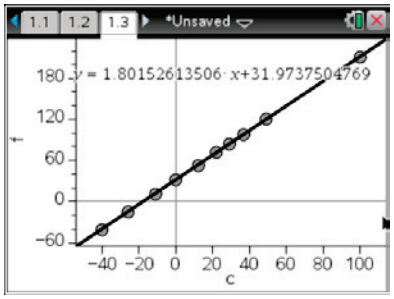
Handheld #1

Temp (˚F)	72	98.6	32	12	-40
Temp (˚C)	22	37	0	-11	-40

Handheld #2

Temp (˚F)	212	85	53	120	-15
Temp (˚C)	100	29	12	49	-26

3. **Teacher:** When both student data sets have been entered, stop the poll, right-click on the data table, and select "Copy Entire Table".
4. **Teacher:** In the DOCUMENT tab, open a new TI-Nspire document, and add a spreadsheet.
5. **Teacher:** With box A1 highlighted, paste your data into the spreadsheet.
6. **Teacher:** Label the columns with appropriate names. Clean up the spreadsheet if needed. (Remove rows with dashes. Make sure that data is correct and uniform.)
7. **Teacher:** Save the document.
8. **Teacher:** Send the document to the students. Now they have a full set of class data ready to be analyzed!

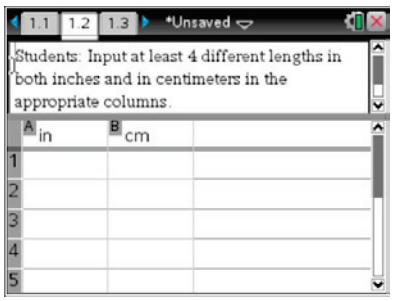


9. **Teacher:** Instruct the student (the other participant) to add a Data & Statistics page to look for the relationship between the temperature data.
10. **Student:** Open the document that was just sent on one of the handhelds. Add a Data & Statistics page to look for the relationship between the temperature data. HINT: Use the MENU button and the ANALYZE feature.

SWITCH ROLES.

The Teacher will now become the Student and the Student will become the Teacher. The two handhelds should now be disconnected from the computer and connected to the new Teacher computer.

11. **Teacher:** Start the class. Create a poll question in which you ask the students to enter data in two columns labeled **Inches** and **Centimeters**. Send them the Quick Poll question.



12. **Student:** Connect two different handhelds to the Teacher's computer and log in. Enter the data below. Submit your data when you are finished entering it by pressing the DOC button on the handheld.

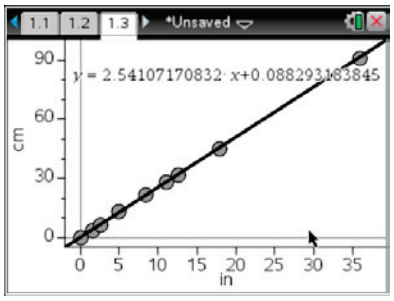
Handheld #1

Inches	1+1/2	4+15/16	8+1/2	17+7/8
Centimeters	3.85	13.00	21.63	45.3

Handheld #2

Inches	2+5/8	11	12+1/2	35+7/8
Centimeters	6.68	28.01	31.95	91.30

13. **Teacher:** When both student data sets have been entered, stop the poll, right-click on the data table, and select "Copy Entire Table".
14. **Teacher:** In the DOCUMENT tab, open a new Nspire document, and add a spreadsheet.
15. **Teacher:** With box A1 highlighted, paste your data into the spreadsheet.
16. **Teacher:** Label the columns with appropriate names. Clean up the spreadsheet if needed. (Remove rows with dashes. Make sure that data is correct and uniform.)
17. **Teacher:** Save the document.
18. **Teacher:** Send the document to the students. Now they have a full set of class data ready to be analyzed!
19. **Teacher:** Instruct the student (the other participant) to add a Data & Statistics page to look for the relationship between the length data.
20. **Student:** Open the document that was just sent on one of the handhelds. Add a Data & Statistics page to look for the relationship between the length data. HINT: Use the MENU button and the ANALYZE feature.



Pendulum Investigation

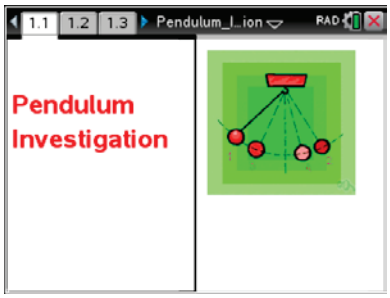
Student Activity

Name _____

Class _____

This activity explores the factors that affect the period of a pendulum. To begin, your teacher will send you a Quick Poll to ask you what you think. Enter your responses on your handheld.

You will then collect data to determine what factors do in fact affect the period of the pendulum.



The **period** of a pendulum is the time for one complete vibration or cycle.

Tech Tip: Press the doc key to submit your answer to the Quick Poll.

1. You and your group members have 15 minutes to collect data for the period of a pendulum, changing one variable each time. Collect two or three values for each type of data and record them below. Pay attention to the units given in the table when making measurements. Measure the length from the top to the middle of the bob or hanging mass.

Experiment A: Collect the data keeping the length constant at 0.5 m and the angle at 15°. Vary the mass.

Trial	Mass (kg)	Period (s)

Experiment B: Collect the data keeping the length constant at 0.5 m and the mass at 0.10 kg. Vary the angle between 5 and 35°.

Trial	Angle (degrees)	Period (s)

Experiment C: Collect the data keeping the mass constant at 0.10 kg and the angle at 15°. Vary the length between 0.1m and 1.5 m.

Trial	Length (m)	Period (s)

Pendulum Investigation

Student Activity

Name _____

Class _____

2. You will now be sent a Quick Poll for each set of measurements. Enter the values that you measured. The data for each group will then be sent to the entire class.

> **Tech Tip:** To insert a page, press ctrl doc to add a new page to a document.

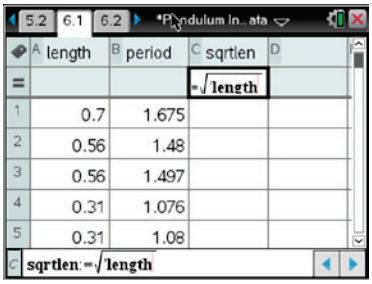
3. Your teacher will send you a document with the entire class data set. Add a Data & Statistics page following the first data table. Create a graph of period as a function of mass. Describe the graph. Does mass affect the period? How do you know? What type of function describes the graph?

4. Add a Data & Statistics page following the second data table. Create a graph of period as a function of angle. Describe the graph. Does angle affect the period? How do you know? What type of function describes the graph?

5. Add a Data & Statistics page following the third data table. Create a graph of period as a function of length. Describe the graph. Does length affect the period? How do you know? What type of function describes the graph?

6. What type of regression would fit the data? Find the equation using a regression and record it here. How well does it fit the data?

7. Linearization is a method where the data is transformed in a way that creates a straight line. Discuss with your group how the data can be linearized. Create a new data list in your spreadsheet to linearize the data. Check the graph to see if your transformation produces a straight line and if so, find the equation. Show your work below. See a sample to the right. Notice that the second row can be used to create a list of values using one of the other lists. When entering the equation, choose the variable name from the variable menu var.



8. Relate your regression to the linearized equation. Describe how they compare.

9. If the length of the pendulum is doubled, how is the period changed?

10. If you want to double the period, how should you change the length?

11. If the mass is doubled, what happens to the period?

12. How is the frequency of a pendulum related to the three variables that you tested?

13. Summarize at least three concepts that you learned in this activity. Be sure to write your summary using complete sentences.

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Pendulum Investigation

TI PROFESSIONAL DEVELOPMENT

TEACHER NOTES

Physics Objectives

- Students will collect data accurately for the period of a pendulum.
- Students will relate the period of a pendulum to the square room of the length.
- Students are developing and using models (NGSS).
- Students are analyzing and interpreting data (NGSS).
- Students are using mathematics and computational thinking (NGSS).

Vocabulary

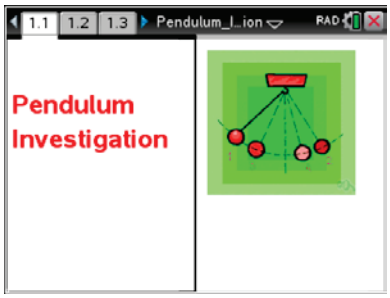
- period
- frequency
- linearization

About the Lesson

- Students will brainstorm factors that may affect the period of a pendulum and then test them through data collection.
- To allow the investigation of three variables, students will collect data for only two or three points for each variable while keeping the other variables at the same class constant. The students will send in their data using a quick poll and the entire class set of data will be shared back to the class.
- As a result, students will:
  - Collect data for period as a function of mass, angle and length
  - Analyze the results of the collected data sets
  - Students will realize that there is no correlation between period and mass as well as period and small angles.
  - Students will see a relationship between period and the square root of length.

TI-Nspire™ Navigator™

- Use Pendulum_Investigation.tns not a student document, but as a teacher document to send Quick Polls to the students.
- Create a document with the data returned from the Quick Polls and send this document out to the class for analysis.



Tech Tips:

- This activity emphasizes data aggregation as a tool to involve students in class explorations while saving time by having students collect data as a large group and analyze one set of data.
- Refer to the data aggregation activity for more information and tips about data aggregation.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:

Student Activity

- Pendulum_Investigation_Student.pdf
- Pendulum_Investigation_Student.doc

TI-Nspire document

- Pendulum_Investigation.tns

Pendulum Investigation

TI PROFESSIONAL DEVELOPMENT

Activity Materials

Compatible TI Technologies : TI-Nspire™ CX Handhelds, TI-Nspire™ Software

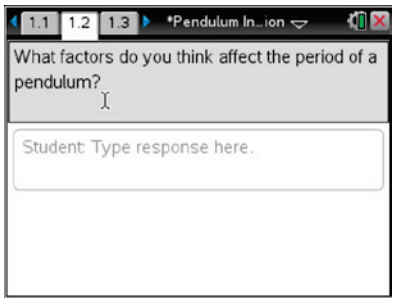
- Hanging masses
- String
- Pendulum clamp or ring stand
- Meter sticks
- Protractor
- Scissors
- Timers or cell phone stopwatch applications

Discussion Points and Possible Answers

Open Pendulum_Investigation.tns but do not send it out to the class. Set up a pendulum and set it in motion. Discuss the definition of the **period** of a pendulum as the time for one complete vibration.

Tech Tip: Move to page 1.2 in the document and select the Quick Poll icon. Questions can be sent out to the class as a Quick Poll by moving to the question in the document and selecting the poll icon.

Move to page 1.2 in the document Pendulum_Investigation.tns.



Begin the class with the question about what factors affect the period of a pendulum. It is helpful to have a pendulum swinging so that students may observe the motion.

Answer: Answers will vary, but should include mass/weight, length, and angle/distance that the pendulum is released from. The responses can be then categorized into examining mass of the bob, angle of release and length of the string.

Teacher Tip: Discuss the accurate measurement of the period of the pendulum. Reaction time is a significant source of error if the time is measured for only one cycle. Students should measure the time for 10 cycles and divide the total time by 10 to find the period.

1. You and your group members have 15 minutes to collect data for the period of a pendulum changing one variable each time. Collect two or three values for each type of data and record them below. Pay attention to the units given in the table when making measurements. Measure the length from the top to the middle of the bob or hanging mass.

Experiment A: Collect the data keeping the length constant at 0.5 m and the angle at 15°. Vary the mass.

Trial	Mass (kg)	Period (s)

Answer: Students will enter their data.

Experiment B: Collect the data keeping the length constant at 0.5 m and the mass at 0.10 kg. Vary the angle between 5 and 35˚.

Trial	Angle (degrees)	Period (s)

Answer: Students will enter their data.

Experiment C: Collect the data keeping the mass constant at 0.10 kg and the angle at 15°. Vary the length between 0.1m and 1.5 m.

Trial	Length (m)	Period (s)

Answer: Students will enter their data.

2. You will now be sent a Quick Poll for each set of measurements. Enter the values that you measured. The data for each group will then be sent to the entire class.

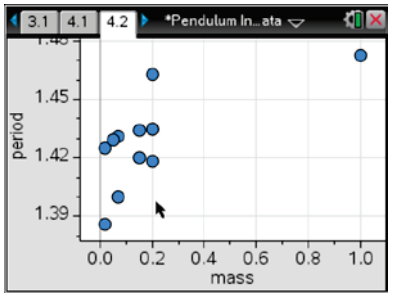
Teacher Tip: Move to the Quick Poll with a list of mass and period. Send the Quick Poll to the class. Groups should send each data point once. Each student can send one point or one group member can send the data for the entire group. Once the students send in their responses, open their responses using the Review Workspace. Right-click on the data set and select Insert Table in Open Document. The spreadsheet will be entered at the end of the document. Repeat this procedure for each of the three data sets.

Tech Tip: Send the entire document out to the class for analysis.

Once students receive the document, they may work on the it with their group, indivdually, or the data can be discussed as a class since the entire class has the same data set. A combination of these methods can be uses where students produce the graphs and then discuss with their group or the entire class.

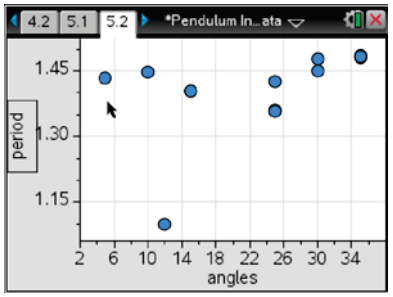
3. Your teacher will send you a document with the entire class data set. Add a Data & Statistics page following the first data table. Create a graph of period as a function of mass. Describe the graph. Does mass affect the period? How do you know? What type of function describes the graph?

Answer: Answers will vary. The graph to the right is a sample for the data of period as a function of mass. The graph shows that there is no correlation between the period and mass. Generally the period is between 1.40 and 1.44. There are a few data points outside of this range, but the graph does not show a relationship.



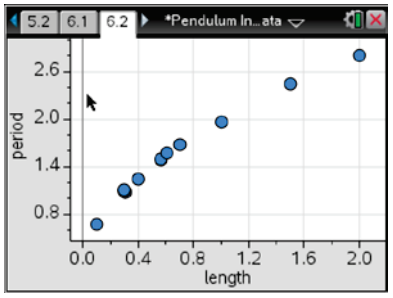
4. Add a Data & Statistics page following the second data table. Create a graph of period as a function of angle. Describe the graph. Does angle affect the period? How do you know? What type of function describes the graph?

Answer: Answers will vary. The graph to the right is a sample for the data of period as a function of angles. The graph shows that there is no correlation between the period and angle. Generally the period is between 1.40 and 1.48. There are a few data points outside of this range, but the graph does not show a relationship. One data point is much lower which probably indicates an error in measurement.

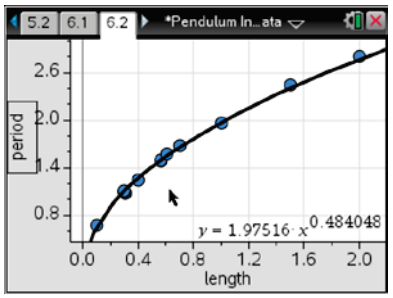


5. Add a Data & Statistics page following the third data table. Create a graph of period as a function of length. Describe the graph. Does length affect the period? How do you know? What type of function describes the graph?

Answer: Answers will vary. The graph to the right is a sample for the data of period as a function of length.

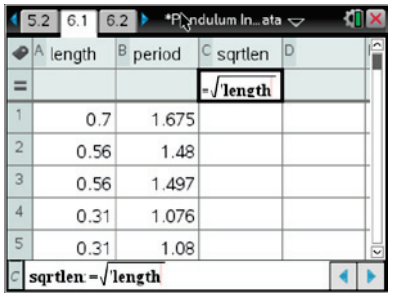


6. What type of regression would fit the data? Find the equation using a regression and record it here. How well does it fit the data?

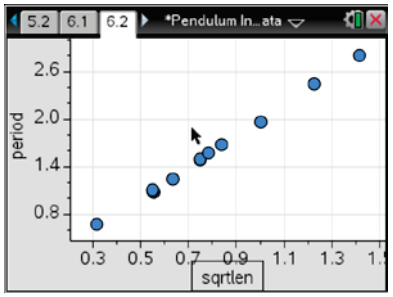


Answer: Answers will vary. This is a time to discuss possible models with the class and perhaps try different options that students suggest. The model is square root. The model is a power regression with the power of ½. In this case the power is 0.484. Some students may suggest logarithmic which does not appear to fit the data as well.

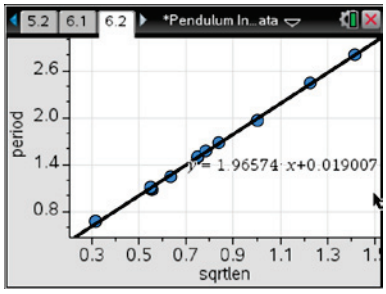
7. Linearization is a method where the data is transformed in a way that creates a straight line. Discuss with your group how the data can be linearized. Create a new data list in your spreadsheet to linearize the data. Check the graph to see if your transformation produces a straight line and if so, find the equation. Show your work below. See a sample to the right. Notice that the second row can be used to create a list of values using one of the other lists. When entering the equation, choose the variable name from the variable menu [var].



Answer: Graphing the period as a function of the square root of length produces a straight line. Graphing the period versus a log of the length would not produce a straight line. This method of linearizing is generally accepted in the physics community as an indication that the model is correct.



The accepted equation for the period of a pendulum is $T = 2\pi\sqrt{\frac{l}{g}}$, where *g* is the acceleration due to gravity (9.8 m/s^2 on earth). Rewriting the equation as $T = \frac{2\pi}{\sqrt{g}}\sqrt{l}$, students can compare the slope value to the $\frac{2\pi}{\sqrt{g}}$, the value of the constant in front of $\sqrt{l}$. The values should be very close.



8. Relate your regression to the linearized equation. Describe how they compare.

   Answer: Answers will vary. Students should discuss that if the equation appears to show the period is a function of square root of length that if they take the square root of the lengths and plot those on the horizontal axis, the graph should be linear.

9. If the length of the pendulum is doubled, how is the period changed?

   Answer: The period should be $\sqrt{2}$ times greater.

10. If you want to double the period, how should you change the length?

    Answer: The length should be 4 times greater to double the period.

11. If the mass is doubled, what happens to the period?

    Answer: The mass does not affect the period so the period would remain the same.

12. How is the frequency of a pendulum related to the three variables that you tested?

    Answer: The frequency is the reciprocal of the period. The mass and angle do not affect the period. The frequency is proportional to one over the square root of the length.
    $f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$

13. Summarize at least three concepts that you learned in this activity. Be sure to write your summary using complete sentences.

    Answer: Students should be able to summarize and write in complete sentences.

TI-Nspire Navigator

Use the TI-Nspire™ Navigator™ System throughout the activity to show student screens and monitor progress with the Class Capture feature. Questions 10–12 are included in the TI-Nspire™ document in multiple-choice format. These can be sent out as Quick Polls for class discussion, answered in the document or answered on paper in the activity.

Walk a Line
Student Activity

Name _____
Class _____

Activity Overview

This activity will introduce the Calculator-Based Ranger 2™ motion sensor motion sensor and the Vernier DataQuest™ application. You will collect and analyze linear data.

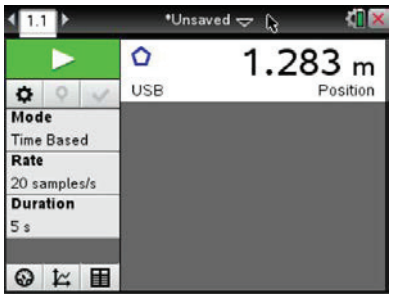
Materials

- CBR 2™
- USB Connection Cable for CBR 2

Step 1:

Open a New Document, and press esc.

Connect the CBR 2 to the handheld with the USB cable. A Vernier DataQuest page will automatically open, and the CBR 2 will begin measuring the position of the closest object.

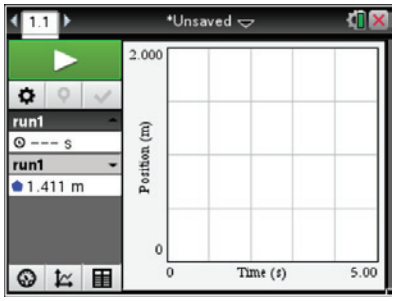


Step 2:

Work in groups of two. One person will operate the TI-Nspire™ and point the CBR 2 toward the other partner, the "walker." The walker should be standing approximately two meters from the motion detector. The walker will walk slowly toward the motion detector at a constant velocity.

Step 3:

Before collecting the data, make a prediction of what the graph of position versus time should look like. Sketch your prediction on the grid to the right.



Step 4:

The calculator operator should click the green **Start Collection** arrow in the upper-left corner of the screen, or press **Tab** until the start arrow is highlighted, then press **Enter** when ready. The walker should walk SLOWLY toward the CBR 2 at a constant velocity to close the gap in approximately 5 seconds. Don't go too fast, or you will run out of room and need to try again. You must walk at the same velocity the entire time.

Step 5:

Graphs for *position versus time* and *velocity versus time* are created and displayed on the same screen. Repeat as necessary until you generate a graph for *position versus time* that is roughly linear. How does the graph compare with your prediction?

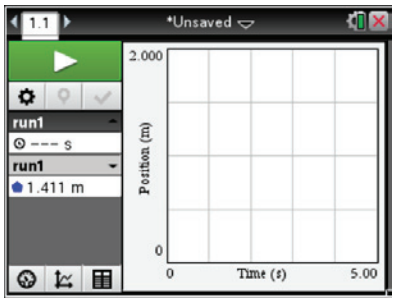
Walk a Line
Student Activity

Name _____
Class _____

Step 6:

To display only the *position versus time* graph, select **Menu > Graph > Show Graph > Graph 1**.

Sketch the actual graph of your *position versus time* graph on the grid shown to the right.



Step 7:

Manual Analysis of Data

a. How can you estimate the average velocity of the walker?

b. What was the position of the walker at time t = 0 seconds? At time t = 5 seconds?

c. Show your work to calculate the approximate slope of your line using your positions at time t = 0 seconds and t = 5 seconds.

d. What does the slope of the graph represent physically?

e. Why is the velocity negative?

f. Linear functions are usually written in the form $f(x) = mx + b$. Determine the y-intercept of your line and write an equation that you think will model the data.

g. What does the y-intercept represent?

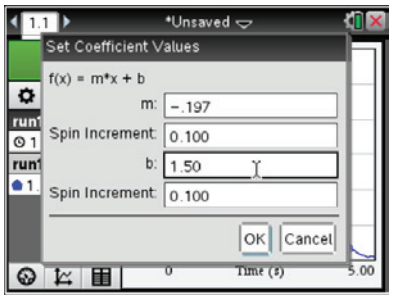
Walk a Line
Student Activity

Name _____
Class _____

Step 8:

Select **Menu > Analyze > Model**. Select **m*x + b** to create a linear model, and press **OK**.

Type the values for the coefficients *m* and *b* that you estimated in Step 7 in the spaces provided, and click **OK**.

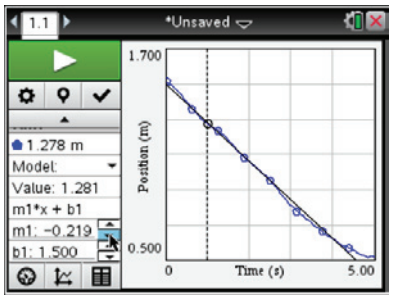


Step 9:

The model can be adjusted or by clicking on the values of *m* and *b* displayed on the left side of the screen and editing them or by clicking the slider arrows. See the sample shown to the right. If you made adjustments, record the new values below.

m =

b =



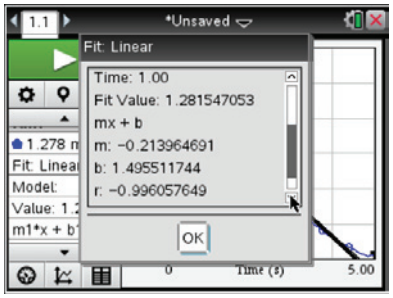
Step 10:

Analyzing the data with a linear regression curve can be performed within the Vernier DataQuest™ application.

Select **Menu > Analyze > Curve Fit > Linear**. This will give the equation of the linear regression model. You will have to scroll down the dialog box to see the values of *m* and *b* for the linear model. Record the values for *m* and *b* below.

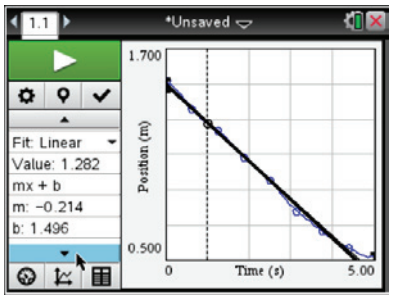
m =

b =



Step 11:

Click **OK** to see the graphical results of the regression. How does your linear regression compare with the equation you found in Step 9? How do the values for *m* and *b* compare?



Walk a Line
Student Activity

Name _____
Class _____

Discussions/Explorations

1. As you might have gathered from your practice trials, the CBR 2 collects data measuring how far an object is located from the sensor. By walking in front of the CBR 2, collect a set of data which appears linear and has a positive slope. Provide a detailed description of your walk. Be sure to discuss the real-world connections for the slope and *y*-intercept of the model.

2. By walking in front of the CBR 2, collect a set of data that appears linear and has a slope that is approximately zero. Provide a detailed description of your walk, including the connection between slope and *y*-intercept and the physical actions.

3. By walking in front of the CBR 2, collect a set of data that represents a piecewise function with two parts, both of which are linear—one with a positive slope and one with a negative slope. Provide a detailed description of your walk, including the connections between slope and *y*-intercept and the physical actions.

Walk a Line

TI PROFESSIONAL DEVELOPMENT

Math and Science Objectives

- Students will find the slope and *y*-intercept of a linear equation to model position versus time data.
- Students will explain the relationship between a position-time graph and the physical motion used to create it.
- Students will model with mathematics (CCSS Mathematical Practice).

Vocabulary

- linear equation
- position
- speed
- velocity
- average velocity

About the Lesson

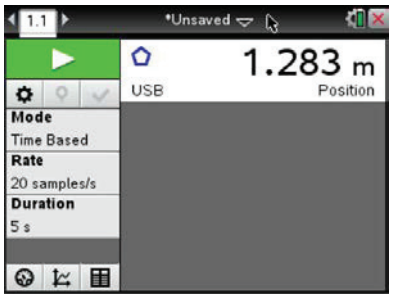
- In this lesson, students collect data by moving at a constant velocity in front of a Calculator-Based Ranger 2™ motion sensor.
- As a result, students will:
  - Develop a linear model for a scatter plot of position versus time data
  - Make a real-world connection between a linear equation used to model the data and the physical motion involved in the data collection process

Materials

- CBR 2™ with USB CBR 2–to–calculator cable
- Mini-standard USB cable (for CBR 2 and computer)
- TI-Nspire Teacher or Student Software (for CBR 2 and computer)
- TI-Nspire™ Lab Cradle (for legacy CBR).
- MDC-BTD cord (for legacy CBR and Lab Cradle)

TI-Nspire™ Navigator™ System

- Use Class Capture to monitor student progress and compare students' mathematical models.
- Use Live Presenter so that a student can demonstrate various steps in the modeling process.
- Share data via File Transfer, if desired.



TI-Nspire™ Technology Skills:

- Collect motion data with the Vernier® DataQuest™ app.
- Run a linear regression in the Vernier DataQuest app.

Tech Tips:

1. Flip the motion detector open. Set the switch to normal.
2. Check the four AA batteries in the CBR 2.
3. Unplug and plug the CBR 2 back in.
4. When using an older CBR or motion detector with the Lab Cradle, you might need to launch Vernier DataQuest™. Then select **Menu > Experiment > Advanced Setup > Configure Sensor > TI-Nspire Lab Cradle: dig1 > Motion Detector**.

Lesson Files:

Student Activity

Walk_a_Line_Student.pdf

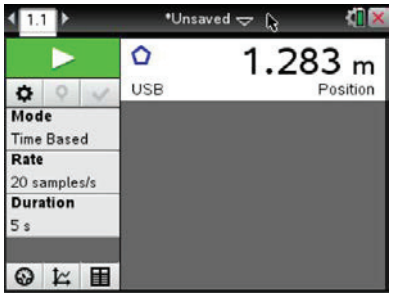
Discussion Points and Possible Answers

Tech Tip: The Vernier DataQuest application should launch when the CBR 2™ is connected. To begin data collection, click the green **Start Collection** arrow in the upper-left corner of the screen. Or press **Tab** until the start arrow is highlighted, then press **Enter** when ready.

Teacher Tip: With the Lab Cradle, you can connect multiple motion detectors to extend your exploration.

Step 1:

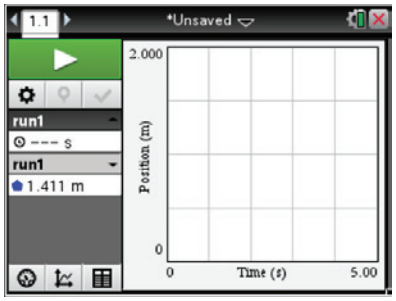
Connect the CBR 2 to the handheld with the USB cable. A Vernier DataQuest page will automatically open, and the CBR 2 will begin measuring the position of the closest object.



Teacher Tip: When the CBR 2 is first connected, it begins clicking and recording measurements. Have the students move the CBR 2 and point it at different objects. Ask them what the motion detector is doing. It should be measuring the distance from the CBR 2 to the object directly in front of it. We call this *the position of the object* with respect to the CBR 2. Be aware that it reads the position of the closest object in its path, so students should have an open area between the CBR 2 and the student whose position they will measure.

Step 2:

Work in groups of two. One person will operate the TI-Nspire handheld and point the CBR 2 toward the other partner, the "walker." The walker should be standing approximately two meters from the motion detector. The walker will walk slowly toward the motion detector at a constant velocity.



Step 3:

Before collecting the data, make a prediction of what the graph of position versus time should look like. Sketch your prediction on the grid to the right.

Answer: Predictions will vary.

Teacher Tip: It is important for students to make a prediction before simply pressing the **Start** button. Making predictions and testing those predictions supports higher-level thinking.

Step 4:

The calculator operator should click the green **Start Collection** arrow in the upper-left corner of the screen, or press **Tab** until the start arrow is highlighted, then press **Enter** when ready. The walker should walk SLOWLY toward the CBR 2 at a constant velocity to close the gap in approximately 5 seconds. Don't go too fast or you will run out of room and need to try again. You must walk at the same velocity the entire time.

Teacher Tip: Students often cannot get the timing right at the beginning of this activity. You might want to suggest that the recording partner press the Enter key to begin data collection after the walker starts walking. This gives students a better opportunity to collect linear data for the entire collection time period. You might also want to remind students that they must walk slowly and at a constant velocity.

Step 5:

Graphs for *position versus time* and *velocity versus time* are created and displayed on the same screen. Repeat as necessary until you generate a graph for *position versus time* that is roughly linear. How does the graph compare with your prediction?

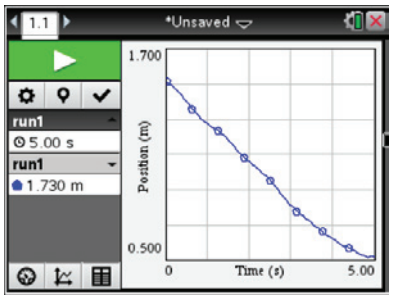
Sample Answer: Comparisons can include function type (linear, quadratic, etc.), *y*-intercept, and whether the graph is increasing or decreasing.

Tech Tip: If the students are not satisfied with their results, they can repeat the data collection by Enter. This will overwrite the previous trial.

Step 6:

To display only the *position versus time* graph, press **Menu > Graph > Show Graph > Graph 1**.

Sketch the actual graph of your *position versus time* graph on the grid shown to the right.



Sample Answer: A sample graph is shown to the right. Since students are all walking toward the CBR 2, all graphs should show a negative slope.

Step 7:

Manual Analysis of Data

a. How can you estimate the average velocity of the walker?

Answer: Find the change in the position (final – initial) and divide that change in position by the elapsed time.

b. What was the position of the walker at time *t* = 0 seconds? At time *t* = 5 seconds?

Sample Answer: At time *t* = 0, the position was 1.5 m. At time *t* = 5, the position was 0.514 m. Answers for the position at time *t* = 5 will vary but should be a positive value, given in meters, and smaller than the starting position.

c. Show your work to calculate the approximate slope of your line using your positions at time *t* = 0 seconds and *t* = 5 seconds.

Sample Answer: (0.514-1.5)/(5-0) = -.197 m/s . Answers will vary, but the slope should be negative.

d. What does the slope of the graph represent physically?

Answer: The slope represents the velocity of the walker.

> **Teacher Tip:** Some students might answer "speed." This is a great opportunity to explain the difference between speed and velocity. Speed indicates how fast the walker is moving but does not include direction. Since speed has magnitude only, it is referred to as a scalar quantity. Speed is always positive. Velocity is called a vector quantity. It includes both speed and direction. Velocity can be positive or negative for a person moving back and forth along a line. Velocity is positive when the walker moves away from the motion detector, increasing the position, and negative when the walker moves toward the motion detector, decreasing the position.

e. Why is the velocity negative?

Answer: The velocity is negative because the position between the walker and the CBR 2 is decreasing.

f. Linear functions are usually written in the form $f(x) = mx + b$. Determine the y-intercept of your line, and write an equation that you think will model the data.

Sample Answer: The y-intercept is 1.5; $f(x) = –0.197x + 1.5$. Equations will vary but should have $b \approx 2$ and m = the slope from part c in Step 7.

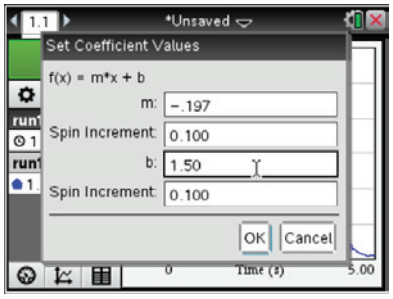
g. What does the y-intercept represent?

Answer: The y-intercept represents the initial or starting position—the distance, in meters, of the walker from the motion detector at time $t = 0$ seconds.

> **Teacher Tip:** Students should determine an equation by hand first to practice finding slope and to help make the connections between the physical actions and the mathematical equation. Students will better understand the meaning and physical representations of the slope and y-intercept if they write their own model rather than simply run a linear regression.

Step 8:

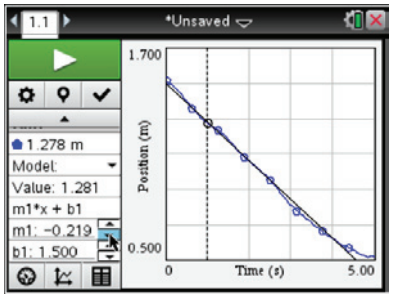
Select **Menu > Analyze > Model**. Select **m*x + b** to create a linear model, and press **OK**. Type the values for the coefficients m and b that you estimated in Step 7 in the spaces provided, and click **OK**.



TI-Nspire Navigator Opportunity: Live Presenter
See Note 1 at the end of this lesson.

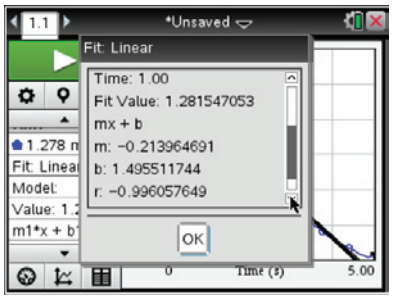
Step 9:

The model can be adjusted or by clicking on the values of m and b displayed on the left side of the screen and editing them or by clicking the slider arrows. See the sample shown to the right. If you made adjustments, record the new values below.



Sample Answer: m = –0.219, b = 1.50; $f(x) = –0.219x + 1.50$

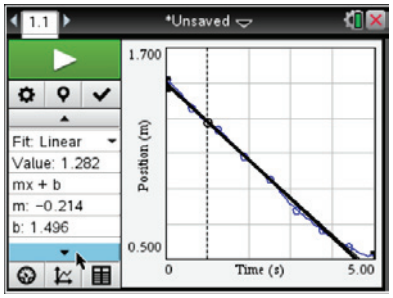
Step 10:



Analyzing the data with a linear regression curve can be performed within the Vernier® DataQuest™ application. Select **Menu > Analyze >Curve Fit > Linear**. This will give the equation of the linear regression model. You will have to scroll down the dialog box to see the values of *m* and *b* for the linear model. Record the values for *m* and *b* below.

Sample Answer: $m = -0.214$; $b = 1.496$

Step 11:



Click **OK** to see the graphical results of the regression. How does your linear regression compare with the equation you found in Step 9? How do the values for *m* and *b* compare?

Sample Answer: The sample linear regression is very similar to the equation from Step 9 but not quite exactly the same. Answers will vary, depending on how constant the walk actually was and how the students read endpoint values.

Teacher Tip: The regression equation should be similar to the students' equations. In some ways, a student's equation might appear to be a better fit because the regression equation might not go through the actual starting position.

Discussions/Explorations

1. As you might have gathered from your practice trials, the CBR 2 collects data measuring how far an object is located from the sensor. By walking in front of the CBR 2, collect a set of data that appears linear and has a positive slope. Provide a detailed description of your walk. Be sure to discuss the real-world connections for the slope and *y*-intercept of the model.

   Sample Answer: The walker stands close to the CBR 2 and slowly walks away at a steady rate. The *y*-intercept is the walker's distance from the CBR 2 at time $t = 0$ seconds. The slope is the walker's average velocity.

2. By walking in front of the CBR 2, collect a set of data that appears linear and has a slope that is approximately zero. Provide a detailed description of your walk, including the connection between slope and *y*-intercept and the physical actions.

   Answer: The walker stands still in front of the CBR 2 and does not move for the entire experiment. The *y*-intercept is the walker's distance from the CBR 2. Since there is no movement toward or away from the CBR 2, the slope is 0.

3. By walking in front of the CBR 2, collect a set of data that represents a piecewise function with two parts, both of which are linear—one with a positive slope and one with a negative slope. Provide a detailed description of your walk, including the connections between slope and *y*-intercept and the physical actions.

   Sample answer: The walker starts close to the CBR 2 and slowly walks away at a steady velocity and then changes direction and heads back toward the CBR 2 at a steady velocity. This could be reversed so that the walker started walking toward the CBR 2 and then walked away. The *y*-intercept is the walker's distance from the CBR 2 at time $t = 0$ seconds. The slopes are the walker's average velocities—positive when walking away from the CBR 2 and negative when walking toward it. During the change in direction, the graph will not be linear.

Wrap Up

Upon completion of the discussion, the teacher should ensure that students are able to understand:

- That the *y*-intercept of a graph of position versus time shows starting position.
- That the slope of a *position versus time* graph shows velocity.
- How negative, zero, and positive slopes relate to motion in a graph of position versus time.

Assessment

Explain why the *y*-intercept on a *position versus time* graph can never be negative.

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Note 1

Step 8, Live Presenter: You might want to use **Live Presenter** here to allow students to share how well their equations fit the data points.

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