

ALGEBRA

TEACHER'S EDITION

Exploring Linear Relations

GAIL F. BURRILL AND PATRICK HOPFENSBERGER

DATA - DRIVEN M A T H E M A T I C S



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Gail F. Burrill and Patrick Hopfensperger

Dale Seymour Publications®

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Table of Contents

Using This Module vii

Unit I: Linearity

Exploratory Lesson:	How Do Events Change Over Time?	3
Lesson 1:	Rates of Change	7
Lesson 2:	Equations of Lines	24
Lesson 3:	Equivalent Forms of Equations	35
Assessment:	Price Changes and Median Earnings	47
Lesson 4 (Optional):	Buying Power	51

Unit II: Lines and Scatter Plots

Exploratory Lesson:	Balloons and More Balloons	57
Lesson 5:	Scatter Plots	61
Lesson 6:	Graphs and Their Special Properties	70
Assessment:	Vital Statistics	90
Lesson 7:	Lines on Scatter Plots	93
Lesson 8:	Technology and Measures of Error	108
Lesson 9:	Lines, Lines, and More Lines	121
Lesson 10:	A Measure of Association	137
Lesson 11:	End-of-Module Project: The Domino Topple	154
Lesson 12 (Optional):	Catapults and Candy	157

Teacher Resources

Quizzes	165
End-of-Module Test	172
Solutions to Quizzes and Test	176
Activity Sheets	182
Procedures for Using the TI-83 Graphing Calculator	201

About *Data-Driven Mathematics*

Historically, the purposes of secondary-school mathematics have been to provide students with opportunities to acquire the mathematical knowledge needed for daily life and effective citizenship, to prepare students for the workforce, and to prepare students for postsecondary education. In order to accomplish these purposes today, students must be able to analyze, interpret, and communicate information from data.

Data-Driven Mathematics is a series of modules meant to complement a mathematics curriculum in the process of reform. The modules offer materials that integrate data analysis with high-school mathematics courses. Using these materials helps teachers motivate, develop, and reinforce concepts taught in current texts. The materials incorporate the major concepts from data analysis to provide realistic situations for the development of mathematical knowledge and realistic opportunities for practice. The extensive use of real data provides opportunities for students to engage in meaningful mathematics. The use of real-world examples increases student motivation and provides opportunities to apply the mathematics taught in secondary school.

The project, funded by the National Science Foundation, included writing and field-testing the modules, and holding conferences for teachers to introduce them to the materials and to seek their input on the form and direction of the modules. The modules are the result of a collaboration between statisticians and teachers who have agreed on the statistical concepts most important for students to know and the relationship of these concepts to the secondary mathematics curriculum.

A diagram of the modules and possible relationships to the curriculum is on the back cover of each module.

Using This Module

Why the Content Is Important

Studying mathematics requires that students first understand both the use of symbols and the concept of variables. The study of relationships between variables and symbols often begins with linearity. Linear relationships between two variables can be explored through questions such as “How do changes in one variable relate to changes in a second variable?” and “Can a pattern be expressed using mathematical symbols?” The relationship between a constant rate of change and linear data provides the foundation for thinking about slope and linear equations.

In this module, students make and interpret scatter plots and plots over time, using various data such as car prices and median incomes of men and women. They investigate slope as a rate of change, summarize data by fitting a straight line, find the equation of that line, and use those results to make predictions. They explore which line is *best*, and in the process they are introduced to measures of error and correlation. The relationship between algebraic expressions and their real-world meanings is emphasized. Working from problems in real-world contexts, students solve equations in one variable, find equivalent forms of equations, and learn about linearity. In each situation, they investigate the data from three perspectives: numerical, graphical, and symbolic.

Emphasis is on student-constructed mathematics to quantify a situation and the use of the information to solve a problem. Many of the problems are open-ended; students have to make decisions about how to construct the data set as well as how to begin to analyze the data. Students learn to recognize the assumptions they make when extrapolating information from graphs or summarizing an entire data set with a line. Practice is provided for some basic concepts. Students learn that there are different ways to represent quantities, and one way might be better for a stated purpose than another. For example, the point-slope form of a linear equation is an efficient way to write the equation of a line given a point and the slope, whereas the slope-intercept form can be used to determine whether or not two lines are equivalent. Sometimes the intercepts are used in graphing a given line, whereas in other situations, the intercepts are not even meaningful. For numerical comparison, slopes can be expressed as decimals; however, when graphing, fractions are often more useful.

An equation in two variables can be derived from a graph. Solving an equation in one variable can then be framed in terms of the graphical application. Students are given data and then asked to find an appropriate line to represent the data. They are also given a line and asked to interpret it in terms of the data. They are introduced first to the point-slope form of a linear equation as a way to write an equation that summarizes the situation.

From a statistical perspective, students work with real-world data to find the answer to a question or the solution to a problem. As students encounter different situations involving data, they learn to think about the data, what the data mean, and how the data are related to the problem. Students learn to understand how two variables might be related, how to describe that relationship, and how to use the relationship to make generalizations or predictions. Students recognize the role of correlation as a way to measure the strength of a relationship between variables. They use the root mean squared error as a way to describe the variability involved in using a line to summarize the relationship. In particular, students gain understanding of how interpolation (reading between data points) is accomplished with some certainty in the reliability of the answer, but how extrapolation (reading beyond given data points) is based on strong and perhaps incorrect assumptions. Therefore, they learn to recognize the dangers of relying too heavily on this kind of reasoning.

Algebra: Students will be able to

- Find and interpret slope as a rate of change.
- Write the equation of a line from given information.
- Identify and interpret intercepts and zeros.
- Graph a linear equation.
- Identify equivalent equations.
- Solve an equation in one variable.
- Graph and interpret the line $y = x$.

Statistics: Students will be able to

- Make and interpret a scatter plot.
- Make and interpret plots over time.
- Find a median fit line.
- Find a measurement for error in a fit for paired data.
- Find a line that is the *best* fit for the data.
- Use the concept of residual to find prediction errors.
- Find and interpret an approximation for a correlation coefficient.

Instructional Model

Exploring Linear Relations (and all of the modules in *Data-Driven Mathematics*) emphasizes discourse and student involvement. Each lesson is designed around a problem or mathematical situation and begins with a series of introductory questions or scenarios that can prompt discussion and raise issues about that problem. These questions can involve students in thinking about the problem and help them understand why such a problem might be of interest to someone in the world outside the classroom. The questions can be used in whole-class discussion or in student groups. In some cases, the questions are appropriate to assign as homework with some family involvement.

These questions are followed by discussion issues that clarify the initial questions and begin to shape the direction of the lesson. Once the stage has been set for the problem, students begin to investigate the situation mathematically. As students work their way through the investigations, it is important that they have the opportunity to share their thinking with others and to discuss their solutions in small groups and with the entire class. Many of the exercises are designed for groups in which each member does one part of the problem and the results are compiled for final analysis and solution. Multiple solutions and solution strategies are also possible, and it is important for students to recognize these situations and to discuss the reasoning behind different approaches. This will provide each student with a wide variety of ways to build his or her own understanding of the mathematics.

In many cases, students are expected to construct their own understanding by thinking about the problem from several perspectives. They do need, however, validation of their thinking and confirmation that they are on the right track, which is why discourse among students, and between students and teacher, is critical. In addition, an important part of the teacher's role is to help students link the ideas within an investigation and to provide an overview of the "big picture" of the mathematics within the investigation. To facilitate this, a review of the mathematics appears in the *Summary* following each investigation.

Each investigation ends with a practice section in which students can revisit ideas presented within the lesson. These exercises may be assigned as homework, given as group work during class, or omitted altogether if students are ready to move ahead.

Periodically, student assessments occur in the student book. These can be assigned as long-range take-home tasks, as group assessment activities, or as in-class work. The assessment pages provide a summary of the lessons up to that point and can serve as a way for students to demonstrate what they know and what they can do with the mathematics. Commenting on the strategies students use to solve a problem can encourage students to apply different strategies. Students also learn to recognize those strategies that enable them to find solutions efficiently.

Teaching Resources

At the back of this Teacher's Edition are the following:

- Quizzes for selected lessons and the End-of-Module Test
- Solution Key for quizzes and test
- Activity Sheets
- Procedures for Using the TI-83 Graphing Calculator

Use of Teacher Resources

These items are referenced in the *Materials* section at the beginning of the lesson commentary.

LESSONS	RESOURCE MATERIALS
Unit I: Linearity	
Exploratory Lesson: How Do Events Change Over Time?	
Lesson 1: Rates of Change	<ul style="list-style-type: none">• Activity Sheet 1 (Questions 2 and 18)
Lesson 2: Equations of Lines	<ul style="list-style-type: none">• Activity Sheet 2 (Questions 4 and 6)• Lesson 2 Quiz
Lesson 3: Equivalent Forms of Equations	<ul style="list-style-type: none">• Lesson 3 Quiz
Assessment: Price Changes and Median Earnings	
Lesson 4 (Optional): Buying Power	<ul style="list-style-type: none">• Activity Sheet 3 (Question 2)
Unit II: Lines and Scatter Plots	
Exploratory Lesson: Balloons and More Balloons	<ul style="list-style-type: none">• Activity Sheet 4 (Question 4)
Lesson 5: Scatter Plots	<ul style="list-style-type: none">• Activity Sheets 5 and 6 (Question 3)• Activity Sheet 7 (Question 5)
Lesson 6: Graphs and Their Special Properties	<ul style="list-style-type: none">• Activity Sheet 8 (Question 11)
Assessment: Vital Statistics	
Lesson 7: Lines on Scatter Plots	<ul style="list-style-type: none">• Activity Sheet 9 (Questions 7 and 10)• Activity Sheet 10 (Questions, 9, 13, 14, and 15)• Activity Sheet 11 (Questions 19 and 22)• Lesson 7 Quiz
Lesson 8: Technology and Measures of Error	<ul style="list-style-type: none">• Procedures for Using the TI-83
Lesson 9: Lines, Lines, and More Lines	<ul style="list-style-type: none">• Activity Sheet 12 (Question 4)• Activity Sheet 13 (Question 5)• Activity Sheet 14 (Question 6)• Lesson 9 Quiz
Lesson 10: A Measure of Association	<ul style="list-style-type: none">• Activity Sheet 15 (Question 3)• Activity Sheet 16 (Question 7)
Lesson 11: End-of-Module Project, The Domino Topple	<ul style="list-style-type: none">• End-of-Module Test
Lesson 12 (Optional): Catapults and Candy	

Where to Use the Module in the Curriculum

This module is about graphing and working with linear equations. It can be used in a first-year algebra course in a variety of ways, most effectively when it is integrated during the first semester of the course.

The module can

- Replace the standard chapter on graphing linear equations in any traditional mathematics text.
- Be used after students have completed a section on solving equations in one variable to illustrate how to apply those concepts in real-world contexts and provide investigations into graphical representations of linear relationships.
- Be used as the second or third unit in a course, following *Exploring Symbols: An Introduction to Expressions and Functions* and possibly *Mathematics in a World of Data* from the *Data-Driven Mathematics* series.
- Be used as the introductory unit on slope, graphing, and equations in any mathematics course of study.

Selected lessons from this module can

- Provide real-world applications of graphing and solving equations.
- Be used in advanced courses to introduce students to curve fitting from data, using linear models in real-world contexts.

Prerequisites

Students should have experience in using variables to describe relationships, plotting points, simplifying simple expressions, and solving simple equations.

Pacing/Planning Guide

The table below provides a possible sequence and pacing of the lessons in this module.

LESSONS	OBJECTIVE	PACING
Unit I: Linearity		
Exploratory Lesson: How Do Events Change over Time?	Experiment with an outcome that will change over time.	1/2 class period or homework
Lesson 1: Rates of Change	Find and interpret slope as a rate of change; find the rate of change from data.	2–3 class periods
Lesson 2: Equations of Lines	Write the equation of a line drawn through a set of points that appear to be linear.	2 class periods
Lesson 3: Equivalent Forms of Equations	Determine if two equations are equivalent by using graphs, ordered pairs, and equivalent forms.	2 class periods
Assessment: Price Changes and Median Earnings	Apply the concepts of slope and lines.	1 class period or homework
Lesson 4 (Optional): Buying Power	Solve problems by applying concepts of percentage, slope, and linearity; analyze data that do not have a constant rate of change.	1 class period
Unit II: Lines and Scatter Plots		
Exploratory Lesson: Balloons and More Balloons	Investigate the relationship between two variables.	1 class period
Lesson 5: Scatter Plots	Read and interpret a scatter plot; summarize a linear relationship between two variables in a scatter plot by drawing a line.	1 class period
Lesson 6: Graphs and Their Special Properties	Recognize different forms of equations that represent a line, and relate these forms to the graph; find and interpret x - and y -intercepts of an equation and its zero.	4 class periods
Assessment: Vital Statistics	Use intercepts, rate of change, and lines to analyze a situation.	1 class period or homework
Lesson 7: Lines on Scatter Plots	Find a “good” line for a scatter plot by considering a measure of error.	3 class periods
Lesson 8: Technology and Measures of Error	Use technology to find a measure of error in predicting by using an equation.	1 class period
Lesson 9: Lines, Lines, and More Lines	Summarize data by drawing a median fit line; solve a linear equation.	3 class periods

Lesson 10: A Measure of Association	Determine the strength of a linear relationship by finding a measure of correlation; understand the connection between correlation and cause/effect.	2 class periods
Lesson 11: End-of-Module Project, The Domino Topple	Explore the relationship between several variables.	1 class period
Lesson 12 (Optional): Catapults and Candy	Collect and organize data; investigate the relationship between two variables; use slope and intercept in meaningful contexts; write an equation that can be used to make predictions; design an experiment, and understand how the variables can change the results; prepare an argument based on data.	1 class period
		approximately 5 weeks total time

Technology

A scientific calculator is necessary for this module. A computer with spreadsheet software or a graphing calculator with list capabilities would be helpful but is not absolutely necessary. (A graphing calculator resource section, entitled *Procedures for Using the TI-83 Graphing Calculator*, is included at the end of this module.) Exercises that might be more efficiently done with technology are indicated by [tech]. Access to these tools will facilitate working with the data and allow students to focus on finding the solutions rather than plotting the data. Entering the data on the spreadsheet before the lesson will enable students to focus on manipulating data rather than entering it.

A link connecting two graphing calculators will help groups share or download data. Data can be stored on a computer disk and accessed by linking to a calculator using a calculator software package.

Lesson 8 contains instructions for graphing with the spreadsheet for Microsoft Works. If you do not have Microsoft Works, adapt the first part of the lesson to your spreadsheet program, or omit the first part and do the second part of the lesson in which graphing calculators are used. It would be useful to have an overhead projection panel for a computer when demonstrating a spreadsheet, or likewise one for a graphing calculator.

An overhead projector will also be helpful. Overhead transparencies of particular data sets, graphs, or *Activity Sheets* can be useful during class discussion.

Grade Level/Course

The module is appropriate for students in an algebra course. The lessons can be used in conjunction with an integrated mathematics course or a mathematical topics course.

Linearity

EXPLORATORY LESSON

How Do Events Change Over Time?

Materials: graph paper, paper, pencils or pens, rulers, stopwatch, basketball, basketball hoop

Pacing: 1/2 class period or homework

Overview

This lesson can be used as an exercise for the entire class, given as a homework assignment, or completed with data given by the teacher. The activity is designed to have students think about events that change over time, how they might be described, and how a graph would relate to the description. Instead of a basketball and hoop, you may want to use paper balls and a wastebasket or small foam balls and plastic hoops. Or, you could have several volunteers perform the experiment at home or in the gymnasium and bring their results to class the next day. Be sure to discuss the experiment before conducting it, noting the possible continued improvement in scores as the shooter practices, and the decrease in scores as he or she gets tired. An outlier in the data can occur when the ball hits the rim at an angle and rebounds at a significant distance from the basket, resulting in fewer baskets for that time interval.

Ask students to think of other changes over time that might be significant: population, height, weight, or incidence of a given disease. For class discussion, students might ask family members about price changes they notice or remember, and students can also look for changes in the prices of items they purchase.

Solution Key

Data Collection and Analysis

1. **a.** Students could make arguments for either hypothesis. An argument for the first hypothesis may come from someone who shoots baskets regularly—it may take a while to get into a rhythm, and then the number of baskets will increase. An argument for the second hypothesis may come from someone who realizes that, in 4 minutes of continuous attempts, a person’s arms are likely to become tired.
- b.** One possible hypothesis is a combination of the two suggested. As a person shoots, the score will improve with practice. But, as the person tires near the end of the 4 minutes, the score will decrease.

EXPLORATORY LESSON

How Do Events Change Over Time?

How does the temperature in your state change from month to month?

From year to year?

Can you predict any patterns?

How does the cost of buying groceries change over time?

How does your height change from year to year?

Analyzing trends in events that occur over time is very important for people in many occupations in government, business, and industry, and for people who study climate, the environment, or agriculture. In this unit, you will explore ways different events change over time and develop mathematics necessary to describe and analyze the changes.

OBJECTIVE
Experiment with an outcome that will change over time.

EXPLORE

Practice Makes Perfect

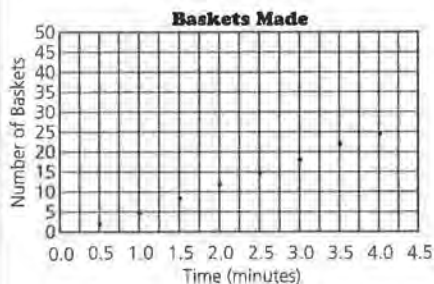
Suppose you shoot a basketball for 4 minutes and record how many baskets you make in the first 30-second interval, in the second 30-second interval, and so forth, throughout the 4 minutes. Do you think that the number of baskets you make in each 30-second time interval will change over time?

Data Collection and Analysis

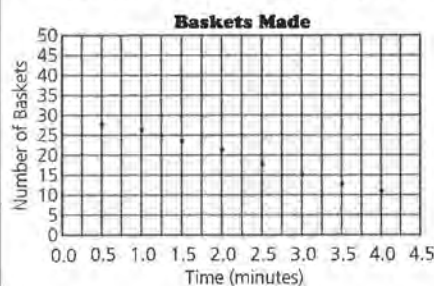
1. One hypothesis might be that as you continue to shoot baskets, you will improve your score with practice. Another

STUDENT PAGE 4

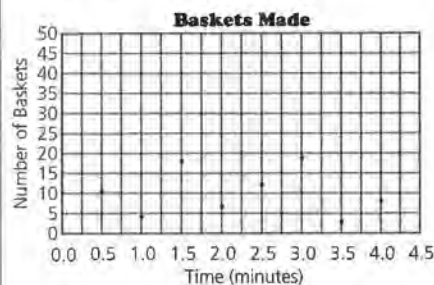
2. a. A graph of the first hypothesis should rise from left to right, and the data points should not be connected. The graph does not have to have a constant rate of increase, nor any particular shape, as long as each successive point is higher than the previous one.



The graph for the second hypothesis should fall from left to right, and the data points should not be connected. The graph does not have to be linear or have any other particular shape as long as it is decreasing over the entire graph.

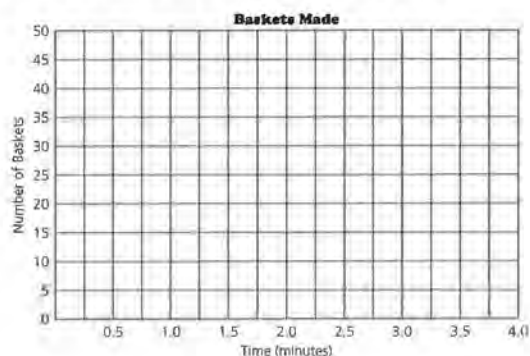


- b. If there is no connection, the points should appear to be random.



might be that as you continue to shoot, your score will become worse because you will grow tired.

- a. Which of these two hypotheses do you think is more reasonable? Explain.
- b. What is another possible hypothesis regarding your scores?
2. A graph showing the time intervals and the number of baskets can help you see the relationship between the length of time and the number of baskets you make.
- a. What will the graph look like if the first hypothesis is true? If the second is true?
- b. What will the graph look like if there is no relationship between the length of time you shoot and the number of baskets you make?
3. Conduct the experiment, and plot the results on a grid like the one below. Plot the time in minutes along the horizontal, or x-axis (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0), and the number of baskets made along the vertical, or y-axis.



- a. What conclusion can you make about the relationship between time and the number of baskets you made?
- b. Do you think everyone in the class will have the same conclusion? Why or why not?

3. The shapes of students' graphs will depend on the data they collect.

- a. Students should justify their conclusions, using the graph of their data.
- b. It is likely that the conclusions will vary because each student's data will be different. There is no reason to expect that everyone's data will have the same pattern.

STUDENT PAGE 5

- 4. a.** The responses will depend on the actual data compared. Students may discuss differences in the shapes of the graphs, the magnitudes of the values, or other variations among the graphs.
- b.** Avoid spending too much time on this question, as there is no right solution, but encourage students to be creative in their approaches.

There are a number of ways the scores could be combined. For example, the sum of the scores or the mean of the scores could be used. In these cases, each score contributes to the combined score. The median score for each time period could also be used. In this case, the individual scores would not necessarily contribute to the combined scores, other than to define the middle value. Using the median would tend to "even out" variation in the scores.

The overall conclusion will depend upon the combined data.

- 4.** Collect and analyze the results gathered by several other students.
 - a.** How are the results alike? How are they different? How does your conclusion compare with those of your classmates?
 - b.** Determine a way to make a graph of the combined scores of the students in your group. Describe how you decided to use this method. How does each individual's score contribute to the overall results shown in the graph of the combined scores? What overall conclusion about time and scores can you make?

LESSON 1

Rates of Change

Materials: graph paper, pencils or pens, rulers, *Activity Sheet 1*

Technology: calculators (optional)

Pacing: 2–3 class periods

Overview

This lesson introduces students to rate of change by analyzing prices that change over time and relating the rate of change to a graph. The initial questions can be used to start class discussion by having students think about rate of change. Varying the horizontal and vertical scales can make the same rate of change appear different; thus, mathematics is useful to quantify the rate of change in a way that can be accepted by everyone. Students investigate what happens to a graph generated by a constant rate of change and, conversely, learn that the rate of change for every two pairs of points on the graph of a line is the same. Students also investigate zero, positive, and negative rates of change in real-world contexts by thinking about the context and looking for patterns in a table of values. They study graphs of quantities, such as gasoline prices that change over time, and use rates of change to compare linear and nonlinear relationships.

Teaching Notes

It is important to allow students to explore the concept of rate of change in a variety of contexts before they are formally introduced to slope. Emphasize the concept of slope rather than the mechanics of its calculation. Stress the fact that for the slope ratio, the numerator is the change in the coordinates on the vertical axis, whereas the denominator is the change in the coordinates on the horizontal axis. Students should think of a negative change as a decrease in a quantity over an interval, using the negative in a way that makes sense for the data. The real-world contexts provide a way for students to understand equivalent ratios and negative rational numbers. Students

should be encouraged to continually refer to the contextual situation for help in making sensible interpretations.

Students should be able to find the rate of change given at least two points on a graph. Be sure they sketch the points each time, using an appropriate scale. Students should recognize the relationships between the rate of change, a table of values that reflects the same rate of change, and the graph. Displaying student graphs, side by side, on the overhead projector or bulletin board can help students recognize the impact of scale on visualization; often the various graphs are correct but look very different because of the scales used.

Follow-Up

Students can discuss graphs from newspapers and magazines in pairs, in small groups, or with the entire class. Have them consider the rate of change in each of the graphs (whether or not it is constant, positive, or negative) and interpret the rate of change in context.

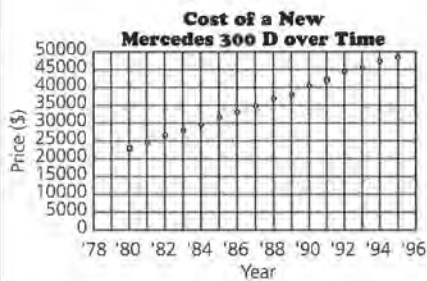
Students might consider rate of change in relation to the concept of slope. For example, how can rate of change be used to describe the slope of a hill, of a roof, or of a line? You might also ask them to describe situations in which the slope would be positive and others in which it would be negative.

Solution Key

Discussion and Practice

1. a. $\$41,350 - \$23,000 = \$18,350$
 b. $\$18,350 \div 11 = \1668.18 , or about \$1668 per year
 c. $\$23,000 + \$1668 = \$24,668$
2. a. Students should answer on *Activity Sheet 1*.

Year	Cost of Mercedes
1980	\$23,000
1981	24,668
1982	26,336
1983	28,004
1984	29,672
1985	31,340
1986	33,008
1987	34,676
1988	36,344
1989	38,012
1990	39,680
1991	41,348
1992	43,016
1993	44,684
1994	46,352
1995	48,020



- b. The pattern is a straight line.

LESSON 1

Rates of Change

Are prices really going up?

Do all prices rise by the same amount?

If your salary rises at the same rate as the price of a car, can you buy the same model again next year?

OBJECTIVES

Find and interpret slope as a rate of change. Find the rate of change from data.

Often measurements change over time. For example, each year young children grow taller; the population increases or decreases; some salaries increase, and some salaries decrease; some prices rise, and some prices fall. It is important to understand change, not only to see what happened in the past but also to look for possible trends and patterns in the future. How much should you expect to pay for a car? How much can you afford to buy with a given salary? The problems in this unit will use mathematics to answer these questions.

INVESTIGATE

New Car Prices and Requirements

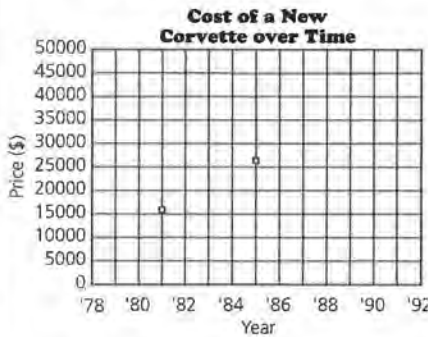
In 1980, a brand-new Mercedes with a 300-diesel engine cost \$23,000. The price went up each year, so that in 1991, the price for the same car was \$41,350. How did the price change over time? Is there a way to describe this change per year?

Discussion and Practice

1. The prices of the Mercedes in 1980 and 1991 are plotted on the next page.
 - a. What is the change in price from 1980 to 1991?
 - b. If the price changes by the same amount each year, about how much is the change in price per year?
 - c. Using your estimate, what was the price of the Mercedes in 1981?

STUDENT PAGE 7

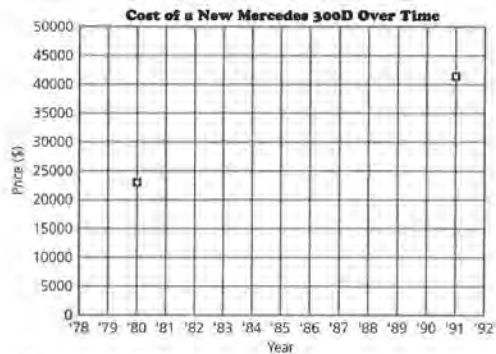
3. a. $\$26,901 - \$16,141 = \$10,760$,
and $1985 - 1981 = 4$.
So, $\$10,760 \div 4 = \2690 .



b. The price increase per year was greater for the Corvette than for the Mercedes. This could be explained a number of different ways. For example, the Corvette might have been dramatically redesigned during the time period, resulting in a sharp price increase in one year whereas the price of the Mercedes rose just a bit each year. The price increases for both cars could have been similar from 1981 to 1985, but since the data for the Mercedes extended over a longer period of time, the average for that car fell. The demand for American, smaller, or sportier cars might have increased, so the makers of the Corvette were able to raise prices faster than the makers of the Mercedes.

c. The price change of the Corvette was not constant. Possible explanations could include that when the increase per year from 1981 to 1985 (\$2690) is compared to either the increase per year from 1981 to 1991 (\$1726.90, or about \$1727) or to the increase per year from 1985 to 1991 (\$1084.83, or about \$1085), they are different. This indicates the price increase was not constant. Another way to show that

the price increase was not constant is to try to draw a single line through all three points. Since this is not possible, the increase is not constant.

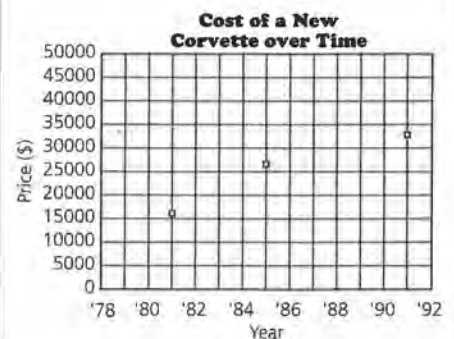


Source: Kelly Blue Book, 1994

2. Assume that the change in price per year is represented by the constant amount found in the table below.

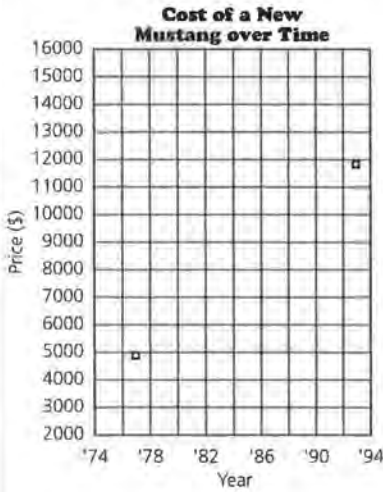
Year	Cost of Mercedes	Year	Cost of Mercedes	Year	Cost of Mercedes
1980	\$23,000	1986	_____	1991	_____
1981	24,668	1987	_____	1992	_____
1982	26,336	1988	_____	1993	_____
1983	_____	1989	_____	1994	_____
1984	_____	1990	_____	1995	_____
1985	_____				

- a. Use *Activity Sheet 1* to complete the table and plot the points (year, cost) on the grid.
- b. Describe the pattern of the points you see in the graph.
3. In 1985, a new Chevrolet Corvette sold for approximately \$26,901; whereas in 1981, a new Corvette sold for \$16,141.
- a. Plot the two ordered pairs for the year and cost of the Corvettes. Using *only* your graph, estimate the change in price per year.
- b. How does your estimate for the change in price per year of the Corvette compare with that of the Mercedes?
- c. In 1991, a Corvette cost about \$33,410. Plot this new point on your graph. Is the change in price the same, or



STUDENT PAGE 8

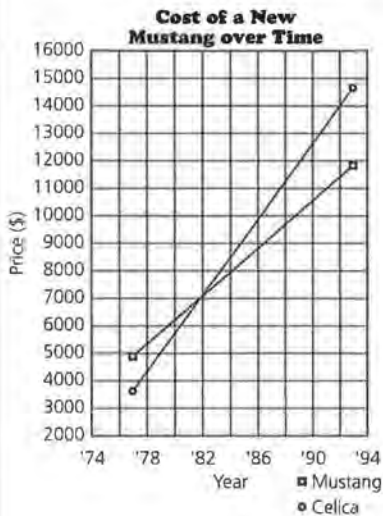
4. a. $\$11,873 - \$4906 = \$6967$, and $\$6967 \div 16 = \435.4375 , or about $\$435$ per year



From 1975 to 1991, the price of a Mustang rose by about $\$435$ per year.

- b. $\$14,658 - \$3694 = \$10,964 \div 16 = \685.25 , or about $\$685$ per year

From 1975 to 1991, the price of a Celica rose by about $\$685$ per year.



constant, from 1981 to 1991? Explain how you found your answer.

Another way to describe the change in price per year is to calculate the rate of change in the price. Look at the following table of car prices.

New Car Prices

Year	Honda Civic	Chevrolet Camaro	Toyota Celica	BMW	Chevrolet Corvette	Mercury Cougar	Ford Mustang
1975	\$2,799	\$4,739	\$3,694	\$10,605	\$9,424	\$6,121	\$4,906
1991	\$9,405	\$13,454	\$14,658	\$35,600	\$33,410	\$16,114	\$11,873

Source: Kelley Blue Book, 1994

This is how to find the rate of change in price for a BMW.

$$\frac{35,600 - 10,605}{1991 - 1975} = \frac{24,995}{16} = 1562$$

The change in price for a BMW is about $\$1562$ per year.

4. Use the table above.



- Plot the points (year, price) for the Ford Mustang. Draw a line through the points, and estimate the rate of change in price per year.
 - On the same grid, plot the prices for the Toyota Celica. Draw a second line, and estimate the rate of change in price per year for the Toyota.
 - How do the two lines compare? How is the difference in the rates of change in prices reflected in the two graphs?
 - Look at *all* the data in the table. Do *all* of the cars have approximately the same rate of change in price over the time shown? Explain your conclusions.
5. Consider a set of data with a zero rate of change.
- What do you think a *zero rate of change* means?
 - Sketch the graph of the cost of a new car for which the change in price over time is zero. Describe your graph.
6. According to the Recording Industry Association of America, there were approximately 53 million CDs (compact discs) sold in 1986. Each year thereafter, 58.5 million more CDs were sold than in the year before.

- The line for the Celica is steeper than the line for the Mustang, so the price of the Celica rose more per year than that of the Mustang. In 1975, the Celica was cheaper than the Mustang, but by 1991, the Celica was more expensive. For this to happen, the price of the Celica must have risen more rapidly.
- No, the prices do not appear to have risen at the same rate over the time period. The rates of change in price depend on many

factors—competition, new designs, demand, tariffs for foreign cars, and so on—so it is logical that the rates of change would be different.

One strategy is to list the cars in ascending order of price in both 1975 and 1991:

- 1975: Civic, Celica, Camaro, Mustang, Cougar, Corvette, BMW
 1991: Civic, Mustang, Camaro, Celica, Cougar, Corvette, BMW

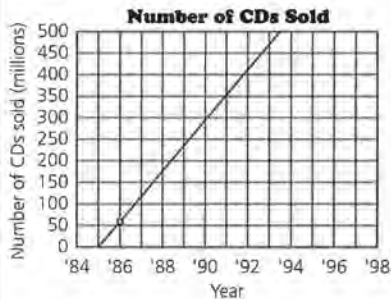
(4d) Notice that the order is different. This means that the prices must not have risen at the same rate, because if they had, the order would be the same for each year. Other explanations could be based on graphs, on actual calculations, or on other justifications.

5. a. A zero rate of change means that the price did not change at all over time but remained the same each year.

b. The line is horizontal.



6. a. In order to make the graph, you assume that the rate of change in CD sales is constant or the same over the years.



b. There are two ways to make the prediction: Either read the value from the graph, or compute the value (462.5 million) using the increase per year and the 1986 value given. In either case, the prediction should be about 460 million CDs.

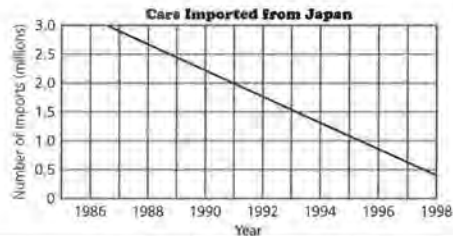
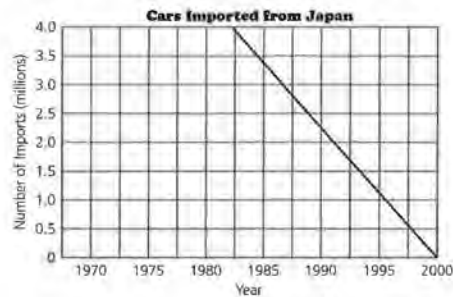
c. If the increase was more than 58.5 million per year, the line would be steeper.



- a.** On grid paper, plot the data representing the number of CDs sold over time, and draw a line to summarize the relationship. What assumption did you make in order to draw your line?
- b.** Using your graph, predict the number of CDs sold in 1993. Explain how you made your prediction.
- c.** Suppose the number of CDs sold per year increased by more than 58.5 million. What would your new line look like?

The *scale* used for a graph affects how you visualize the magnitude of a rate of change.

7. One newspaper reported that in 1988, 2.7 million cars were imported from Japan to the United States; whereas in 1992, 1.8 million cars were imported from Japan. A second newspaper reported that in 1988, 2.7 million cars were imported from Japan to the United States, and in 1990, 2.25 million cars were imported from Japan. Each newspaper article included a graph of a straight line representing the number of cars imported from Japan over the years, as shown here.

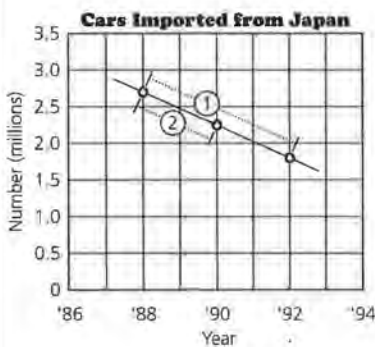


7. a. $1.8 - 2.7 = -0.9 \div 4 = -0.225$
and $2.25 - 2.7 = -0.45$
 $\div 2 = -0.225$

The rate of change was -0.225 million cars.

You would expect the lines to have the same steepness. They do not because in the first graph, the x -axis represents 30 years whereas in the second graph, the x -axis represents 10 years. But the length in both cases is the same. The scale on the y -axes in both graphs is the same, so the change per year appears different because of the different scales on the x -axes.

- b. There was a decrease of about 225,000 foreign cars imported each year.
- c. The articles do not appear to have contradicted each other. Both reported the same number of imports in 1988. The three points appear to fall in a straight line, but even if they were not in a line, the articles still would not have contradicted each other because there was no claim of a constant change.



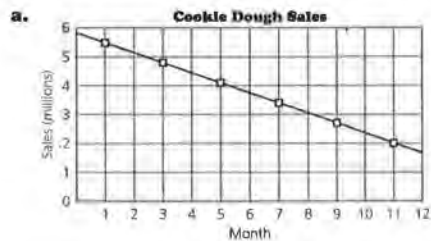
- d. Students should agree with this statement. Either the actual numbers should be compared or two graphs with the same scale should be used. Graphs with different scales might be used to compare change if the x - and y -axes are reduced or enlarged by the same amount.



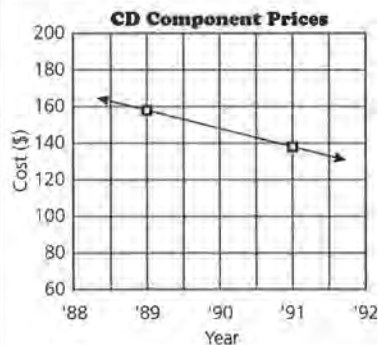
- a. What is the rate of change in the number of cars imported from 1988 to 1992 as quoted in each newspaper? Explain the difference between the two graphs shown.
- b. What can you conclude about the number of cars imported from Japan to the United States?
- c. Plot the points (*year, number of imports*) on the same set of axes for both sets of data from the news articles. What conclusion can you now make? Do the articles contradict each other? Why or why not?
- d. "To compare two rates of change, you either have to use mathematics or be very careful about your graph." What does this statement mean?
5. In 1991, the cost of a CD component with remote control was \$139. In 1989, the same component cost \$159.



- a. On graph paper, plot the points representing the cost of the CD component each year.
- b. What is the change in price per year? What does it tell you?
- c. What might explain the fact that the price of the CD player has decreased?
- d. Name at least two other items whose prices have decreased over the past several years.
9. Describe, in words, the rate of change shown in each of the next two graphs.



8. a.



STUDENT PAGE 11

b. $\$139 - \$159 = -\$20$ and
 $-\$20 \div 2 = -\10

The price decreased \$10 per year.

c. There are a number of possible explanations, including these: The price of the parts needed to make the component decreased, the price needed to cover research and development decreased, or the competition increased, thus encouraging the manufacturer to reduce the price.

d. There are many possibilities, particularly products involving technology, such as computers, CD players, answering machines, and VCRs.

9. a. The sales of cookie dough decreased steadily from one month to the next over the year.

$\$1.7 - \$5.9 = -\$4.2$, and
 $-\$4.2 \div 12 = -\0.35

The rate of change is approximately $-\$0.35$ million, or a decrease of about \$350,000 per month.

b. The number of cellular phones increased by about the same amount every year from 1989 to 1993.

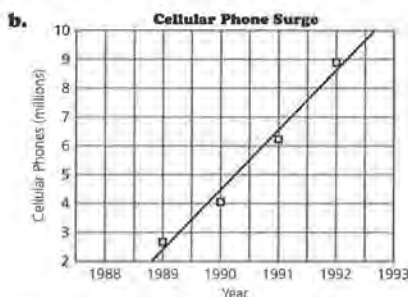
$10 - 3 = 7$, and $7 \div 4 = 1.75$,
 or about 2

The rate of change is an increase of about 2 million phones per year.

10. a. The graph shows that there was an average of about 10,430 vehicle miles in 1974.

$10,430 - 10,270 = 160$ and
 $160 \div 4 = 40$

This means there was an increase of 40 miles per year from 1970 to 1974.



Source: Cellular Telecommunications Industry Association, 1992

10. According to the 1993 Council on Environmental Quality, people drove a yearly average of 10,270 vehicle miles in 1970. The data for the estimated average number of vehicle miles per year, driven through 1994 are graphed below.



Source: data from 1993 Council on Environmental Quality

- 10. b.** There was an average of about 11,230 vehicle miles in 1994 and 10,990 in 1988.

$$11,230 - 10,990 = 240, \text{ and } 240 \div 6 = 40$$

The rate of change is 40 miles per year.

- c.** Since the graph appears to be linear, the value for 1993 will be halfway between the values for 1992 and 1994. The value for 1992 is 11,150, and the value for 1994 is 11,230.

$$11,230 - 11,150 = 80, \text{ and } 80 \div 2 = 40 \text{ and } 11,150 + 40 = 11,190$$

The value for 1993 is 11,190.

This value could also be found by simply adding the 40 miles per year found in **b** to the 1992 value of 11,150, or 11,190. Either way, this is not exactly the value given in the council's report, but it is close.

- 11. a.** $38 - 68 = -30$, and $1984 - 1980 = 4$

$$-30 \div 4 = -7.5, \text{ for a rate of change of } -7.5.$$

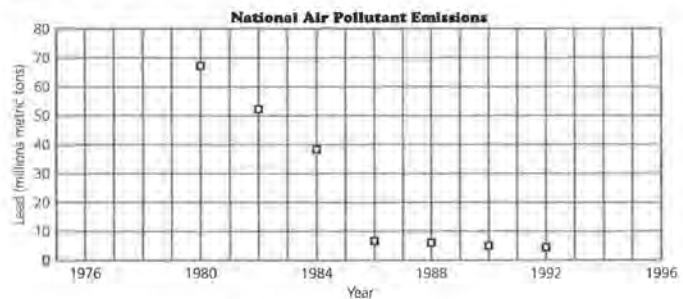
Therefore, from 1980 to 1984, the rate of change in the amount of lead in the air was -7.5 million metric tons per year, or the amount of lead in the air decreased by about 7.5 million metric tons per year.

- b.** $7 - 38 = -31$, and $1986 - 1984 = 2$
 $-31 \div 2 = -15.5$

The rate of change of the amount of lead in the air from 1984 to 1986 was about -15.5 million metric tons per year.

- a.** Find the average number of vehicle miles driven in 1974. What was the rate of change from 1970 to 1974?
- b.** What was the rate of change in the average number of vehicle miles driven from 1988 to 1994? How did you find your answer?
- c.** According to the report of the council, the average number of vehicle miles driven in 1993 was 11,090 miles. How does this value compare with the data shown in the graph? How did you find your estimate?

- 11.** The amount of lead in the air from 1970 to 1992, based on information from the United States Bureau of the Census, is shown on the following graph. Recall that a graph of ordered pairs like this one is called a *scatter plot*.



Source: data from United States Bureau of the Census.

- a.** Estimate the amount of lead in the air in 1980. What is the approximate rate of change from 1980 to 1984?
- b.** What was the rate of change in the amount of lead in the air from 1984 to 1986? How did you find the rate?
- c.** According to one environmentalist, the rate of change in the amount of lead in the air has *not* been constant, and in recent years it has been decreasing. Do you agree or disagree with that statement? Explain your reasoning.
- d.** For which scatter plot—the one for the amount of lead in the air or the one for the average number of miles driven per year—does it seem more reasonable to summarize the relationship with a straight line? How does the rate of change help you make your conclusion?

c. One would be inclined to agree with the environmentalist. Looking at the years after 1986, each successive pair of points shows a smaller and smaller change. This can be seen by noting that a line connecting each successive pair of points is close to horizontal.

d. It is more reasonable to summarize the average number of miles driven per year as a line. If any two

points on this scatter plot are chosen and the rate of change per year is calculated, the value is about the same, or constant. This is not the case for the scatter plot of the lead in the air.

Students having difficulty should be encouraged to try drawing a single straight line on each graph to summarize the relationship, so that they can see the difficulty with the scatter plot of the lead in the air. Once they are convinced, they should be encouraged to explore the rate of change between pairs of points on each scatter plot and to see the relationship between a constant rate of change and a straight line.

Practice and Applications

12. a. (1991, 139) and (1989, 159)
 b. Yes, $\frac{-20}{2} = -10$, which is the same value.

Students might think of this either as beginning from 1989 at 159 and going right to 1991, then down (negative) to 139; or as going from 1991 at 139 left (negative) to 1989 and up to 159. In other words, the rate of change of -10 can be expressed as "Two years ago, it was 10 units larger," or "In two years, the value has decreased by 10."

SUMMARY

When the rate of change is *constant* for equal time intervals, the graph of the relationship is a straight line. The *rate of change* is sometimes called the *slope* of the line. You can find the slope by finding the ratio of the change in the y -values of two representative data points and the corresponding change in the x -values of the same data points.

If (x_1, y_1) and (x_2, y_2) are two data points on a line, then the *slope* of the line is

$$\frac{\text{Change in } y}{\text{Change in } x} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

(Note: Δ is a symbol used in mathematics and science to represent a change. For example, Δy means a change in the y -values.)

- The rate of change can be determined by any two points on the line.
- The rate of change can be positive, negative, or zero.
- If the rate of change is negative, the y -values decrease as the x -values increase. If the rate of change is positive, the y -values increase as the x -values increase; if the rate of change is zero, the y -values remain the same as the x -values increase.
- You can find the rate of change by reading a graph, by looking at the data in a table, or by finding the slope.
- For a straight line, the rate of change will be the same, or *constant*, between any pair of points on that line.

Practice and Applications

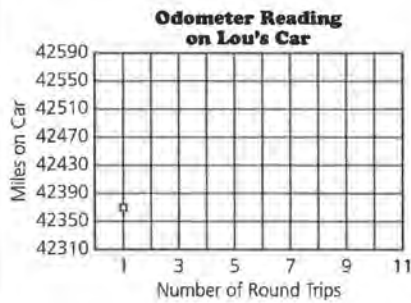
12. Jose finds the slope by using two data points as follows:

$$\frac{139 - 159}{1991 - 1989} = \frac{-20}{2}$$

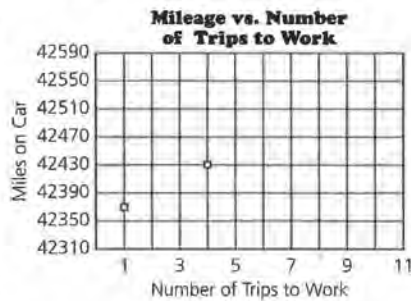
- a. What ordered pairs (x, y) did he use?
 b. Sue finds the slope by reversing the order of the same data points. Is the slope the same?

$$\frac{159 - 139}{1989 - 1991}$$

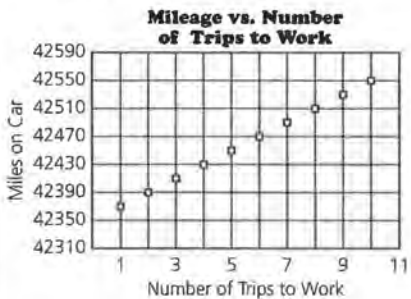
13. a.



b. The mileage increases 20 miles per day.



c. A straight line with a slope of 20



d. $\frac{42,450 - 42,350}{5 - 0} = \frac{100}{5} = 20$

$\frac{42,550 - 42,350}{10 - 0} = \frac{200}{10} = 20$

The values are the same. This indicates that the points form a straight line.

13. Lou's family purchased a used car that Lou was allowed to drive only to work. The car originally had 42,350 miles on it, and no one else in the family used it during the school year.

a. Lou worked at a car wash 10 miles from home. Plot on graph paper the point that represents the number of miles on the odometer after the first day Lou used the car.



b. Then plot the point that represents the mileage after Lou has used the car for 4 days. What is the rate of change in miles per day?

c. Continue to plot points that represent the mileage after any given number of days. Describe the pattern you see.

d. Calculate the rate of change in miles per day, first using the number of miles after 5 days of work and then again after 10 days of work. What can you conclude?

14. Gasoline prices are not constant but change continually depending upon demand, weather, and availability of gasoline. The price of gasoline at a given gas station did not change from Monday through Friday for a given week.



a. On graph paper, plot the prices for each weekday if the price was \$1.12 on Monday.

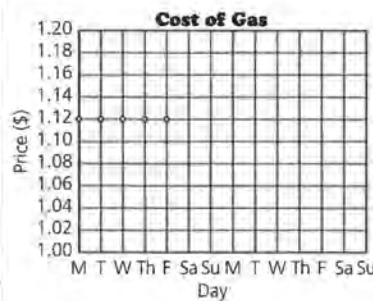
b. During the rest of a 2-week period, the prices were as follows:

\$1.15 on Saturday; \$1.15 on Sunday; \$1.12 on Monday; \$1.10 on Tuesday; \$1.10 on Wednesday; \$1.18 on Thursday; \$1.18 on Friday; \$1.18 on Saturday; and \$1.18 on Sunday. Plot the remaining data points for the 2-week period.

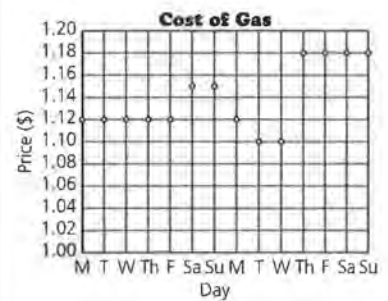
c. What was the largest drop in price? When did it happen?

d. What might cause prices to vary during this time?

14. a.



b.



STUDENT PAGE 15

c. The largest drop in price was \$.03 and occurred between Sunday and Monday.

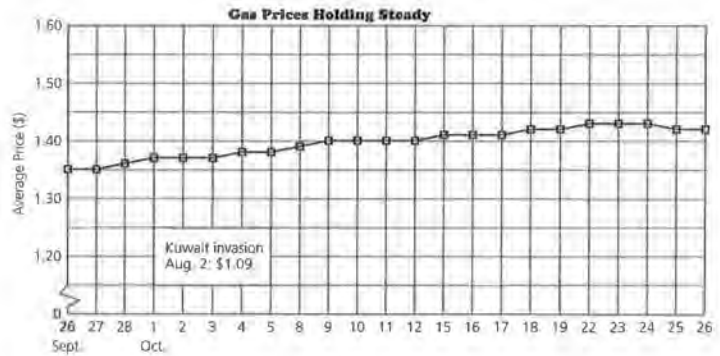
d. The prices seem to rise for the weekend. This could indicate that more people travel during the weekend, so prices were increased. In particular, in the second week, prices rose on Thursday, which could indicate the start of a long weekend when many people take car trips. If dealers had deliveries of gasoline at the end of the week, prices could be adjusted for the weekends.

15. Students should react just as they might if they read the graph in a newspaper, making only general comments. These data were taken right after the Gulf War and the Kuwait invasion, which seemed likely to have a direct impact on gas prices because Kuwait was a major supplier of oil used as a source of gasoline.

a. The scale used on this graph makes the changes appear very small. Also, the meaning of the horizontal lines is unclear, and the gas pump makes the graph difficult to read. It is also worth noting that the horizontal axis does not contain the two weekend days: September 29 and 30 are missing; October 6, 7, 13, 14, and so forth are also missing. This could make the appearance of change deceptive.

b. It appears there was no more than a \$.03 change in price per week and no more than a \$.02 price change per day. The average change in price appears to be quite small, either per day or per week. Basically, the headline matches the graph because the average change is small. However, you could argue that the headline is misleading

15. The average daily price for gasoline at suburban New York City gas stations during the fall of 1990 is shown by the following graph.



Source: data from *The Milwaukee Journal*, October 27, 1990.

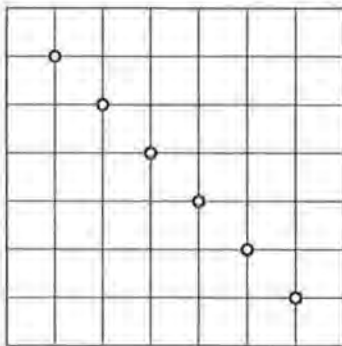
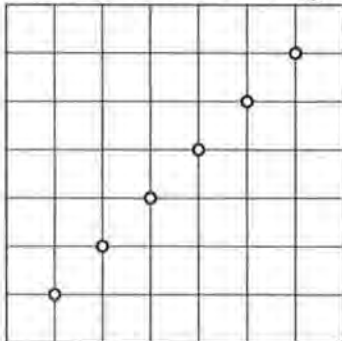
- a. Describe how the graph was drawn.
 - b. What is your impression of the rate of change in the average price of gasoline per week and per day? Do you think the title of the graph is accurate? Why or why not?
16. For some data, the slope or rate of change is constant; for other relationships, the slope varies. How will graphs with these two types of slopes look? Draw an example of each.

since the graph shows a steady (but slow) increase in prices.

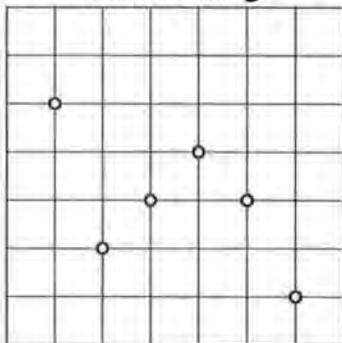
Students could make arguments for or against the headline. It is important that they justify their arguments with details from the data.

16. If the rate of change is constant, the data points will fall in a straight line. If the rate of change varies, it will be impossible to draw one straight line through all of the data points.

Constant Rate of Change



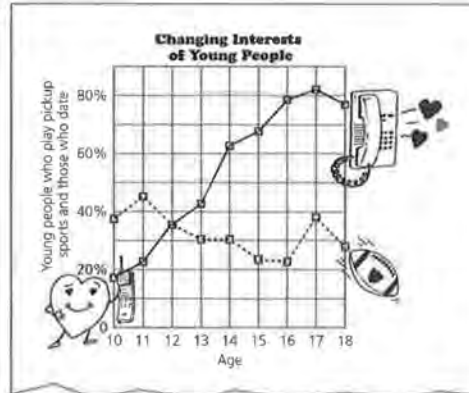
Nonconstant Rate of Change



17. a. The percentage of youths who choose to play casual sports games is about 40% at age 10, and then it increases to nearly 45% at age 11; it decreases fairly steadily until

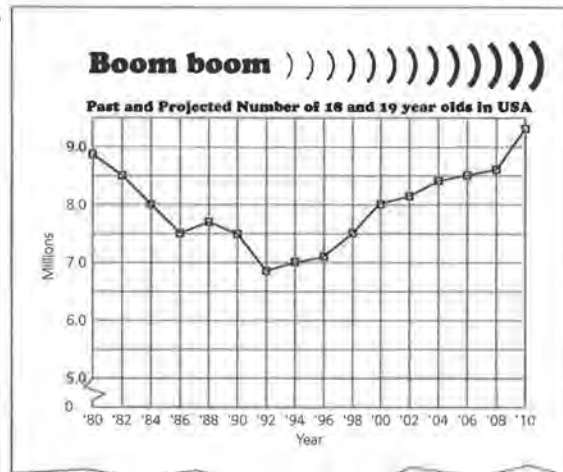
17. Describe the rate of change in each of the two graphs below.

a.



Source: Youth Sports Institute, Michigan State University.

b.



Source: data from USA TODAY, April 19, 1995.

age 16, when it is around 22%, and then it increases to over 35% at age 17; by age 18 it decreases to about 28%.

The percentage of youths who date is nearly 0 at age 10 and increases at nearly a constant rate to over 80% by age 17; it then decreases slightly to around 76% at age 18.

b. There were about 8.8 million 18- and 19-year old teenagers in the United States in 1980. There was a steady decrease until about

1987. The number rose slightly until 1989, and then fell continuously until it reached a low of about 6.9 million in 1992. Since then, the number has risen to about 7.1 million for 1995. The number of 18- and 19-year old teenagers is projected to grow steadily at about the same rate it decreased until there are about 9.3 million in 2010. A slight decrease is projected for 2002 to 2003, but the trend continues upward after that.

18. a. Yes, the rate of growth was slower than it had been, but since the value representing the growth is positive, the revenue was still growing. The decrease was in the amount of revenue, or money earned.

b. $\$200,000 \times 1.122 = \$224,400$

c. Students should answer on *Activity Sheet 1*. These percentages are all approximate and depend on how the graph was read. (See table below.)

d. In terms of percentages, the growth in 1990 was half of that in 1981. However, in terms of dollars, the growth in 1990 was \$27,883, and the growth in 1981 was \$24,400. The dollar amount of the growth in 1990 was definitely not half of that in 1981. Have students look at the column for the growth in dollars and compare it to the graph, observing how the growth increased in such years as 1989 (which corresponds to a point on the graph that is high relative to the point the year before) and how it decreased in such years as 1982 (which corresponds to a point that is lower than the point the year before).

16. The following graph and headline were used to describe the amount of business at fast-food restaurants.

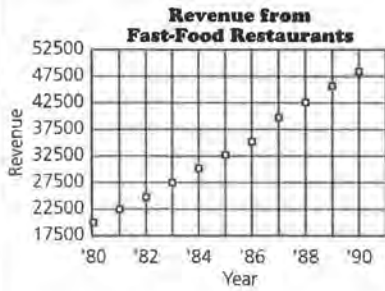


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- a.** Was the fast-food industry still growing in 1990? Explain your answer.
- b.** Suppose the total revenue for fast-food restaurants was \$200,000 in 1980. According to the graph, the growth in revenue in 1981 was 12.2%. Find the amount of revenue for 1981.
- c.** Some percentages of growth in revenue have been estimated from the graph and entered in the table on the next page. Estimate the remaining percentages to complete the table. Use the table on *Activity Sheet 1* to record the percentages.

Year	Revenue (\$)	% Growth in Revenue	Growth in Revenue (\$)
1980	\$200,000	_____	_____
1981	224,400	12.2%	\$24,400
1982	246,840	10.0%	22,440
1983	275,227	11.5%	28,387
1984	302,749	10.0%	27,523
1985	326,969	8.0%	24,220
1986	362,936	11.0%	35,967
1987	398,504	9.8%	35,568
1988	426,399	7.0%	27,895
1989	457,100	7.2%	30,701
1990	484,983	6.1%	27,883

18. e.



The graph of revenue shows how fast-food restaurants have continued to make money each year since 1980 at what appears to be a fairly constant rate. However, the rate-of-growth graph shows that the percentage of this increase was not constant, and in fact, the rate of growth slowed down.

19. a. $\$5 - \$2.50 = \$2.50$, and $\$2.50 \div 3 = \$.83$

The rate of change is $\$.83$ per year. This means that the price of something increases about $\$.83$ per year. This could represent the price of an article of clothing, a pound of coffee, a quart of paint, or a bottle of shampoo.

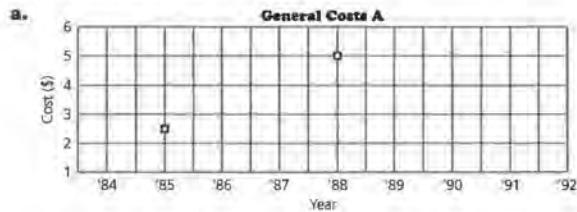
b. $\$100 - \$400 = -\$300$, and $-\$300 \div 60 = -\5

The rate of change is $-\$5.00$ per year. This means that the price of something decreases about $\$5.00$ per year. This could represent the price of an electronic or computing product.

Year	Revenue (\$)	% Growth in Revenue	Growth in Revenue
1980	\$200,000	—	—
1981		12.2%	
1982		10.0%	
1983		11.5%	
1984			
1985		8.0%	
1986		11.0%	
1987		9.8%	
1988			
1989		7.2%	
1990			

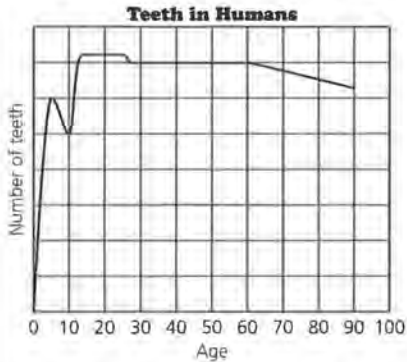


- d. Was the amount of growth in revenue in 1990 (6.1%) half of that in 1981 (12.2%)? Explain why or why not.
 - e. Draw a graph of the *amount* of revenue. The graph in the article shows the *rate of growth* in revenue. How does your graph compare to the one shown?
19. Find the slope, or rate of change in price, for each pair of points plotted on the following two grids. What real-world situations could the points represent? Describe what each rate of change tells you.



STUDENT PAGE 19

- 20.** Students' graphs should include the following components: rapid accumulation of teeth, slight loss in early elementary school, all teeth by about age 20, constant number of teeth through middle age, and gradual loss of teeth in old age.



- 21. a.** The rate of change per year in the data for the number of refugees is not constant. The rate of change per year in the data for the percentage of working women is constant. The rate of change per year in the number of football games is not constant.

Some students may compute the rate of change per year using the first two entries and then using the first and last entry. Other students may compute a rate of change and then use it to generate other values and compare these to the ones in the table. Still other students may compute the differences in the entries for each consecutive set of ordered pairs and determine whether or not the differences are the same.

- b.** The graph of the data for working women will be a straight line because the rate of change is constant. The graphs of the data from the other two tables will not be straight lines because the rates of change vary.



- 20.** Draw a graph that reflects the change in the number of teeth a person has over his or her lifetime. Explain why your graph looks the way it does.

- 21.** Study the following tables.

Year	Number of Refugees in United States (millions)	Year	% of Working Married Women with Children Under Age 6	Year	Number of College Football Games Cable Cast
1980	8	1965	23%	1987	56
1981	10	1970	30%	1988	62
1990	16	1975	37%	1989	98
1992	18	1990	59%	1990	192

Sources: Worldwatch Institute, United Nations High Commission for Refugees; USA Today, September 2, 1993, and Federal Communications Commission Interim Report, 1992.

- a.** Does the rate of change appear to be constant for each table?
b. Which, if any, of the graphs for the data sets in the tables above do you think will be straight lines? How did you decide on your answer?

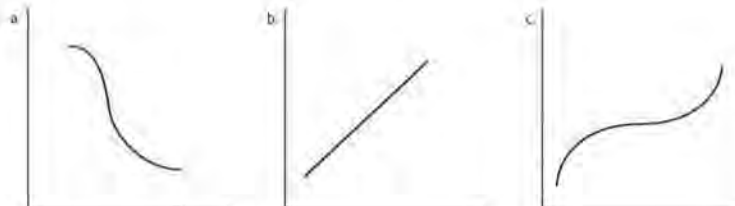
22. There is no one correct answer. The purpose of the question is to have students verbalize different rates of change and to recognize the kinds of situations in which studying rate of change can be useful. It is important that students justify their choices with both outside information and the information represented in the graph. Some (but not all) possible justifications follow:

Graph a could be for dress shoes. Over the past 10 years, the population has, in general, become more casually dressed, and thus the demand for dress shoes has decreased. It decreased slowly at first and then quite rapidly. Recently, the decrease has slowed down, and the demand appears to be leveling out.

Graph b could be for tennis shoes. Over the past 10 years, there has been a steady increase in the sales of tennis shoes. People seem to be walking and exercising more, and this might mean that they buy more tennis shoes. **Graph b** also could be for boots. Over the past 10 years there has been a slow but steady increase in the popularity of western and of hiking attire. This trend contributes to the steady increase in the sale of boots.

Graph c could represent tennis shoes. Overall, there has been an increase in sales over the last ten years. At first there was a sharp increase as people bought all the different kinds of newly available athletic shoes. For a while the demand leveled out, but then newer types of "gimmick" shoes have caused a rapid increase in sales.

22. The following graphs show the sales of three types of shoes—tennis shoes, boots, and dress shoes—over the past 10 years. Match each graph with a shoe type. Explain your choices.



23. Describe each of the following:

- a. a line with positive slope.
- b. a line with negative slope.
- c. a line with zero slope.

24. Ask an adult to approximate how much an item such as a candy bar or a loaf of bread cost at least 10 years ago, then find how much the same item costs today. On graph paper, plot the data, calculate the slope, and predict how much you think the item will cost in the year 2000. How reliable do you think your prediction is?

25. Challenge Inflation is the increase each year in the cost of goods and services. Suppose the rate of inflation has averaged approximately 3% per year. Calculate how much a 1991 Corvette would cost if its price had increased by the average rate of inflation each year since 1975, when it cost \$9424. Record the data in a table.



- a. Make a scatter plot of these points.
- b. How does the 1991 "rate of inflation" price compare with the actual price in Question 3 on pages 7–8? Why do you think the prices are different?
- c. Is the rate of change in the price of an item due to inflation constant? How did you decide?

23. a. A line with a positive slope rises from left to right.

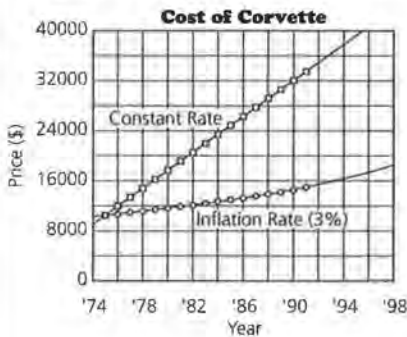
b. A line with negative slope falls from left to right.

c. A line with zero slope is horizontal.

24. Project The results and graph will depend on the information students collect. It is important that students consider the reliability of their predictions. Encourage students to consider recession, inflation, and other economic factors. This question helps assess whether or not students understand what the meaning of a constant rate of change is in a particular context.

LESSON 1: RATES OF CHANGE

- 25. a. Challenge** The data for the scatter plot are made going from an initial price of \$9424 and a rate of change of 3% each year, ending at approximately \$1499 based on the price of \$33,408 given for 1991.



- b.** The 1991 *rate of inflation price* (\$15,123) is lower than the actual price (\$33,408). One explanation might be that the percentage used for inflation was an average, and the actual percentage of inflation might have been very high in some years. Also, change in price may be affected by factors other than inflation, such as redesigned cars and increased demand that can drive up the prices.

- c.** The rate of change in the price due to inflation alone is not constant. It is difficult to tell from a graph, because the points look as if they form a straight line. If more points are generated and plotted, a curve begins to appear. You might have students investigate what will happen if the rate of inflation is 5%.

A table of values can help students see more clearly what happens per year. If the initial price in 1975 is the same for both a constant rate of change of \$1499 and a 3% inflation rate of change in price, students will see that the inflation data are not constant.

Year	Price with 3% Rate of Inflation Change	Amount of Change	Price with Constant Rate of Change	Amount of Change
1975	\$9,424		\$9,424	
1976	9,707	\$283	10,923	\$1,499
1977	9,998	291	12,422	1,499
1978	10,298	300	13,921	1,499
1979	10,607	309	15,420	1,499
1980	10,925	318	16,919	1,499
1981	11,253	328	18,418	1,499
1982	11,590	337	19,917	1,499
1983	11,938	348	21,416	1,499
1984	12,296	358	22,915	1,499
1985	12,665	369	24,414	1,499
1986	13,045	380	25,913	1,499
1987	13,436	391	27,412	1,499
1988	13,839	403	28,911	1,499
1989	14,255	416	30,410	1,499
1990	14,682	427	31,909	1,499
1991	15,123	441	33,408	1,499

LESSON 2

Equations of Lines

Materials: graph paper, pencils or pens, rulers, toothpicks (optional), *Activity Sheet 2*, Lesson 2 Quiz

Technology: calculators, graphing calculators (optional)

Pacing: 2 class periods

Overview

In this lesson, students work with ordered pairs of data that seem to have a linear relationship or a rate of change that is approximately constant. They draw a line to summarize the relationship between year and the price of a new car and learn to write the equation of that line using the point-slope form of the equation for a line. They investigate how the equation is related to the graph and how they can use either the graph or the equation to make predictions.

Teaching Notes

The prices for new cars are given, beginning with 1971. As students inspect the data, they should think about appropriate scales for the graphs. Students should recognize that they are working in a region on the grid far to the right of the origin. An appropriate range of values for years might be $1970 < T < 2000$, while an appropriate range of the new car prices is $\$0 < P < \$50,000$. You might ask students when the first car was invented (by Oliver Evans in Philadelphia in 1804, although it wasn't until Henry Ford in 1909 presented the Model T that cars started to sell) or where the Ford Mustang fits into the time frame (early 1960s). This motivates the need for a restricted domain (T) and range (P).

Students should recognize the importance of stating clearly what each variable in the equation represents and how using different variables may obtain the same solution for the problem. For example, T can

represent the year or it can be the elapsed time from some starting year. The symbol for slope is not necessarily designated as m , nor is the y -intercept always b . Rather, students are encouraged to let the context help define the letters used and to interpret values from the equation itself rather than from strict adherence to the customary meanings of certain letters.

Students should think about data in tables, in graphs, and as summarized by equations. Ask students to look at the table to decide if a set of points seems to be linear, and then to look at the graph. Most should find the graph more helpful. If the differences between x -values are constant, resulting in a constant increase in y -values, the relationship is linear. Before they draw a line, ask students to predict what a new car in the year 1980 might have cost so that they can see that the line helps them predict. Without the line, they would have to choose an arbitrary value between the two known values. The line provides a summary of the relationship, which can be used for any point in the domain (time). Why are equations for lines needed? Generalizing and finding an equation or rule will help students compare different situations. Show them the separate graphs for Question 10 on an overhead, and point out how, without mathematics, it is difficult to make comparisons or to communicate the relationships. It is even difficult when all of the graphs are on the same axes. An equation is also useful for predicting results that are not known, although students should be careful not to extrapolate too far into the future by making predictions that are too dependent on the continuation of conditions that might change.

The rule for the equation of a line is generated by thinking about how to describe, in general, a prediction for some future price given a starting price and the rate of change. This leads to the point-slope form of the equation of a line, $y = y_1 + m(x - x_1)$, or, $y - y_1 = m(x - x_1)$. The point-slope form of an equation of a line is a powerful way to think about defining a response, or y as a function of a known x -value, or x_1 and a change determined by the rate of change for the situation. The point-slope form also lends itself to calculating the differences in y -values, or residuals, as the differences in the vertical distances between points. This form occurs often in calculus books and is commonly used in science classes. In many of the situations presented here and often in other real-world contexts, the y -intercept does not exist.

It is important to note that the exercises in this lesson have been selected so that students do not have to make many choices about how to write an equation of a line. The notions of equivalent lines and how to find a “good” line are treated in later lessons. The activities in this lesson are focused on understanding what the equation of a line is and how the rate of change helps determine the equation.

Technology

Students should do most of the graphing in this lesson by hand. It is important that they recognize how a constant rate of change will generate a straight line, and one of the best ways to help students do this is to have them graph some of the relationships by hand. They should use a calculator to do tedious calculations. In this lesson, avoid fitting a line to the data by using a graphing calculator or computer. However, students can use a graphing calculator to make a scatter plot and then lay a toothpick on the screen to represent a line. Students can use the cursor to find two points that lie under the toothpick, use the coordinates of those points to find the rate of change, and write the appropriate equation. Instead of the toothpick, students can use the Draw Line command in the Draw menu to draw in a line they think suitable and again use the cursor to estimate points on the line. For the most part, however, students are given the lines on the scatter plots and are asked occasionally to make graphs of their own data. They will have many

more opportunities to graph lines and write equations as the module progresses.

Follow-Up

The table in Question 1 can be updated with the most recent prices of cars. You can find the prices in a recent *Kelley Blue Book* which can be found in most city libraries, or by consulting a dealer of new or used cars. Answers to Questions 1–5 as well as questions in later lessons will be affected by changes in data.

Occasionally, articles from newspapers or car magazines can add interest to this lesson. The firearm data can be updated by checking the latest *Statistical Abstract of the United States*.

Students can check with a car dealer for the most recent price of one of the cars studied in the lesson and decide how well the line and equation they found in their work predicts the price of that car. They should be ready to explain what might cause any significant difference between the actual price and the predicted price.

Solution Key**Discussion and Practice**

Note that there is no 1983 Corvette price because no new model was made that year. There was a large increase in price by 1985.

1. **a.** Students may predict a line. They should note that the graph would show a pattern of increasing prices, except for price drops in 1983 and in 1993. They might discuss what could cause a decrease: no change in model, lack of customers, and so on.
- b.** Student responses will vary.

LESSON 2

Equations of Lines

How do you think the prices of new cars have actually changed over the years?

What will the graph look like if you include the prices from several years?

Do you think the rate of change has actually been constant?

In Lesson 1, you investigated lines using only two data points. In doing so, you had to assume that the line drawn through the two points represented all of the data. If you have more data points, you can study the scatter plot for any overall pattern and determine if most of the points lie near one straight line.

OBJECTIVE

Write the equation of a line drawn through a set of points that appear to be linear.

INVESTIGATE**Buying a Honda Civic**

The list prices for several types of cars are shown in the table on the next page.

Discussion and Practice

1. Look at the prices for the Honda Civic.
 - a.** What pattern do you think a scatter plot of the prices for a new Honda Civic for the given years will show?
 - b.** The following scatter plot shows the prices of the Honda Civic. How does the pattern you see reflect your guess?

STUDENT PAGE 22

2. a. Two points determine a line.
- b. This is probably not the best idea because 1993 seems to differ from the previous trend. If it is used as an endpoint, the line will fall below most of the points.
- c. This is probably a good idea, but it may be difficult. By drawing the line through as many points as possible, she knows her line accurately reflects as many points as possible.

New Car List Prices

Year	Honda Civic	Chevrolet Camaro	Toyota Celica	Ford Mustang	Mercury Cougar*	BMW	Chevrolet Corvette
1971	\$1,395	\$3,790	\$2,847	\$3,783	\$4,069	\$5,845	\$6,327
1973	2,150	3,829	3,159	3,723	4,045	8,230	7,007
1975	2,799	4,739	3,694	4,906	6,121	10,605	9,424
1977	2,849	5,423	5,252	4,814	6,225	14,840	11,508
1979	3,649	6,021	6,904	5,339	6,423	20,185	12,550
1981	5,199	8,142	7,974	7,581	8,762	24,605	16,141
1983	4,899	9,862	8,824	8,466	10,725	24,760	N/A
1985	6,479	10,273	9,549	8,441	11,825	25,360	26,901
1987	7,968	11,674	12,608	9,948	14,062	29,220	28,874
1989	9,140	13,199	13,528	11,145	15,903	37,325	32,445
1991	9,405	13,454	14,658	12,321	16,890	35,600	33,410
1993	8,730	16,385	15,983	12,847	17,833	38,355	36,230
1995	10,130	17,536	19,410	17,550	18,960	39,775	37,955

Source: Kelley Blue Book, 1996.
 *Prices are for V8 or V6 depending on model made that year.



Source: Kelly Blue Book, 1996

2. Suppose you draw a line representing the pattern you see in the plotted data.
- a. How many points are necessary to determine a line?
- b. Bashom drew his line through the point for 1971 and the point for 1993. Do you think his technique was a good one? Explain why or why not.
- c. Audrey drew her line so that it went through as many points as possible. What do you think about her method compared with Bashom's method?

STUDENT PAGE 23

3. a. Yes. It looks like the point (1985, \$6500), labeled C, may be on the line.

b. Using the line, the price is about \$8000. Using the graphed data point, the actual price is about \$9100. The difference is about \$1100.

c. $\$8000 - \$4500 = \$3500$, and $\$3500 \div 9 = \388.88 , or \$389. The rate of change of the Honda Civic is about \$389 per year, using the line.

4. a. Students should answer on *Activity Sheet 2*. If the increase is \$389 per year, then the increase over 2 years would be $2 \times \$389$, or \$778. The line shows a price of about \$5500 in 1982, and the 1980 price is \$4500, so the increase is about \$1100 which is greater than \$778.

b. See table below. The x stands for the year in question.

c. $\$4500 + \$389(1994 - 1980) = \$9946$

d. The increase in cost is the product of the rate of change per year and the number of years since the initial cost.

When the points show a pattern similar to the one above, they are approximately *linear* over the time interval given. A line can be drawn close to the points summarizing the relationship of the ordered pairs of data.

3. The following scatter plot shows a line drawn to approximate the pattern in the prices of the Honda Civic over time. The ordered pairs (1980, \$4500) and (1989, \$8000) are labeled A and B, respectively.



- Are any of the actual data points on the line? If so, which ordered pairs do the points represent?
 - Using the line, estimate the price of a Honda in 1989. What is the difference between the estimated price and the actual price?
 - Using *only* points that lie on the line, estimate the annual rate of change in the price of a Honda.
4. In 1980, a new Honda cost about \$4500. Two years later, the price of a new Honda was about \$778 more than it was in 1980.
- Using the graph from Question 3, find the cost of the Honda in 1982. How does this value compare with an increase of \$778?
 - Complete the table at the top of the next page using *Activity Sheet 2*. Use your completed table to help you write a general rule or equation for the cost. Be sure to indicate what the variables in your equation represent.

Cost	Calculations	Dollar Amount
Cost in 1980 =	$\$4,500 + \$389(0)$	= \$4500
Cost in 1983 =	$4,500 + 389(3)$	= 5667
Cost in 1979 =	$4,500 + 389(-1)$	= 4111
Cost in 1988 =	$4,500 + 389(8)$	= 7612
Cost in General =	$4,500 + 389(x - 1980)$	

5. a. $(T, \$4500)$

b. DF represents the cost in 1980, or the initial cost. ED represents the increase from the initial cost.

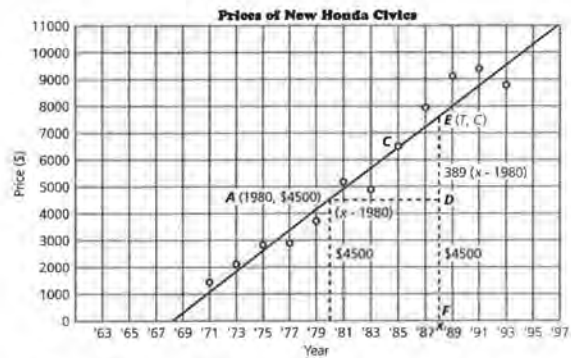
c. EF is the price of a Honda at time T .

d. The cost, or the y -coordinate of point E , is \$4500 (the length of DF) plus \$389 times 9 (the length of ED).

Cost	Calculations	Dollar Amount
Cost in 1980 =	$4500 + 389(0)$	4500
Cost in 1983 =	$4500 + 389(\quad)$	_____
Cost in 1979 =	$4500 + 389(\quad)$	_____
Cost in 1988 =	$4500 + 389(\quad)$	_____
Cost In General =	$4500 + 389(\quad)$	_____

- c. Use your rule or equation to estimate the cost of a new Honda in 1994.
- d. If you use the rule "The cost of a new Honda equals the initial cost plus the increase in cost," how can you find the increase in cost?

5. Use the following scatter plot to help you analyze the equation or rule you wrote to describe the general price of a Honda based on the price in 1980.



- a. What are the coordinates of point D ?
- b. What does DF represent? (Recall that DF means the length of the line segment DF .) What does ED represent?
- c. How does EF relate to the price of a Honda?
- d. Use the graph to help you describe what the numbers represent in this equation:
 $\text{Cost} = \$4500 + \$389(9) = \$8001$

6. a. T stands for the number of years since the price was \$4500. \$4500 represents the initial price, or the price of the car in the year being used as the reference year (1980). \$389 is the increase in price each year after the reference year (1980). 1980 is the reference year in this case. It is the year in which the price was the initial price.

b. $\$4500 + \$389(1991 - 1980) = \$8779$

c. The price of about \$8800, using the equation or line, is less than the actual price, which is \$9405.

d. Students should answer on *Activity Sheet 2*. Students should realize each entry increases by \$778.

Year	Cost
1970	\$610
1972	1,388
1974	2,166
1976	2,944
1978	3,722
1980	4,500
1982	5,278
1984	6,056
1986	6,834
1988	7,612
1990	8,390
1992	9,168
1994	9,946

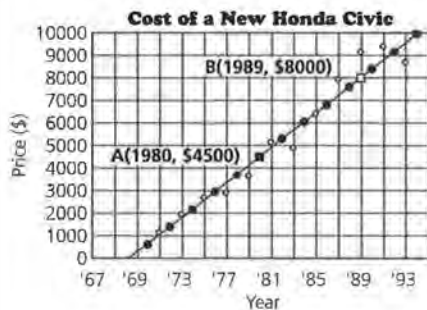
6. Sara wrote this equation to describe the price of a new Honda:

$$\text{Cost} = \$4500 + \$389(T - 1980)$$

- a. In Sara's equation, what does T represent? Describe in words what the numbers \$4500, \$389, and 1980 represent.
- b. Use Sara's equation to estimate the price of a new Honda in 1991.
- c. How does the price from the line compare with the actual price shown as a data point on the scatter plot?
- d. Use Sara's equation to make a table for the price of a Honda Civic in even-numbered years. Using the table and grid shown on *Activity Sheet 2*, describe a quick way to generate the data in the table, and then plot these points on the grid. Where do the points lie on the scatter plot?

Year	Cost in \$
1970	_____
1972	_____
⋮	_____

7. When the ordered pair (1980, \$4500) is used as the initial value for the price of a Honda, the equation is $C = \$4500 + \$389(T - 1980)$.
- a. Rewrite the equation when the initial value is (1989, \$8000).
- b. Use each equation to predict the prices of a Honda in 1995. How do the results compare?
8. Suppose the equation for the cost of a new Mercedes is $C = \$23,000 + \$1668(T - 1980)$.
- a. What do the numbers in the equation represent?
- b. According to the equation, approximately how much did a new Mercedes cost in 1991?
- c. Using these ordered pairs, on graph paper draw a scatter plot of the prices of a new Mercedes over time. How do these prices of a Mercedes compare with the data in Question 2 from Lesson 1?



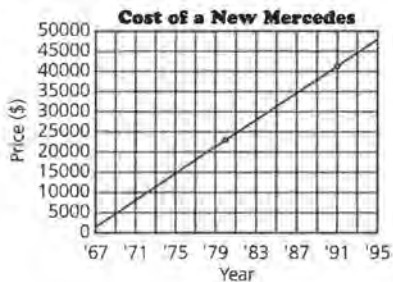
These points lie on a straight line.

7. a. $C = \$8000 + \$389(T - 1989)$
 b. $\$4500 + \$389(1995 - 1980) =$
 $\$10,335; \$8000 + \$389$
 $(1995 - 1989) = \$10,334$

The results are very close. The difference is due to the rounding done in working with the original slope. If the slope of 389 is replaced with $\frac{3500}{9}$, both equations will give a price of \$10,333.33333.

Rounding errors can be very significant in some problems. If students round a rate of change to the nearest tenth, they are dropping values of 0.01. If these values are multiplied by a year, 1990 for example, this could result in a 19.90 difference. In the price of a car, it is insignificant. In the price of a hamburger, it is important. Students should be alert to this potential problem and think about rounded values as a possible explanation for solutions that are not reasonable. A general rule is to retain all of the digits from any computation for as long as possible and then to round the final answer. Using a calculator aids in following this rule.

8. a. The car cost \$23,000 in 1980, and the increase in price was about \$1668 per year.
 b. $\$23,000 + \$1668(1991 - 1980) =$
 $= \$41,348$
 c.



Students might read values from the graph and compare these prices with those predicted by the equation (or with the data in the table).

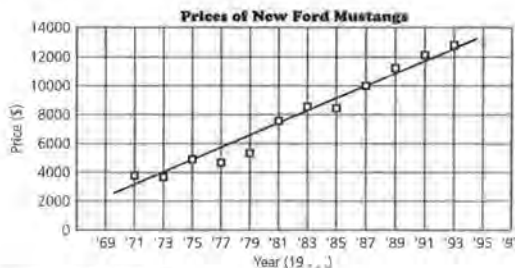
SUMMARY

Points that form a straight line can be represented by a *linear equation*.

- To summarize linear patterns, you can draw a straight line approximating the pattern shown in the scatter plot of the data.
- The relationship shown by the line can be written as a rule or equation.
- To write the equation of the line determine an initial value (t, c) and a rate of change.
- An equation of the form $C = c + r(T - t)$ can be used to represent the relationship between cost and time in which T is any year in general, t is a specific year, C is the cost in general, and c is the cost in the specific year.
- In general, if the ordered pair (x_1, y_1) is the initial value, and m is the rate of change or slope, then the equation of the line is $y = y_1 + m(x - x_1)$.
- The equation of the line can be used to generate any point on the line. Every point on the graph of the line satisfies the equation.

Practice and Applications

9. The following scatter plot shows the actual prices of a new Ford Mustang for every other year from 1971 to 1993. Look carefully at the line drawn on the scatter plot.



Source: Kelly Blue Book, 1996

Practice and Applications

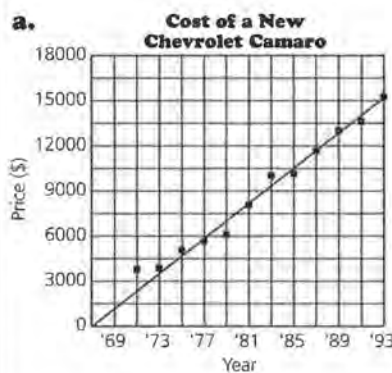
9. a. Another possible point is (1974, \$4500). $\$10,500 - \$4500 =$
 $\$6000$, and $\$6000 \div 14 =$
 $\$428.57$, or about \$429. The rate of change is about \$429 per year. This means that each year, the price of a Mustang increases by about \$429.
 b. One possible equation is
 $C = \$10,500 + \$429(T - 1988)$.

9. **c.** Another point is (1994, \$13,000). $\$10,500 + \$429(1994 - 1988) = \$13,074$. Yes, the equation is correct. This is close to the value \$13,000 estimated from the line.
- d.** $\$10,500 + \$429(1992 - 1988) = \$12,216$. This seems to be very close.
- e.** $\$10,500 + \$429(1995 - 1988) = \$13,503$. The equation predicts a price that is about \$4000 less than the actual price of about \$17,550 in the table. 1995 is an outlier. The rate of change was not constant.

10. Each student should select one of the cars and carry out the analysis, sketching a line that seems to reflect the pattern of points. Group members can then compare their work for all of the cars. Encourage students to consolidate their scatter plots onto one grid to really see how the graphs compare, as well as use the numerical values they find for rates of change. They will find that the only sensible way to compare the equations is by using the same initial year for all equations. This will allow them to compare all of the car prices for a given year and then see how the rate of change will affect the trend.

Student responses will differ, depending on how they drew their lines and how they selected their points. It is difficult to compare scatter plots with different scales and without lines or equations. Make students aware of this, and also remind them to look at different scatter plots to decide which one seems to have the most constant rate of change and so is most linear. Have them compare the numerical values for rates of change as a way to judge the relative changes in prices for the cars and look at the relationships of the lines to each other.

- a.** Find the point (1988, \$10,500). Find another point on the line, and calculate the rate of change in price for a new Mustang. What does this tell you about the price of a new Mustang over the years?
- b.** Use the ordered pairs to write an equation for the line.
- c.** Find a third point on the line. Substitute the ordered pair into your equation. Is your equation a true statement?
- d.** Use your equation to predict the price of a new Mustang in 1992. How close to the actual price do you think your prediction will be?
- e.** What price does your equation predict for the cost of a new Mustang in 1995? What is the difference between the prediction and the actual cost of a Mustang in 1995? What might explain the difference?
- 10.** Have each group member choose one of the following from the table at the beginning of this lesson on page 22: Camaro, Celica, Cougar, BMW, or Corvette. Plot the points for the years and the prices since 1971, and draw a line to summarize the relationship if it seems appropriate. Compare the scatter plots of all of the cars and use them to answer the following questions. Be sure to choose the same scale for all of the graphs so you can compare the scatter plots easily.
- a.** Estimate the rate of change in the price of the car you selected, and explain what it means.
- b.** Compare your graph with the others in your group. For which car does a constant rate of change seem most appropriate? How does your graph differ from the others?
- c.** Do any cars have a rate of change in price that does not seem very constant? Explain how you decided on your answer.
- d.** Which car's cost has the greatest rate of change? How does its graph differ from the others?
- e.** Write an equation for each line using the year 1975 as the starting year. What observations can you make?



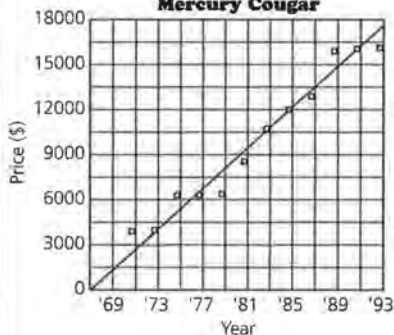
The rate of change is about \$590 per year.



The rate of change is about \$610 per year.

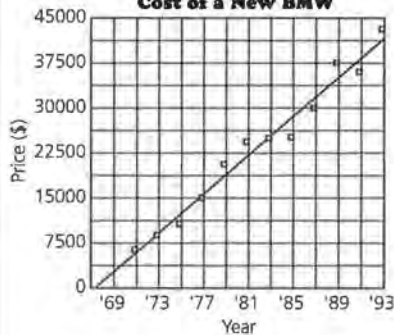
(10a)

Cost of a New Mercury Cougar



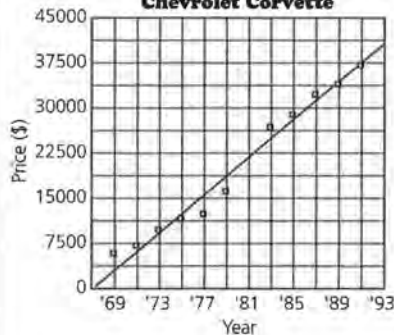
The rate of change is about \$675 per year.

Cost of a New BMW



The rate of change is about \$1630 per year.

Cost of a New Chevrolet Corvette



The rate of change is about \$1600 per year.

11. Sales for Outlook Graphics, a company that sells baseball cards, were worth \$7.7 million in 1986 and \$65 million in 1992. The change in price of baseball cards was relatively constant.

- a. Write an equation to describe the sales for the company over the years.
- b. What do your variables represent?
- c. Use your equation to predict the sales of the baseball cards in 1995.

12. The cost of a share of stock in Outlook Graphics in September 1991 was \$11.75. At the end of January 1992, it was \$22.00.

- a. The price of a share rose at about the same rate each month. Write an equation that describes the cost of the stock over the months. What do your variables represent?
- b. Describe the slope, or rate of change, in terms of price and time.
- c. Predict the cost of a share of stock in 1994. What assumptions did you make?

13. The following table gives the number of firearm homicide victims in the United States, according to the Federal Bureau of Investigation.

Firearm Homicide Victims

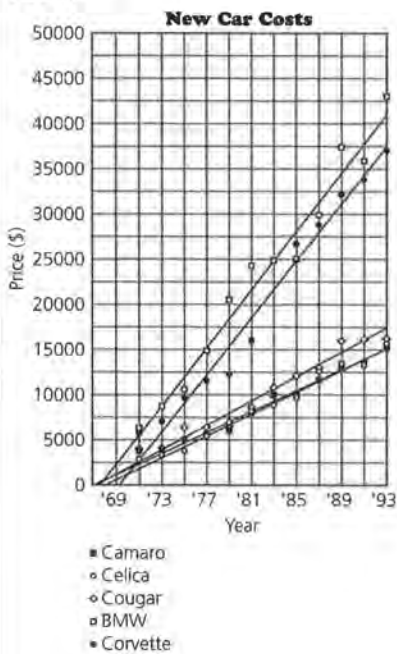
Year	1988	1989	1990	1991	1992
Number of Victims	10,900	12,000	13,000	14,200	15,400

Source: Statistical Abstract of the United States, 1995.



- a. Plot the points and draw a line that you think will summarize the relationship between time and the number of homicide victims.
- b. Write an equation describing this relationship.
- c. How many firearm homicide victims would you expect in 1993?

(10a)



b. A constant rate of change appears to be most appropriate for the Camaro or the Toyota Celica. The graphs appear to be the most linear. You might point out that the Celica started out with a lower price than the Camaro but has a greater rate of change, so somewhere around 1985, the price of a new Celica exceeded the price of a new Camaro, although the prices and lines are actually quite close.

c. The rate of change does not appear to be very constant for the Cougar. The points seem to vary widely around the line. At some points the rate of change is zero; at others there is a large rate of change.

d. The BMW has the greatest rate of change. Its line is the steepest.

e. A possible equation is given for each car.

Camaro:
 $P = \$4500 + \$590(T - 1975)$

Celica:
 $P = \$4300 + \$610(T - 1975)$

Cougar:
 $P = \$5250 + \$675(T - 1975)$

BMW:
 $P = \$10,800 + \$1630(T - 1975)$

Corvette:
 $P = \$9125 + \$1600(T - 1975)$

The BMW and the Corvette could be approximated by lines that are almost parallel because they have almost the same rate of change. The same thing is true of the Camaro and the Celica, although the Celica was priced lower in 1975. Students might also notice the similarity of the lines representing the costs for the Camaro and the Celica.

11. a. $S = \$7.7 + \$9.55(T - 1986)$, or
 $S = \$65 + \$9.55(T - 1992)$

b. S is the total sales in millions and T is the year in question.

c. $\$7.7 + \$9.55(1995 - 1986) = \$93.65$. The equation predicts 1995 sales of \$93.65 million.

12. a. $C = \$11.75 + \$2.56(M)$. C is the cost in the month that is M months since September 1991.

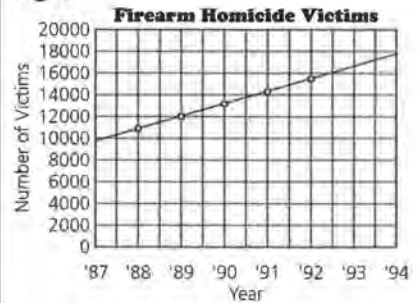
b. The price goes up an average of \$2.56 per month.

c. $\$11.75 + \$2.56(3 \times 12) = \$103.91$. The equation predicts a cost of \$103.91 in September 1994 (three years from the starting date).

Student responses will vary depending on the month in 1994 for which they compute the price. The costs should range from \$83.43 to \$111.59.

These answers assume that the price of shares continues to rise at the same rate each month and that the company does not merge, dissolve, or change otherwise by 1994.

13. a.



b. $V = 10,900 + 1050(T - 1988)$. V is the number of victims, and T is the year in question.

c. $10,900 + 1050(1993 - 1988) = 16,150$. You could expect about 16,150 victims in 1993.

LESSON 3

Equivalent Forms of Equations

Materials: graph paper, rulers, pens or pencils, Lesson 3 Quiz

Technology: calculators, graphing calculators (optional)

Pacing: 2 class periods

Overview

The focus of this lesson is to help students recognize equivalent linear equations. They have written equations for data sets, using ordered pairs and rate of change. Now they investigate what happens if different points are used to write the equation. How do they know if the equations are describing the same relationship? Students investigate this question using graphs, sets of ordered pairs, and equivalent forms of the equations.

Teaching Notes

A major recurring theme in the module is to investigate a real-world problem using data, graphs, and symbols and to think about what information each process will provide. The problem in this lesson is about baseball and televised baseball games. It is particularly interesting to think about the data in terms of the baseball strike of 1994–1995 and to question students about how the data they are investigating might have had an impact on the decisions made about the strike. Do the data provide owners with enough evidence to back up their case? The players' case?

In question 3, students are asked to think about how to determine whether or not two equations represent the same line. This can provide a rich discussion that may make questions 4–9 unnecessary or simply useful for review. Encourage students to share their thoughts:

If the graphs are the same, does that mean the equations are equivalent? Equivalent equations are usually thought of as equations that produce the same y -value for any given x -value. If the sets of ordered pairs generated seem to be identical, are the equations equivalent? If the graphs are the same, it seems reasonable to assume the equations are equivalent.

However, even if the ordered pairs seem to be identical, the evidence for equivalent equations is incomplete. Locally over a small region, many functions produce nearly the same sets of ordered pairs. A linear function and an absolute value function can generate identical ordered pairs over a certain domain. To use ordered pairs to determine whether or not equations are equivalent, students must either list all possible the ordered pairs (which is impossible); know from some characteristic, such as rate of change, that the equations represent straight lines and can be verified using any two points; or find other support for their argument. Students may feel that if two equations share the same ordered pair, the equations are equivalent. In addition to the exercises, another example might be necessary to demonstrate that this does not always work; indeed, any time a pattern is determined by just two elements, there is a danger of coming to the wrong conclusion because of too little evidence. If two equations share one point, that point might be the point of intersection. However, if students recognize that the rate of change for each equation is identical and that the equations share a point, then they can be certain that the equations define the same line and are equivalent. When the rates of change for two

equations are different, the equations could never produce the same line or be equivalent. This kind of reasoning may emerge from class discussion or may have to be elicited by questioning the class.

Because it is impossible to list exhaustively all ordered pairs and because graphing, although suggestive, cannot conclusively determine whether or not two equations are equivalent, another method is necessary. By using the distributive property and combining like terms, students can write the point-slope form of an equation of a line in the slope-intercept form, even when the intercept does not make sense in terms of the context. The slope-intercept form involves the same two constants and can easily be used to judge whether or not two equations are equivalent.

Technology

Technology can be of great help in this lesson. Students should not have to graph each equation by hand. They might use any graphing utility that will allow them to plot the data and to graph the equation. Equations of the form $y = mx + b$ can be used with most graphing calculators. Using a table feature of a calculator, students should also be able to generate ordered pairs determined by an equation. They can evaluate an equation for a set of given values by a variety of methods, including using the $y =$ menu and evaluating the y variable at the given x ; finding the value of y for an x entered through the calculate menu; tracing on the graph; or using an input from the home screen. By using technology, students will focus on what it means to identify equivalent ordered pairs and how this relates to producing equivalent equations.

When graphed, equivalent equations will appear as a single line. Students can determine which graph they are inspecting by looking at the upper right corner of the calculator for the rule that is being displayed. If using the down or up arrow key identifies a different equation but the graph remains unchanged (remember to look beyond just one viewing window), the equations are equivalent.

Exercises for which a graphing calculator or some other graphing utility is recommended are marked with



Follow-Up

Students might check on the effects of the 1994–1995 strike on baseball and televised games. The data might be available from a major league office or contained in a sports almanac.

LESSON 3

Equivalent Forms of Equations

In 1992, approximately 92.1 million households had television sets. During that year, major league baseball club owners decided to find out how many of these people were watching televised major league games. Were TV baseball ratings declining?

What kind of audience is predicted for the future, and what does this mean to baseball club owners and to the television networks?

Baseball club owners wanted to predict the trend in the number of people watching baseball games on TV. The number of viewers affects the ratings; the ratings affect how much television networks are willing to spend to purchase the rights to televise the baseball games.

OBJECTIVE

Determine if two equations are equivalent by using graphs, ordered pairs, and equivalent forms.

INVESTIGATE**Watching Baseball on TV**

The table that follows on the next page displays information from the Federal Communications Commission interim report. The report shows the average TV ratings of nationally televised regular season major league baseball games since 1980. Suppose the data are linear; a line has been drawn to summarize the pattern. If two of the owners used different sets of points on that line to find its equation, would the equation be the same? Stated another way, does every line have only one equation?

STUDENT PAGE 30

Solution Key**Discussion and Practice**

1. Student answers will vary. Networks want to know how many people are watching so they can gauge how much to charge advertisers. Owners want the game to maintain its popularity so that fans will support the teams and buy team merchandise.
2. A 3.4 rating means 3.4% of the TV households; 3.4% of 92.1 million is $0.034 \times 92.1 = 3.1314$; therefore about 3,131,400 households could have been watching.
3.
 - a. Equations will vary, depending on the points chosen. Using (1982, 7.5) and (1985, 6.5), one possible equation is $R = 7.5 - 0.33(Y - 1982)$.
 - b. Student suggestions may include plotting the lines either by hand or using technology, finding ordered pairs and comparing, or using algebraic properties.

Regular Season TV Ratings for Major League Baseball

Year	Ratings in Points
1980	8.0
1981	6.5
1982	8.1
1983	8.0
1984	7.0
1985	6.5
1986	5.5
1987	6.6
1988	6.0
1989	5.0
1990	4.6
1991	4.0
1992	3.4

Source: Federal Communications Commission Interim Report, July 1, 1993

Discussion and Practice

1. Why do you think the networks and baseball club owners would be concerned about the number of TV viewers?
2. One rating point means approximately 1% of the TV households in the United States. How many households could have been watching major league baseball in 1992?

Suppose you have two equations, and you would like to know whether or not they represent the same line. Remember that you can find sets of ordered pairs for any linear equation that make the equation true. The graph of every linear equation is a straight line. If two equations represent the same graph, they are called *equivalent equations*.

STUDENT PAGE 31

4. a. For the first equation, the rate of change is 2, and the point (4, 20) is on the line.

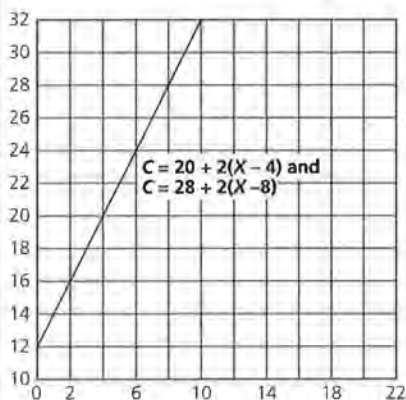
$$20 = 20 + 2(4 - 4) = 20 + 2(0) = 20$$

For the second equation, the rate of change is 2, and the point (8, 28) is on the line.

$$28 = 28 + 2(8 - 8) = 28 + 2(0) = 28$$



- b. The lines are on top of each other, so the equations seem to be equivalent. (Encourage students to use a graphing utility to make their graphs.)

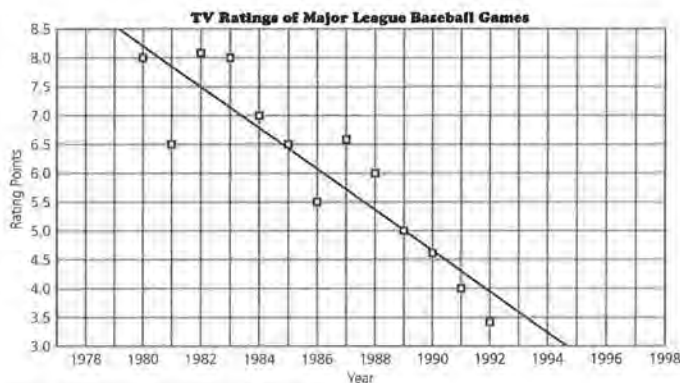


5. a. For both equations, $c = 32$ if $x = 10$. Students may assume this means the equations are equivalent. Remind students that two equations that share a common point may be intersecting. In this case however, both equations have the same rate of change (2) and a common point that together make the equations equivalent.



- b. Encourage students to use the table feature of a graphing calculator to find the ordered pairs. The table produces the same values for both equations, $c = 20 + 2(x - 4)$ and $c = 28 + 2(x - 8)$.

3. A scatter plot of baseball TV ratings with a line used to summarize the data, is shown here.



Source: Federal Communications Commission Report, July 1, 1993

- a. Find two points on the line, determine the rate of change, and write an equation for the line.
- b. Compare your equation to the ones found by your classmates. Describe how you could determine whether or not all of the equations represent the line shown in the scatter plot.
4. Consider these two equations: $c = 20 + 2(x - 4)$, and $c = 28 + 2(x - 8)$.
- a. For each equation, find the rate of change or slope and a point (x, c) on the line determined by that equation.



- b. Graph each equation. How do graphs help you determine whether or not two equations are equivalent?
5. Let $x = 10$. Find c for the equations $c = 20 + 2(x - 4)$ and $c = 28 + 2(x - 8)$.
- a. Are the two equations equivalent? Justify your response.
- b. Generate tables of ordered pairs (x, c) that satisfy both equations, beginning with $x = 0$. Compare the two tables. What conclusion can you make?



$$\begin{aligned} c &= 20 + 2(10 - 4) \\ &= 20 + 2(6) \\ &= 20 + 12 \\ &= 32 \end{aligned}$$

$$\begin{aligned} c &= 28 + 2(10 - 8) \\ &= 28 + 2(2) \\ &= 28 + 4 \\ &= 32 \end{aligned}$$

x	c
0	12
1	14
2	16
3	18
4	20
5	22
6	24

STUDENT PAGE 32

5. **c.** If the rates of change are identical for the equations, only one point needs to be verified in the equations to determine whether or not they are equivalent. But if the rates of change are not the same, the equations are not equivalent. If you cannot immediately tell about the rate of change, you need further information about the ordered pairs and the situation before you can conclusively indicate that the two equations are equivalent.

6. Encourage students to investigate this question using a graphing calculator.

a. For the first equation, $c = 28$ if $x = 7$.

$$\begin{aligned} c &= 18 + 2(7 - 2) \\ &= 18 + 2(5) \\ &= 18 + 10 \\ &= 28 \end{aligned}$$

For the second equation, $c = 28$ if $x = 7$.

$$\begin{aligned} c &= 12 + 4(7 - 3) \\ &= 12 + 4(4) \\ &= 12 + 16 \\ &= 28 \end{aligned}$$

You can conclude only that the two lines have a point in common. In this case, some students may recognize that the rates of change are different (2 and 4), so the equations do not represent the same line and thus are not equivalent.



b. On a graph, the lines intersect at (7, 28).

Since the ordered pairs in the table are different, or since the lines do not coincide, the equations are not equivalent.

- c.** How many identical ordered pairs do you need before you can determine whether or not the equations are equivalent?
- b.** Consider $c = 18 + 2(x - 2)$ and $c = 12 + 4(x - 3)$.
- a.** Let $x = 7$ for both equations, and find c . Are the two equations equivalent? Justify your response.
- b.** Make tables of ordered pairs and graph these two equations to determine whether or not the equations are equivalent.
- c.** How do ordered pairs help determine whether or not two equations are equivalent?



To determine if two equations represent the same line and the same set of ordered pairs, you can rewrite each equation in a different form using algebraic properties. Distribute and combine like terms in each equation, and then compare the forms. If the forms for the equations are identical, the equations represent the same line. Rewriting the equations is an efficient way to determine whether or not two equations are equivalent.

Are $c = 20 + 2(x + -4)$ and $c = 28 + 2(x + -8)$ equivalent equations?

$c = 20 + 2(x + -4)$	$c = 28 + 2(x + -8)$
$c = 20 + 2x + -8$	Distribute. $c = 28 + 2x + -16$
$c = 12 + 2x$	Combine like terms. $c = 12 + 2x$

7. Do the two equations above represent the same line? Why or why not?
8. Using the **Distributive Property**, rewrite each of the following so that the expression is in the form $a + bx$ for some numbers a and b . Combine like terms where possible.
- a.** $2(x + 5)$
- b.** $3(x - 4)$
- c.** $10 + 5(x - 9)$
- d.** $-4 + 2(x + 3)$
9. Consider these two equations: $r = 26 + -12(x - 2)$ and $r = 70 + -12(x - 10)$.
- a.** Can you find an equivalent form for each equation? Do the two equations represent the same line?

	$c = 18 + 2(x - 2)$	$c = 12 + 4(x - 3)$
0	14	0
1	16	4
2	18	8
3	20	12
4	22	16
5	24	20
6	26	24
7	28	28

c. If the ordered pairs are the same for two different equations of lines and if the rates of change are identical, then the equations are equivalent.

STUDENT PAGE 33

7. Yes. Some students may need to create a table or graph or generate two ordered pairs; some may realize that since the equations can be rewritten in the same form, they are equivalent.

- 8. a. $10 + 2x$
- b. $-12 + 3x$
- c. $-35 + 5x$
- d. $2 + 2x$

9. a. For the first equation,
 $r = 50 - 12x$.
 $r = 26 + -12(x - 2)$
 $= 26 - 12x + 24$
 $= 50 - 12x$

For the second equation,
 $r = 190 - 12x$.
 $r = 70 + -12(x - 10)$
 $= 70 - 12x + 120$
 $= 190 - 12x$

No, they do not represent the same line. They have the same rate of change but do not share any points. The equations represent parallel lines.

b. Rewriting equations in equivalent forms is a relatively easy and efficient way to determine whether or not the equations are equivalent. Finding all possible ordered pairs is an infinite process that cannot be completed; graphs can indicate that equations seem to be equivalent, but slight shifts in scale or variation in values may not be seen on a graph.

10. The students' equations may vary slightly, depending on the values they computed for the slope. The equations should be fairly close to $y = 661.56 - 0.33x$.

b. Why do you think using equivalent forms is a useful way to determine whether or not two equations are equivalent?

10. Use the equation of the line you found for the baseball ratings in Question 3 on page 31. Rewrite your equation in the form $y = a + bx$, in which a and b are numbers, x represents time, and y represents rating points. Compare your results with the results of your classmates.

11. As the baseball club owners and TV networks analyzed the situation in 1993, they looked at other information about baseball and television viewing. In particular, they looked at the numbers of local telecasts and national telecasts of regular season baseball games as shown in the following table.

Televised Baseball Games

Year	National Telecasts	Local Telecasts
1982	63	1954
1983	63	2217
1984	52	2623
1985	51	2356
1986	68	2473
1987	48	2568
1988	48	2661
1989	46	2714
1990	16	2849
1991	16	2917
1992	16	2922

Source: data from USA Today, July 23, 1993

STUDENT PAGE 34

11. a. There are significantly more local telecasts than national telecasts. The number of local telecasts is increasing, whereas the number of national telecasts is decreasing. The data for the local telecasts show a more distinctive linear pattern than the data for the national telecasts. Local telecasts appear to be increasing at a constant rate of change, whereas the number of national telecasts do not.

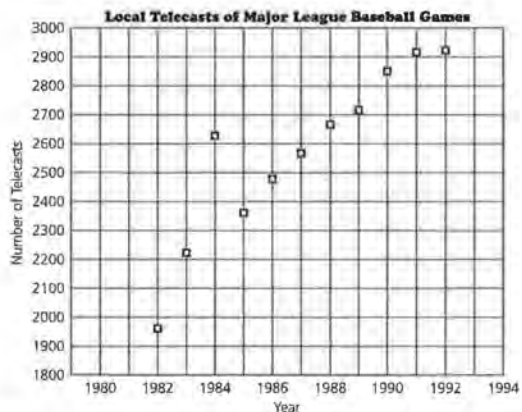
b. It makes sense to use a line for the local telecasts because the points fall close to a line. It does not make sense to use a line for the national telecasts because there is very little change for a few years, and then a dramatic change, then very little change again.

c. The ratings have dropped, and there are fewer nationally telecast games.

- a.** Look at the graphs of the data in the following two scatter plots. What are some significant differences between the scatter plots of the two sets of data?



Source: data from USA Today, July 23, 1993



Source: data from USA Today, July 23, 1993

STUDENT PAGE 35

12. a. From the data, there were 2623. This is many more than would be expected, given the values of surrounding years.

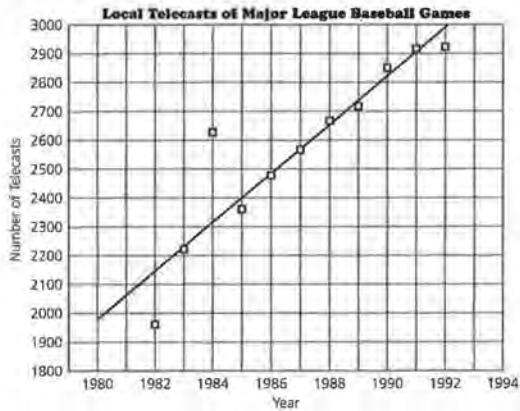
b. Equations will vary slightly, depending on the points students choose. One possibility is $T = 2150 + 83(Y - 1982)$. T is the number of local telecasts, and Y is the year in question. There are about 83 more local telecasts each year than in the previous one.

c. In most cases, the equations should be nearly equivalent, with some differences due to the points chosen. Students may produce equations of the form $y = a + bx$ to compare.

d. For the equation given in **b**, $y = -162,356 + 83x$. The equation predicts 3146 local telecasts in 1994. Students should all get about the same value.

- b.** Explain whether or not it makes sense to draw a line to summarize either relationship.
- c.** What connections might there be between these data and the data on TV viewing ratings at the beginning of this lesson on page 30?

12. A line summarizing the data for the number of local telecasts is shown on the following scatter plot.



- a.** Using the line, how many local telecasts were there in 1984? How would you describe the data point for that year?
- b.** Write an equation for the line. What do your variables represent? Describe the rate of change in the number of local telecasts over time.
- c.** Compare your equation with the equation of a classmate. Are the two equations equivalent? How can you decide?
- d.** Write your equation in the form $y = a + bx$. Use your equation to predict the number of local telecasts in 1994. Compare your prediction with those of your classmates.

STUDENT PAGE 36

13. a. Similarities: 1980 is the initial value in both graphs. The points are in the same position relative to one another. Differences: The points in the second graph are translated to the left in contrast to the first graph. The x-axis is labeled from 0 to 12 rather than from 1980 to 1994.

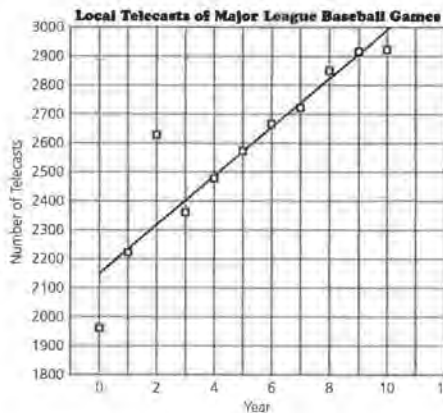
b. Equations will vary slightly, based on the points students choose. One equation is $y = 2150 + 83(x - 0)$ in which y is the number of local telecasts and x is the number of years since 1982.

c. $y = 2150 + 83x$

d. Answers will depend on the students' equations. In both instances, the rate of change of 83 remains constant.

14. Advice will vary. Students should use the facts presented to make a meaningful argument. Those interested in the effects of the strike of 1994–1995 might want to investigate the data since then, to determine whether the pattern of declining numbers of viewers was reversed.

13. The following is a different scatter plot of the number of local telecasts.



- a.** How is this scatter plot like the scatter plot in Question 12 on page 35? How are the two scatter plots different?
- b.** Write the equation of the line shown in this scatter plot. What do your variables represent?
- c.** Write your equation in the form $y = a + bx$.
- d.** How is this equation like the one you wrote before? How are they different?

14. You have looked at several different data sets about television and major league baseball. What advice would you have given to the owners and networks in 1993, based on the analysis you have done in this lesson?

SUMMARY

Two equations are equivalent if they

- Have exactly the same graph.
- Generate the same set of ordered pairs given equal slopes.
- Can be rewritten in exactly the same form.

If two equations have the same slope and share a common point, they are equivalent. An equation of the form

Practice and Applications

15. a. Bob: $y = 18 + 0.5(x - 2)$
 $= 18 + 0.5x - 1$
 $= 17 + 0.5x$

Suzie: $y = 20 + 0.5(x - 6)$
 $= 20 + 0.5x - 3$
 $= 17 + 0.5x$

Tom: $y = 22 + 0.5(x - 10)$
 $= 22 + 0.5x - 5$
 $= 17 + 0.5x$

Lee: $y = 16 + 0.5(x - 1)$
 $= 16 + 0.5x - 0.5$
 $= 15.5 + 0.5x$

Lashanda: $y = 19 + 5(x - 3)$
 $= 19 + 5x - 15$
 $= 4 + 5x$

Pat: $y = 34 + 2x$

Sol: $y = 2x - 34$
 $= -34 + 2x$

Bob, Tom, and Suzie have equations equivalent to $y = 17 + 0.5x$.

b. Bob's, Tom's, and Suzie's equations determine the same straight line because the equations are equivalent. Students may reach this conclusion also by making graphs or by comparing tables of ordered pairs.

16. a. $(\$365 - \$46) \div 10 = \$31.9$, so, $F = \$46 + \$31.9(Y - 1980)$. The slope is 31.9 and indicates that each year, \$31.9 million more in fees is paid.

b. $F = \$46 + \$31.9(13)$
 $= \$46 + \414.7
 $= \$460.7$

The fees in 1993 would be about \$460.7 million.

c. $\$460,700,000 \div \$60,000 = 7678.33$, or about 7679. (Note that the value is rounded up.)

They would need 7679 commercials to cover the fees.

$y = a + m(x - c)$ for some numbers a , m , and c and variables (x, y) can be rewritten as $y = d + mx$, in which $d = a - mc$, by distributing and combining like terms. In both forms, m represents the rate of change or slope.

Practice and Applications

15. Recall the conditions under which two or more equations are equivalent.

a. Which of the following equations are equivalent?

Bob: $y = 18 + 0.5(x - 2)$ Suzie: $y = 20 + 0.5(x - 6)$

Tom: $y = 22 + 0.5(x - 10)$ Lee: $y = 16 + 0.5(x - 1)$

Lashanda: $y = 19 + 5(x - 3)$ Pat: $y = 34 + 2x$

Sol: $y = 2x - 34$

b. Which of these equations determine the same straight line? How did you decide?

16. The annual fees paid by TV networks to televise major league baseball were \$46 million in 1980 and \$365 million in 1990. Assume the rate of change has been relatively constant over the years.

a. Write an equation that describes the relationship between the annual fees and time. What is the slope of your equation, and what does it tell you about the fees?

b. Use your equation to estimate the annual fees in 1993.

c. In 1993, the cost of a 30-second commercial during the telecast of a regular National Baseball League game was \$60,000. How many 30-second commercials would the network show to cover the cost of their fees?

17. Kuong says the line determined by $y = 10 + 3(x - 2)$ contains the point (10, 2) and has a slope of 3. Is he correct? Why or why not?

18. If two lines have the same slope, what do you know about the lines?

19. If the two equations $y = a + bx$ and $y = c + dx$ represent the same line, what can you say about the numbers a , b , c , and d ? Give an example to justify your answer.

20. The growth and projected growth of the population in the industrialized nations of the world, according to the United

17. He is incorrect. The slope and point can be read directly from the equation. The point is (2, 10) not (10, 2).

Substituting (10, 2) into the equation results in

$$2 = 10 + 3(10 - 2) ?$$

$$= 10 + 24 ?$$

$$\neq 34.$$

18. The lines are either parallel or the same line.

19. $a = c$ and $b = d$. Students' examples will vary.

STUDENT PAGE 38

20. a. Answers will vary. Industrial countries include the United States, Canada, Russia, England, Germany, and Japan.

b. Equations will vary slightly. One possible equation is
 $y = -195 + 0.1x$.

$$\begin{aligned} y &= -195 + 0.1(1990) \\ &= -195 + 199 \\ &= 4 \end{aligned}$$

This equation predicts a population of 4 billion in 1990, which is very close to the actual value of 4.086 billion.

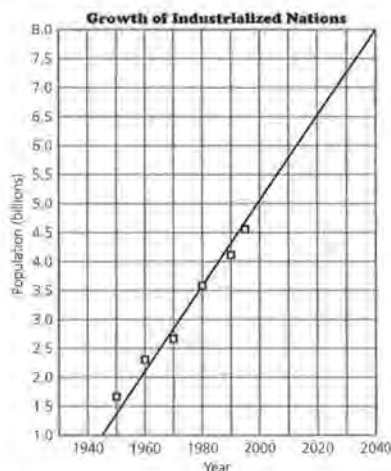
c. $y = -195 + 0.1(2020)$
 $= -195 + 202$
 $= 7$

According to the equation from **b**, the population in 2020 will be about 7 billion. It is likely that the United Nations' estimate of 8.2 billion indicates a more complex model than a line—probably a curve moving upward. As the world's population increases, greater numbers of people reproduce at a greater rate, a trend that suggests a nonlinear model.

d. Student answers will vary. Some may think the models seem to work pretty well for known data, so they will continue to work. Others may be skeptical about predicting human behavior.

21. Project Examples will vary based on what students find. One example may be stock prices, which tend to fluctuate, whereas another may be daily temperatures. Many other examples such as population growth, growth in the marriage rate, and growth in the number of automobile accidents are not linear.

Nations Population Fund, is shown on the following scatter plot. A line has been drawn to summarize the data.



Source: data from United Nations; Population Reference Bureau

- a.** Name some countries that you think would be included as industrialized nations.
 - b.** Write an equation you could use to make projections about the population. Use this equation to estimate the population in industrialized nations in 1990. The actual population according to the United Nations was 4.086 billion. What is the difference between your estimate and the actual population?
 - c.** Predict the population for the year 2020, using the line shown. The projected population according to the United Nations is 8.2 billion. What might explain the difference between the two projections?
 - d.** In general, how reliable do you think these projections will be? Give a reason for your answer.
- 21.** Not all scatter plots of data over time will show a linear pattern. Look through newspapers or magazines to find at least two examples in which data graphed over time are not linear. Provide descriptions along with your examples.

ASSESSMENT

Price Changes and Median Earnings

Materials: graph paper, rulers, pencils or pens

Technology: the same used for previous lessons

Pacing: 1 class period (if done in class)

Overview

Students analyze how men's income has changed over the years and then compare this with how women's income has changed. You will be able to determine whether or not students can graph data, draw a summary line, and write the equation of that line. Students should be able to find and interpret slope as rate of change and compare two different rates of change. They should also be able to predict an outcome, using a table, a line, or an equation.

Teaching Notes

The assessment can be given in class, given as a take-home assignment, or assigned to pairs. If working in pairs, one student analyzes the men's salaries, the other the women's salaries, and then they share their work to make conclusions. Be sure student work includes both graphs and equations. Frequently, students tend not to use mathematics to make their cases but simply argue commonly held opinions: "Men earn more than women." Encourage students to quantify their statements and to refer to their graphs as they build arguments for Question 4.

If students use a graphing calculator to do their scatter plots they should either use the link to a computer and provide a hard copy of the plots, or make a rough sketch of the plots to accompany their work. They should also include an explanation of how they approached the problems and the work they did, rather than just reporting the final numerical results. Check to see how students made their predictions: Did they use the lines they drew or the equations they

wrote? Either strategy is acceptable, and both should be given full credit. All students should be able to answer the questions to some degree; scoring should be based on the completeness of their responses and how well they organize and interpret the data.

This data set provides an excellent example of the way different lines of reasoning can lead to different conclusions about the same information. If the data are analyzed using scatter plots and lines, it seems as if men are earning more than women and that the gap is increasing. If the data are analyzed using percentages, however, the difference appears to be decreasing, leading to the inference that women's earnings are catching up to men's. This dichotomy can stimulate class discussion as well as make the point that percentage is dependent on the base used. A 50% gain from 2 to 3 is quite different from a 50% gain from 2000 to 3000.

Follow-Up

In some classes, it might be appropriate to discuss why there is such a difference in incomes. Answers may include these: Men and women do different kinds of jobs; more women have low-paying jobs; women started in the workforce later, so it will take them longer to catch up in income; and many women work only part-time, so they are not included in the data.

Early each spring, additional data are usually released comparing men's and women's income. Students might be asked to watch for this information and to compare it with the conclusions they made based on the data in this self-test.

Solution Key

Project

1. These answers will depend on the students' experiences and memories. They may know of some products that have decreased in price as well as many that have increased.
2. Student responses will vary. Some examples in which the rate of change is not constant might be the increase in the population of a city, the inflation rate studied in Lesson 1, and the speed of a car. Students should provide appropriate sketches for each situation.

Assessment

1. Men consistently earn more than women. The differences in the salaries appear to be increasing if actual salaries are compared.

2.



- a. Equations will vary, depending on students' lines. A possible equation is $y = \$20,000 + 917(x - 1980)$.
- b. The median income for men increased by about \$900 per year.
- c. $y = \$20,000 + 917(13)$, and $\$20,000 + \$11,921 = \$31,921$
The equation predicts \$31,921, which appears to be a little high.
- d. The prediction is \$321 more than the actual income of \$31,600.

ASSESSMENT

Price Changes and Median Earnings

Project: Price Changes

1. Choose five things you have purchased several times over the past four years. Make a graph for each item showing the year and prices.
 - a. Estimate the rate of change in price for each item.
 - b. Compare the changes in price over time.
2. Think of several situations in which data change, but the rate of change is not constant. Describe and sketch a graph for each example.

OBJECTIVE
Apply the concepts of slope and lines.

Assessment: Median Earnings for Men and Women

The median earnings of year-round, full-time workers age 25 years and older for men and women are given in the following table.

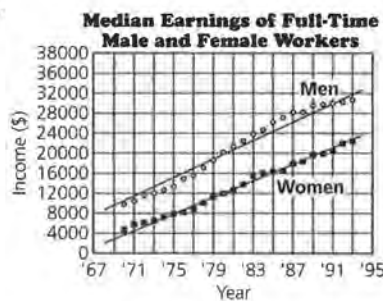
Median Earnings

Year	Men	Women	Year	Men	Women
1970	\$9,521	\$5,616	1981	\$21,689	\$13,259
1971	10,038	5,872	1982	22,857	14,477
1972	11,148	6,331	1983	23,891	15,292
1973	12,088	6,791	1984	25,497	16,169
1974	12,786	7,370	1985	26,365	17,124
1975	13,821	8,117	1986	27,335	17,675
1976	14,732	8,728	1987	28,313	18,531
1977	15,726	9,257	1988	28,180	18,509
1978	16,882	10,121	1989	29,556	19,752
1979	18,711	11,071	1990	29,987	20,556
1980	20,297	12,156	1991	30,674	21,272
			1992	31,408	22,141

Source: U. S. Census Bureau, 1995.

1. Study the table above. Compare the earnings of men with those of women over time.

3.



- a. The line for the women is below the line for the men, which indicates that the earnings for women were continually less than those for men.

Although the lines are almost parallel, the rate of change for the women, about \$857, appears to be slightly less than the rate of change for the men at \$917. It appears as if the gap between the incomes is widening.

- b. One possible equation is $y = \$4000 + 857(x - 1971)$. This equation predicts an income of \$22,854 for women in 1993.
- c. The prediction is \$432 more than the actual income of \$22,422.

STUDENT PAGE 40

4. The responses will depend on individual students' equations. They should use their values for the slopes to make the argument. According to the equations given above, since the slope for the women is less than that for the men the statement would be incorrect. If, however, students look at the percentage of increase in the median incomes for both men and women, they will find some justification for the argument. Women's incomes show a larger percent increase than men's incomes; you could say that men have only a 0.6% increase whereas women have an 1.3% increase.

Percent Increase in Men's and Women's Median Incomes

Years	% Increase for Men	% Increase for Women
1989 to 1990	1.5%	4.1%
1990 to 1991	3.0%	3.5%
1991 to 1992	1.7%	4.1%
1992 to 1993	0.6%	1.3%

5. **Bonus** Students' choices of options can indicate the depth and perspective of their analyses of the problem.

Students may suggest a scatter plot of the differences in incomes as a useful way to compare them. Notice that in the "difference plot," the difference was increasing until 1984, when it leveled off and then decreased. This provides another argument to say that women's incomes are catching up to men's incomes. This is similar to the revenue plot in Question 18, Lesson 1, in which the difference is



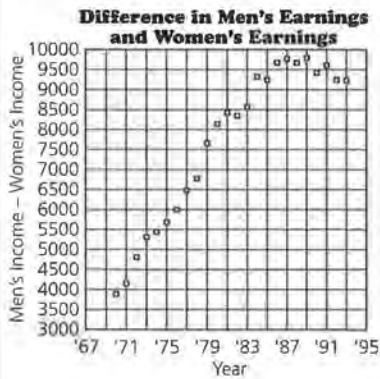
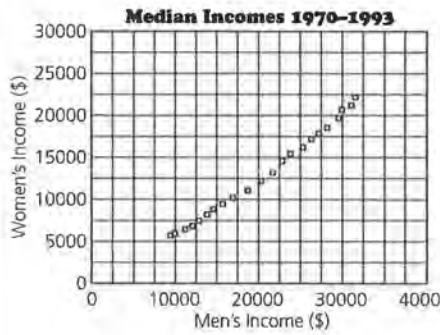
2. Plot the median earnings of men since 1970. Along the horizontal axis graph the year, and along the vertical axis graph men's earnings. Draw a line to represent the relationship.
- Write an equation that relates the year and the median earnings of men.
 - What does the rate of change tell you about men's earnings?
 - Predict how much a man would have earned in 1993, according to your line. Circle this point on your graph. How accurate do you think your prediction is?
 - The median earnings in 1993 for a male was \$31,600. What is the difference between this value and your prediction?
3. The median earnings of women are also given in the table. Plot the earnings data for women on the same grid you made for men's earnings. Draw a line that represents this relationship.
- How do the two lines compare? How do the two rates of change compare?
 - Write an equation that can be used to predict, in general, the median earnings for women. Predict the median earnings for women in 1993.
 - The actual median earnings for women in 1993 was \$22,422. How close to this value is your prediction?
4. A local newspaper article reported that women's salaries are growing at a faster rate than men's salaries. Use the graph and your work to refute or defend the statement.
5. **Bonus** Describe another way to represent both men's and women's earnings, using a scatter plot. Explain how this representation can be used to compare men's and women's earnings over time.

still increasing, but at a slower rate than it was earlier. This point may be difficult for many students to understand, but for those who think of "difference plots," it is worth illustrating.

Differences in Men's and Women's Median Incomes

Year	Difference
1970	\$3,905
1971	4,166
1972	4,817
1973	5,297
1974	5,416
1975	5,704
1976	6,004
1977	6,469
1978	6,761
1979	7,640
1980	8,141
1981	\$8,430
1982	8,380
1983	8,599
1984	9,328
1985	9,241
1986	9,660
1987	9,782
1988	9,671
1989	9,804
1990	9,431
1991	9,602
1992	9,267
1993	9,178

Students might also graph the ordered pairs (*men's income, women's income*). The rate of change for a line in that scatter plot would be about $\$917 \div \$857 = 1.07001 \dots$, indicating that men earn \$1.07 for every \$1.00 earned by women. A careful inspection of this scatter plot will reveal that the data points are really not linear but curved. Students might recognize that this means the rate of change is not constant, which agrees with the analysis from the "difference plot."



LESSON 4 (OPTIONAL)

Buying Power

Materials: graph paper, rulers, pencils or pens, *Activity Sheet 3*

Technology: calculators, graphing calculators

Pacing: 1 class period

Overview

This is an optional lesson that makes connections among the data sets used throughout the first three lessons and introduces data that are not linear. Students relate median income data to car prices and to the cost of groceries by focusing on “buying power,” the percentage of income used to purchase an item. Although the rate of change in the income is relatively constant, the rate of change in buying power is not, and students investigate the scatter plot (*year*, *buying power*) and its characteristics as a contrast to the study of linearity.

Teaching Notes

Students might work in groups in which everyone works on Question 1. Then one pair does Question 2, analyzing the buying power of men; another pair does Question 4 analyzing the buying power for women; and the group shares the results to answer Questions 4b and 4c.

Follow-Up

If students are interested in these data, they might also be interested in analyzing data on the purchasing power of the dollar or consumer price indexes, both found in any volume of the *Statistical Abstract of the United States*.

Solution Key

Discussion and Practice

1. a. $\$5199 \div \$21,689 = 0.2397 \dots$; about 24% of a man's income would have been spent to buy a Honda Civic in 1981.

b. $\$9405 \div \$30,874 = 0.3046 \dots$; it would have taken about 30% of a man's 1991 income to buy a Honda Civic. It would have taken a greater percentage of income to buy a Civic in 1991 than it did in 1981.

c. Men's buying power has decreased by about 6%.



2. a. Students should answer a and b on *Activity Sheet 3*. See completed table and graph below.

LESSON 4 (OPTIONAL)

Buying Power

Has the change in what you can buy with the money you earn been constant?

"Buying power" refers to the percentage of income needed to purchase an item. What would a graph of your buying power look like?

Unless earnings and the cost of living change at exactly the same rate, buying power will vary. By analyzing data, you can determine how much buying power has increased or decreased over time.

OBJECTIVES

Solve problems by applying the concepts of percentages, slope, and linearity. Analyze data that do not have a constant rate of change.

INVESTIGATE

Earnings, New Cars, and Groceries

Using the median earnings data for men, how much of his salary did a man spend to buy a new Honda Civic in 1981? How much did he spend in 1991 to make the same purchase? What has happened to his "buying power" in the past 11 years? How are these two sets of data related: median earnings of men and women, and new car prices over time?

Discussion and Practice

1. Use the car prices data at the beginning of Lesson 2 on page 22 and the earnings data at the beginning of the Assessment on page 39 to answer the questions.

a. In 1981, the median earnings for a man was \$21,689, and a new Honda Civic cost \$5199. What percentage of a man's income would be spent to buy a Honda?

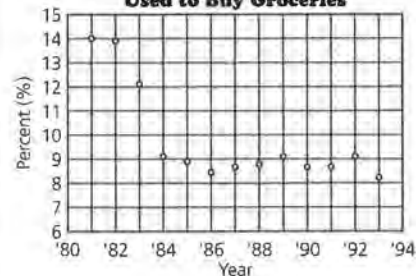
b. Find the percentage of a man's income spent to buy a new Honda in 1991. How do the two percentages for 1981 and 1991 compare?

Grocery Cost and Percentage of Men's Median Income

Year	Weekly Cost of Groceries (\$)	% of Yearly Income	Year	Weekly Cost of Groceries (\$)	% of Yearly Income
1981	\$59.00	14.1%	1988	\$47.00	8.7%
1982	61.00	13.9	1989	51.50	9.1
1983	56.00	12.2	1990	49.50	8.6
1984	45.00	9.2	1991	51.00	8.6
1985	45.00	8.9	1992	55.00	9.1
1986	44.50	8.5	1993	50.00	8.2
1987	47.00	8.6			

Source: *The Milwaukee Journal Consumer Analysis*, 1981–1993.

b. **Percent of Men's Income Used to Buy Groceries**




STUDENT PAGE 42


2. c. You had to assume the yearly grocery bill was 52 times the weekly bill.

d. The buying power decreased sharply from 1982 to 1984. Since that time, it has remained close to constant. The rate of change is not constant over the whole period.

e. If you used a straight line to summarize the relationship, you would not have a very good model. You could use a straight line to describe the buying power since 1984, but to describe the entire trend, a straight line would indicate too high a percentage for the middle years and too low a percentage for the early and later years. A curve would make a much better model because the rate of change is not constant.

 3. a. A man's buying power relative to the cost of a Honda Civic changed by 6%. It cost about 6% more of men's income in 1991 to buy a Civic than it did in 1981. Relative to groceries, a man's buying power changed by 5.5% ($14.1 - 8.6 = 5.5$), but the change was in the opposite direction. It cost 5.5% less of his income to buy groceries in 1991 than it did in 1981.

b. The scatter plot would start in the lower left part of the grid and increase with a positive rate of change that may or may not be constant.

 4. a. See table at the right and graph on the next page.

c. With respect to buying a new Honda, how has men's buying power changed?

2. The table shows the average weekly cost of groceries for a family of four in the Milwaukee, Wisconsin, area.

Grocery Cost and Percentage of Men's Median Income

Year	Weekly Cost of Groceries	% Income for Year	Year	Weekly Cost of Groceries	% Income for Year
1981	\$59.00		1988	\$47.00	
1982	61.00		1989	51.50	
1983	56.00		1990	49.50	
1984	45.00		1991	51.00	
1985	45.00		1992	55.00	
1986	44.50		1993	50.00	
1987	47.00				

Source: *The Milwaukee Journal Consumer Analysis*, 1981-1993.



- a. Using *Activity Sheet 3*, complete column 3 in the table to calculate men's buying power for a year's worth of groceries, based on men's median earnings (page 39).
- b. On *Activity Sheet 3*, graph the year and the percent of income used to buy groceries.
- c. What assumption did you make to complete the table?
- d. How has the buying power related to groceries changed since 1981? Is the rate of change constant?
- e. What happens if you use a straight line to show the relationship between time and buying power for groceries?



- 3. Refer to the car prices data in Lesson 2, page 22.
 - a. Compare the change in a man's buying power for a new Honda Civic with the change in a man's buying power for groceries from 1981 to 1991.
 - b. Describe what the graph over time of a man's buying power in purchasing a new Honda might look like.



- 4. Use the cost per week of groceries from the table above.
 - a. Make a table and a graph of women's buying power.
 - b. How does women's buying power in purchasing groceries compare with that of men?
 - c. If women earn the median women's income, what do the results from a and b mean to families headed by women?

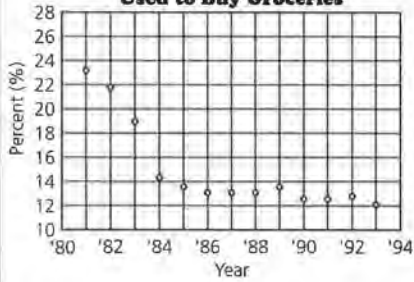
Grocery Cost and Percentage of Women's Median Income

Year	Weekly Cost of Groceries (\$)	% of Yearly Income	Year	Weekly Cost of Groceries (\$)	% of Yearly Income
1981	\$59.00	23.1%	1988	\$47.00	13.2%
1982	61.00	21.9	1989	51.50	13.6
1983	56.00	19.0	1990	49.50	12.5
1984	45.00	14.5	1991	51.00	12.5
1985	45.00	13.7	1992	55.00	12.9
1986	44.50	13.1	1993	50.00	12.2
1987	47.00	13.2			

Source: *The Milwaukee Journal Consumer Analysis*, 1981-1993.

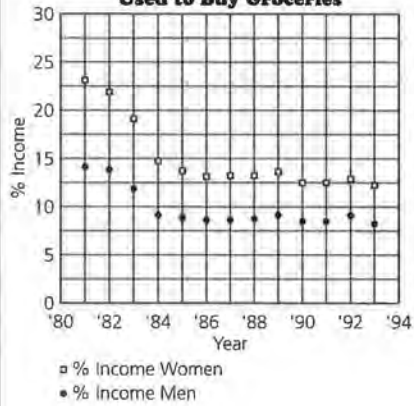
(4a)

Percent of Women's Income Used to Buy Groceries



b. It took more of a woman's income to buy groceries than it did of a man's. Notice that the plots reflect the "parallelism" that was apparent in the $(year, income)$ scatter plots.

Percent of Incomes Used to Buy Groceries



c. In the households headed by women, more of the income is spent for groceries. This means that there will be a smaller percentage of income available for other needs.

Lines and Scatter Plots

EXPLORATORY LESSON

Balloons and More Balloons

Materials: graph paper, pencils or pens, rulers, string, scissors, meter stick or tape measure, straws, stopwatch or a watch that can time to the nearest tenth of a second, 4 or 5 balloons for each group, *Activity Sheet 4*

Technology: graphing utility (optional), link and overhead projector (optional)

Note: You might use a calculator program as a stopwatch.

Pacing: 1 class period

Overview

In Unit II, students investigate a linear relation in scatter plots where the horizontal axis is not time. In this experiment, a measurement for balloon size is graphed along the horizontal axis, and time is graphed along the vertical axis in the scatter plot. If the experiment is done rather carefully, the results will show a pattern that is somewhat linear, although with much more variability than in previous examples. Students can draw a line to summarize the relationship and use it to make predictions, but they should give some consideration to the variation. The problem of fitting a line to data that are scattered is explored in the remaining lessons of this unit.

Teaching Notes

Give each group 4 or 5 balloons that have somewhat the same shape, and tell students that they can use some or all of the materials to design and conduct their experiment. Ask students to think first about the variables and the best way to design an experiment to account for them. Let students design and conduct their own experiment and then have each group share their design and the results. Expect differing results because of the various ways the experiment is designed and conducted. Advise each group to have at

least 7 or 8 data points before beginning to analyze any patterns.

Some groups will use the tape measure to find the circumference of the balloon at its widest part. Other groups may measure the length of the balloon, and still other groups may collect both dimensions and then devise some way to combine these two into a single measurement. Sometimes groups will use the meter stick and place two rulers or straws perpendicular to the ends or sides of the balloon and then read the measurement on the meter stick between the “markers” to approximate the diameter of the balloon.

Groups will also vary the way in which they release the balloons. Some groups will mark a place on the wall, drop each balloon from that place, and measure the length of time the balloon stays in the air; other groups will blow up the balloon, let it fly, and measure the length of time the balloon stays in the air. Still other groups may blow up balloons of different sizes, tie off the ends, drop each size several times, and time how long each size stays in the air. An efficient way to carry out the experiment is to thread a string through a straw from one end of the room to another (with some slack), blow up a balloon to the desired size, slide it onto the straw at one end of the string, let the balloon go, and time how long it takes to deflate. This method controls the flight path of the balloon after it is released.

Students can conduct the experiment in class, then analyze their results individually for homework if you would like to use the activity for assessment. Be sure students include a complete description of the experiment and the results.

For an additional experiment that generates a linear pattern, refer to Lesson 12 (Optional) *Catapults and Candy* found at the end of this unit.

Follow-Up

Discuss how changing the design of the experiment might affect the results. Ask students to consider what they might do differently if they were to repeat the experiment. Point out that students are not predicting how something will change over time, but rather predicting how something will change with a variation in size. Also note that the data are more scattered than students have seen in previous lessons.

Solution Key**Data Collection and Analysis**

1. **a.** Most students will hypothesize that the larger the balloon, the longer it will stay in the air.

b. Students may suggest different variables: the number of times a given balloon is blown up (the rubber stretches and therefore snaps back more slowly); different ways in which various people hold a balloon or record time; the height at which a balloon is held; the direction at which the end of the balloon is pointed (up, down, or sideways); and the shape of the balloon that is being used (long, round).

c. Student descriptions will vary. Some suggestions are given in the *Teaching Notes* for this lesson.
2. Student results will vary. Students should record their data and make a scatter plot on *Activity Sheet 4*.
3. **a.** Student responses will depend on their data.

EXPLORATORY LESSON

Balloons and More Balloons

Will a balloon that is blown up with lots of air stay in the air longer than a blown-up balloon that is smaller?

To answer the question, you are going to do an experiment. Collect the materials from your teacher, then work in small groups to design an experiment to collect data that might help you answer the question.

OBJECTIVE

Investigate the relationship between two variables.

EXPLORE**Balloons and More Balloons**

Materials 4 or 5 balloons, string, scissors, a tape measure or meterstick, straws, stopwatch

Data Collection and Analysis

1. Plan the experiment.
 - a.** What is your hypothesis for the outcome of this experiment?
 - b.** What are the variables in your experiment?
 - c.** Describe in detail how you plan to conduct your experiment.
2. Conduct the experiment you designed, and record your data on *Activity Sheet 4*.
3. Make at least one scatter plot of the data collected by your group.
 - a.** Which variables in your experiment might have affected the results? Explain.

STUDENT 46

- 3. b.** Outliers may occur when the balloon hits something in its path or when it bounces around on the floor before coming to rest.
- c.** Students should include a scatter plot and a line. They should find the equation of the line and discuss what the rate of change is and what it represents.
- 4.** Student responses will depend on their data.

- b.** Are there any outliers in your data? If yes, why do you think the outlier(s) occurred?
- c.** Using what you learned in Unit I, summarize your results.
- 4.** Predict the length of time a balloon with a circumference of 22 centimeters will stay in the air. Based on the data you have gathered and the analysis, how reliable do you think your prediction will be? Explain.

LESSON 5

Scatter Plots

Materials: graph paper, pencils or pens, rulers, *Activity Sheets 5–7*

Technology: graphing utility (optional), link (optional)

Pacing: 1 class period

Overview

Until this unit, all of the plots have been with time on the horizontal axis and equations created to describe relationships over time. The lessons in this unit offer opportunities for students to work with scatter plots in a general way. In this lesson, students study growth charts used by physicians to record babies' heights and weights. On these growth charts, the horizontal axis is age and the vertical axis has two different scales, one for height and one for weight. Students use height and weight data to make scatter plots of just height and weight and then look for a relationship. The height and weight data are not clearly linear, but the relationship is strong enough to be summarized by a line and its equation. Students are informally introduced to the concept of *function* as they think about weight as a function of height.

Teaching Notes

You might want to bring to class samples of growth charts used by physicians at nearby clinics or growth records from your own family. You might ask students to share with the class any records they have. With these types of materials, students have the opportunity to discuss whether the rate of growth over someone's lifetime is constant. Students will discover a fairly linear relationship exists for young children; then as they get older, different growth spurts occur for different children, with a very large spurt usually somewhere from ages 12 to 15. After that, there is a small amount of growth for many, then zero growth, and finally as people become older, they decrease in size, and their growth rate is nega-

tive. Students might graph this progression for you to see how well they understand a graphic representation of the situation.

Emphasize interpreting the slope in the given context. Students are accustomed to thinking about slope as a change in price over time, but in this lesson they begin to think about slope in the context of other variables, such as height and weight. Students will benefit from practice verbalizing what the slope represents using the units for these variables, particularly when the units are awkward. Some ratios seem to make less sense to students than others: -0.01 kilograms per centimeter can be described as a loss of 1 kilogram for every 100 centimeters. Using equivalent representations for fractions, decimals, and percentages can help students with their interpretations.

You may consider the use of the end-of-lesson practice problems and even Question 5 optional if students seem to understand how to think about lines in a scatter plot. In Question 7, students collect their own data. This activity can be a good long-range project, assigned at the beginning of the unit and due in 3 or 4 days. You will be able to evaluate students' exact understanding of concepts as they apply the techniques they have learned to analyze the different data they encounter. Also encourage students to share their results with the class or display their work on bulletin boards for others to peruse on their own.

Technology

If possible, students should make their plots using a graphing utility, downloading data sets into calculators or computers so they do not have to enter them

by hand. If students are organized in groups, one person can be responsible for the technology. Prior to class, list on the board data needed for the day. Each technology person can then download those sets from the disk before class begins, and then use the link to transmit the data to the others in the group.

Follow-Up

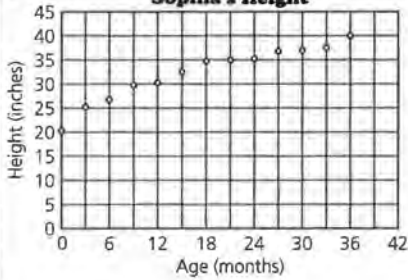
Some students might be interested in how their own baby records compare with those in the lesson. An extension project might be to address the question: Are children in the middle school getting larger? Students could decide what data might help answer the question, explore the sources, and use the information gathered to answer the question.

Solution Key

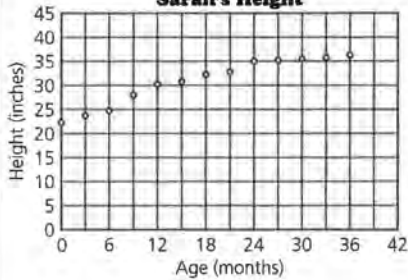
Discussion and Practice

1. a.

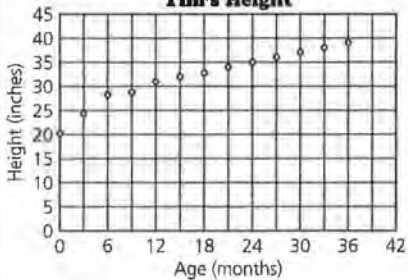
Sophia's Height



Sarah's Height



Tim's Height



LESSON 5

Scatter Plots

When you were born, you were probably weighed and had your height measured. Why would doctors care about babies' heights, weights, and growth rates?

Is there some regularity in the growth rate of children?

Do babies' heights and weights also follow a growth pattern?

In Unit I, you studied scatter plots of data over time by investigating rates of change and whether or not the data were linear. For solving problems in which time is not a variable, but the data are still ordered pairs, scatter plots of the data can provide useful information. In some scatter plots, two or more points can appear with the same x-value and points can even be repeated or plotted on top of each other.

OBJECTIVES
Read and interpret a scatter plot. Summarize a linear relationship between two variables in a scatter plot by drawing a line.

INVESTIGATE

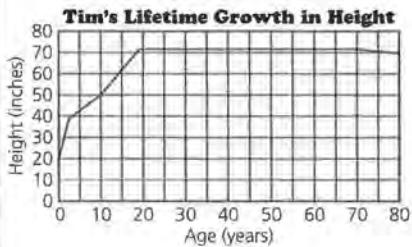
Baby Records

Parents and doctors keep records of a child's immunizations and height and weight, usually from the child's birth through high-school admission. The immunization records are required in many states for entrance into elementary school. Patterns in height and weight changes can be used as health indicators.

Discussion and Practice

- Sophia, Sarah, and Tim all belong to the same family. The three tables on the next page show the record of each child's growth.

- b.** There is not a substantial difference between the heights of the girls and Tim. There is never more than an inch difference between Tim and one of his sisters.
- c.** Both girls seemed to grow in spurts and then level off for a while. Tim's growth was more constant.
- d.** About 35 inches
- e.** Student responses will vary, but the following sample is provided.



Height and Weight

Sophia		
Age	Height	Weight
Birth	21.5 in.	9 lb 10 oz
3 mo	26.5	12 lb
6 mo	27	18 lb 10 oz
9 mo	29.5	21 lb
12 mo	30	23 lb
15 mo	33	25 lb
18 mo	34.5	26 lb 8 oz
21 mo	35	27 lb 10 oz
24 mo	35.5	28 lb 14 oz
27 mo	37	29 lb
30 mo	37.5	29 lb 5 oz
33 mo	38	30 lb 2 oz
36 mo	39.5	31 lb

Sarah

Height	Weight
22.5 in.	9 lb 2 oz
24.25	13 lb 4 oz
25.5	14 lb 4 oz
28.5	18 lb 9 oz
30.5	21 lb
31	22 lb 2 oz
32.5	23 lb 10 oz
33	24 lb 2 oz
35	24 lb 15 oz
35.5	25 lb. 3 oz
36	26 lb 9 oz
36.5	27 lb 14 oz
37.5	29 lb

Tim

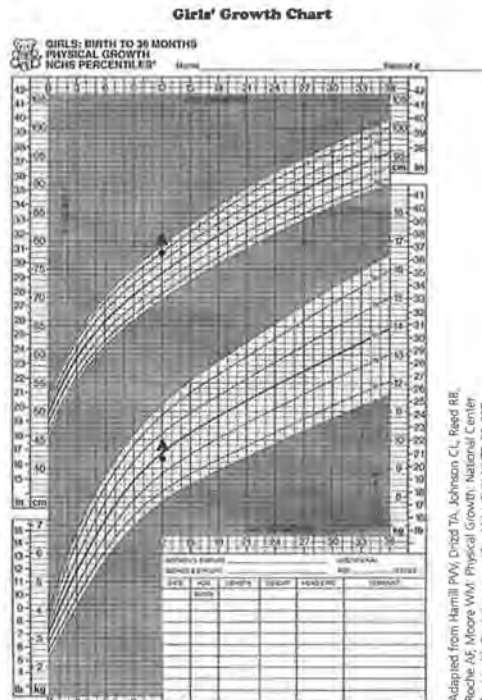
Height	Weight
21 in.	7 lb 8 oz
24.5	14 lb 4 oz
28	18 lb
28.5	19 lb
31	19 lb 12 oz
32	21 lb 7 oz
33	23 lb
34	24 lb
35	26 lb
36	28 lb
37	29 lb
38	29 lb 10 oz
39	30 lb 5 oz

- a.** Have each member of your group choose one of the children and, plot the data (*age, height*) for the first 36 months of that child's life.
- b.** Is there a difference between Tim's height and the heights of his sisters? If so, how can you tell?
- c.** Describe how each child's height changed over time.
- d.** What do you think the typical height for a child in this family will be at age 2 years?
- e.** Sketch a graph that you think will show Tim's height over his lifetime.

Doctors actually use a very complicated chart with the three variables of age, weight, and height to show a child's growth. The vertical scale on this chart shows both weight and height while the horizontal scale shows time, or age. As a result there is (*time, height*) and (*time, weight*) on the same plot. The upper band on the chart shows a typical interval for a child's height at a given age; the lower band shows a typical interval for a child's weight at a given age. The curves inside the bands indicate the median height and weight for a child at a given age. From the growth chart, you can find the median heights and weights for given ages and intervals that suggest typical variability.

2. **a.** At the age of 12 months, Sarah, at 30.5 inches, was longer (taller) than the median child, and her weight of 21 pounds was slightly less than the median child. She could be characterized as tall and thin for a one-year-old.
- b.** The median weight for a two-year-old girl is about 26.5 pounds and almost 34 inches, or about 85.2 centimeters.
- c.** There would be more variation in the weights than in the heights. One would expect that a longer (taller) baby girl would weigh more at 2 years of age.
- d.** Neither the change in height nor in weight is constant as a baby grows. If it were, then the bands would be straight rather than curved. However, between 12 and 36 months, the change in height and weight appears to be almost constant.

2. The following chart is used to record the growth of infant girls.



- a.** If the two points labeled A on the growth chart represent Sarah, what can you say about her age, height, and weight?
- b.** What is the median height and weight for a typical 2-year-old girl?
- c.** How might you expect the height and weight of a 2-year-old girl to vary?
- d.** Is the change in height constant as an infant girl grows? How can you tell? Is the change in weight constant? How can you tell?

STUDENT PAGE 50

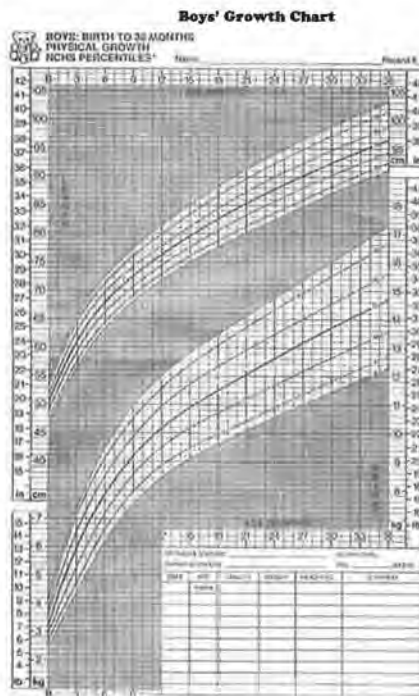
2. e. Sophia was very tall for her age. In fact, she was above the 95th percentile according to the growth chart, or taller than 95% of girls that age. Sophia weighed more than the median for her age, but her weight was not extraordinary; thus her mother was justified if she was referring to height but not if she was referring to weight.

3. a. Students should use *Activity Sheet 5* or *6* on which to answer. At birth, boys and girls are about the same size. But within the first three months, the boys grow slightly more quickly, tend to be slightly longer, and weigh slightly more throughout the time represented. The variation in the growth rates of boys and girls seems to be about the same.

b. Check students' graphs on the growth charts and their descriptions of each child's growth.

e. Sophia was 34.5 inches tall and weighed 26 pounds 8 ounces at 18 months. Was her mother justified in claiming that she was very large for her age? Why or why not?

3. The following chart is used to record the growth of infant boys.

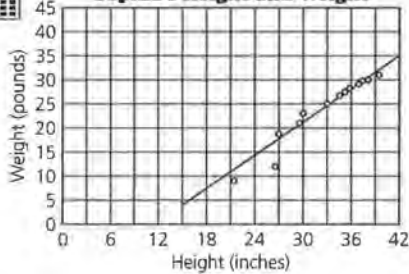


a. How does the growth chart for infant girls compare with that for infant boys?

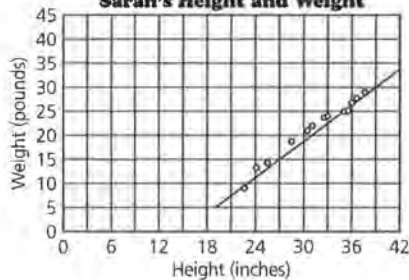
b. Have each member of your group now plot either Sarah's, Sophia's, or Tim's growth data on the appropriate growth charts shown on *Activity Sheet 5* or *6*. Describe the growth of the child you chose.



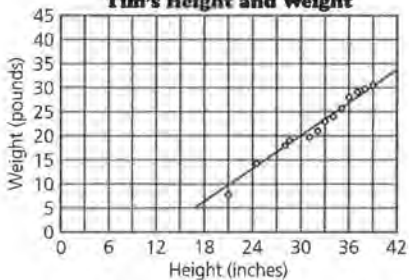
4. a. Sophia's Height and Weight



Sarah's Height and Weight



Tim's Height and Weight



b. Sophia: A possible equation is $W = 28 + 1.17(H - 36)$. Sophia gained about 1.17 pounds for every inch she grew.

Sarah: A possible equation is $W = 15 + 1.33(H - 27)$. Sarah gained about 1.33 pounds for every inch she grew.

Tim: A possible equation is $W = 13 + 1.3(H - 27)$. Tim gained about 1.13 pounds for every inch he grew.

c. All of the children gained about the same rate of weight compared to their height. For each additional inch of height, each child gained from 1 to 1 1/2 pounds.



- 4.** You just investigated the relationship between time and height and also between time and weight. Now consider the relationship between height and weight.
- Plot the data (*height, weight*) for the child you chose in Question 3 and draw a line to describe the relationship between the child's height and weight.
 - Write the equation of your line. What does the slope mean?
 - Compare your scatter plot and equation with the scatter plots and equations for the two other children by looking at the slopes and the overall patterns. Describe what you see.
 - Give two ways in which the growth patterns of the children were alike. Give two ways in which the growth patterns were different.

Whenever you make a scatter plot, you must first decide which variable to assign to the horizontal axis. Sometimes, the variable on the horizontal axis is the *independent, or explanatory, variable*; and the variable on the vertical axis is the *dependent, or response, variable*. In other words, given an ordered pair, the first variable (on the horizontal axis) can be used to predict or determine the second variable (on the vertical axis). In the scatter plots over time (*year, price*) from Unit I, the price of a car, for example, is determined by year, or the price is a *function* of time. In other cases, there is no clear explanatory (independent) and response (dependent) relationship; and therefore it is not important which variable is assigned to either the horizontal axis or to the vertical axis.

The heights and weights of a sample of high school football players are shown in the table on the next page. The relationship between the heights and weights of the football players can be analyzed.

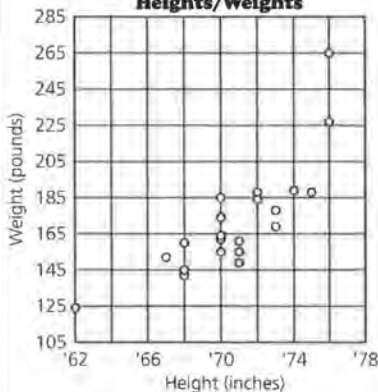
d. All of the children grew at about the same rate: all of the children grew a substantial amount during the first few months, and then their growth slowed. Tim's growth appears to be the most linear. All of the actual data points varied from one child to the next, but the lines of data are very similar for all three children.



5. a. Student responses will vary. There appears to be an increasing relationship between height and weight; the taller the player, the more the player weighs. It appears that the slope will be greater than 1 since it looks as if players' weights increase faster than their heights.

b. Students should answer on *Activity Sheet 7*.

Football Team Heights/Weights



Probably yes. Most students will think that it is easier to see a relationship in the scatter plot because the data are ordered.

c. It looks as if the 76-inch, 265-pound player would be an outlier, because it appears that the data point representing this player would be far above a line drawn to represent the trend in the data.

Students might be interested in labeling the points in the scatter plot with the position for the player represented by the point to see if there are any patterns in the data using the positions.

High School Football Players

Height (inches)	Weight (pounds)	Position
70	160	QB
68	145	K
70	185	LB
74	190	FS
70	169	LB
71	155	K
68	140	FS
68	160	DB
62	125	SS
70	160	SS
67	154	RB

Height (inches)	Weight (pounds)	Position
70	155	FS
71	150	LB
73	178	FS
72	190	LB
71	160	LB
72	205	LB
73	170	C
75	190	LB
76	230	DT
76	265	DT

(FS = Free Safety, RB = Running Back, DT = Defensive Tackle, SS = Strong Safety, K = Kicker, C = Center, LB = Linebacker, QB = Quarterback, DB = Defensive Back)



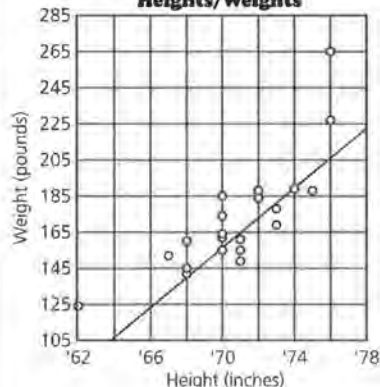
5. Look at the data in the table above.

- a.** Make a conjecture about the relationship between the heights and weights of the football players.
- b.** Use the grid on *Activity Sheet 7* to plot the data (*height, weight*). Based on your scatter plot, is your conjecture valid? Is it easier to see the relationship between height and weight when using the table or your scatter plot? Why?
- c.** Are there any outliers in the data? If so, describe them.
- d.** Draw a line on your scatter plot, write its equation, and use your equation to predict the weight of a football player whose height is 5 feet 11 inches.

SUMMARY

A *scatter plot* is a plot of a relationship using ordered pairs of data. There can be several points with the same *x*-value. If the pattern in a scatter plot is linear, you can draw a line and write its equation. If there is a variable you would like to predict, that variable is usually plotted on the vertical or *y*-axis.

d. **Football Team Heights/Weights**



A possible equation is $W = 165 + 8.3(H - 71)$.

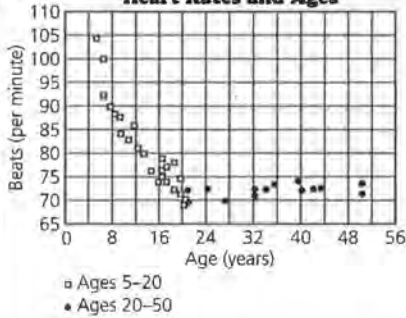
$$W = 165 + 8.3(71 - 71) = 165 + 0$$

So, this equation would predict a weight of 165 pounds for a football player whose height is 5 feet 11 inches.

Practice and Applications

6. a.

Heart Rates and Ages



Until about the age of 20, the number of heartbeats per minute decreases in a nearly linear pattern. After age 20, the number of heartbeats seems to stabilize.

b. There is the most variability in the 5 to 20 age group. This is clear from the scatter plot because the y-values for the 5 to 20 age group range from about 70 to 105; the y-values for the 21 to 50 age group are between 70 and 75.

c. Pulse rate seems to stabilize at about the age of 20. This can be seen from the scatter plot because after that age the best line through the data is nearly horizontal.

7. These answers depend on student data. Encourage students to look for linear relationships and explain any that are expected or unexpected. Suggestions for collecting data might be (*hours watching television, hours doing homework, number of vowels in words, number of letters in words, hours talking on phone, hours doing homework*), or (*number of points scored by each player in a basketball game, number of attempts by each player*). Have students share their data and scatter plots with the class.

Practice and Applications

6. A group of high school students collected data on the effect of age on a person's heart rate. Following are two tables: The first shows the data collected from people ages 5 to 20; the second shows data collected from people ages 21 to 50.

Age and Heart Rates

Ages 5 to 20

Age	Beats Per Minute	Age	Beats Per Minute
5	104	15	74
6	100	16	75
6	92	16	76
7	90	16	79
8	88	17	74
9	87	17	77
9	84	18	72
10	83	18	78
11	86	19	71
12	81	19	75
13	80	20	69
14	76	20	70

Ages 21 to 50

Age	Beats Per Minute
21	72
21	70
24	72
27	70
32	72
32	71
34	72
35	73
39	74
40	72
42	72
43	72
50	71
50	73

- a.** Using the same grid, make a scatter plot of (*age, beats per minute*) for each set of data. Use one symbol or color for the data in the 5 to 20 age group and a different symbol or color for the data in the 21 to 50 age group. Describe any trends you observe.
 - b.** For which age group does there seem to be the most variability? How can you tell from the scatter plot?
 - c.** At what age does a person's pulse rate seem to stabilize? How can you tell this from the scatter plot?
- 7.** Think of a situation in which the data are ordered pairs. Collect at least 15 ordered pairs and make a scatter plot of your data. Using your scatter plot, what observations can you make about the situation or relationship in the data you collected?

LESSON 6

Graphs and Their Special Properties

Materials: graph paper, pencils or pens, rulers, *Activity Sheet 8*

Technology: graphing calculators (optional)

Pacing: 4 class periods

Overview

In earlier lessons, students began with a set of data, plotted the data, then fit a line, and interpreted the line in terms of the data. In this lesson, students study different forms of a linear equation, the slope and intercepts, and their relationship to the equation and to the graph of the line. Students learn to think about different scales for the horizontal and vertical axes and how these can affect the perception of a relationship. Students investigate the x - and y -intercepts and how these can be interpreted for different data sets. They learn that a zero of an equation is the value of x that makes $y = 0$ and how the zero is related to the x -intercept of the graph. In addition, they experiment with finding the right viewing window to draw a given line by thinking about the ordered pairs or the intercepts that make sense for the line used to summarize the data. Students consider the line $y = x$ as a measure of equality and investigate whether there is any difference in men's and women's television viewing preferences.

Teaching Notes

Students should recognize that in mathematics they are given choices about equivalent forms of expressions: For example, a ratio can be written as a fraction, decimal, or percent. One of the objectives of this lesson is to help students begin to see that they can make choices about the forms they use. Should an equation of a line be written in the general form, the

point-slope form, the slope-intercept form, or even in factored form? They should recognize that these are equivalent forms for the equation of a line, and each form is useful in a particular situation. If you are given a point and the slope, the point-slope form is a logical choice to write as the equation. Students may need to refer back to *Lesson 3* in which they used ordered pairs, graphs, and algebraic properties to demonstrate equivalency of equations.

Should you graph a given line using the slope and intercept, the slope and a point, or the two intercepts? In each case, the situation itself usually makes one of the choices reasonable. If the line has x - and y -intercepts of 1000 and 20, respectively, it is easier to use these points rather than to try to mark off a slope of 0.02 from an intercept of 1000 to graph the line. Depending on the choices made for the ranges on the scales in the viewing window, the graph of a line may or may not appear in the window and it may or may not convey any meaning. Question 23 is a good exercise for those students who might be having difficulty understanding how to make a quick and accurate sketch of the graph by reading information from an equation.

Be sure students recognize the connections between the words, the numerical, the graphical, and the symbolic representations of intercepts and slope. The y -intercept is the coordinate where a line crosses the y -axis, such as in $(0, 5)$. It can be found on the graph of the line by looking at where the line intersects the y -axis. In the equation $y = 5 + 3x$, the y -intercept is

the constant term 5 (let $x = 0$). Also, students are asked to find and describe the intercepts and to use *zero* as a way to talk about the x -intercept.

The identity line $y = x$ is used to show where two sets of values would be identical, and thus, to observe quickly on the scatter plot, data items that are greater or smaller than others. The notion of prediction is not involved in this application of the identity line.

You may choose to omit some of the questions and problems if you feel your students understand the concepts. You might also want to select from the practice problems those problems you feel will meet the particular needs of your students.

Technology

Students should be able to graph lines on calculators or graphing utilities and find the intercepts and the slope from the graphs they generate by using the cursor and arrow keys. They often have trouble finding the appropriate window and may need practice on finding one.

Follow-Up

Students can collect their own data: used cars from classified ads or temperatures from almanacs. Ask them to analyze the relationships, identify the slope and intercepts of any possible linear relation, and explain what these mean.

Solution Key**Discussion and Practice**

1. a. *Scatter Plot A* reveals more information about the relationship between year and price of a Ford Mustang because the points are dispersed enough to show a trend. It is more difficult to see the relationship or trend in *Scatter Plot B* because of the horizontal scale being used.

LESSON 6

Graphs and Their Special Properties

Will every line cross an axis?

What do you know about a line when you know its rate of change?

What do you know about a linear equation when you know its rate of change?

OBJECTIVES

Recognize different forms of equations that represent a line and relate these forms to the graph. Find and interpret x - and y -intercepts of an equation and the zeros of an expression.

To summarize linear data, lines can be drawn in plots over time and in scatter plots. Sometimes it is difficult to tell, however, what a graph represents; two graphs can represent the same information and yet look totally different because of differences in the scales along the axes. Two equations can represent the same line but look different because they are written in different forms. What impressions can you get by looking at different representations, either in graphs or in equations? Are there any key features or common characteristics that are important?

INVESTIGATE**Cost of a Mustang**

Sometimes the scales on the axes show only the part of a grid where the data are given or where the data would make sense.

Discussion and Practice.

1. The following two scatter plots show the prices of a new Mustang taken from the data at the beginning of Lesson 2.

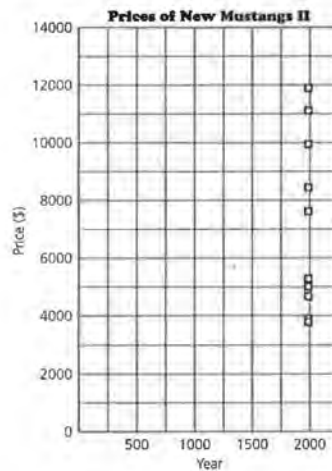
STUDENT PAGE 55

1. **b.** A possible answer might be from 1950 to 2000; $1950 \leq Y \leq 2000$.

c. Equations will vary slightly depending on the points students choose. One possible equation is $P = 9000 + 444(Y - 1985)$ in which P is the price of a new Mustang and Y is the year.



Source: data from *Kelly Blue Book*, 1994



- a. Study the two scatter plots. Which plot shows more information about the relationship between the year and the price of a new Mustang? Why?
- b. What horizontal scale will make sense when you are graphing the prices of cars? Write an expression that describes this axis.

STUDENT PAGE 56

1. **d.** Student responses will vary slightly because they cannot read the exact year. (1971, 3000) or (1972, 3000) are acceptable. This means that in 1971 or 1972, the price of a new Mustang was \$3000.
2. The point is (1971, 3000) or (1972, 3000). This seems a little low judging by the data point above it, but it is generally reasonable.

- c. A line has been drawn through the data in the following scatter plot. Write an equation of the line, relating price and year.



- d. What is the ordered pair at C? What does this ordered pair represent?

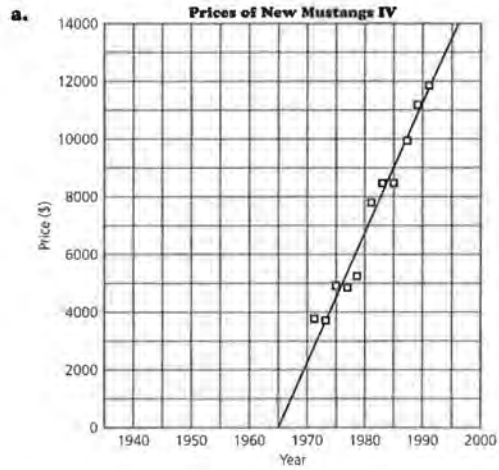
Sometimes the points at which lines cross the x- and y-axes make sense for the data, and sometimes they do not.

2. Does the point at which the line crosses the horizontal axis in the preceding scatter plot make sense for the data? Why or why not?
3. Look at the next two scatter plots. Estimate the ordered pair where the line crosses the horizontal axis in each scatter plot. Describe what the ordered pairs would represent in each case. Does the ordered pair seem reasonable for each situation? Explain.


STUDENT PAGE 57

3. a. The point is (1965, 0). This means that in 1965, the price of a new Mustang was \$0. This is not reasonable because new cars were and are never free.

b. The point is (1990.5, 0). This means that at some time in 1991, there were no shipments of LP records. This is not reasonable, because in 1991, there were still a few new LPs shipped, though not very many.




STUDENT PAGE 58

4. **a.** A horizontal or vertical line will have only one intercept. All other lines will have two.
- b.** Because that is the point at which the equation “equals” zero. The y -value is zero at that point, and many equations are written in the form $y =$.
- c.** Probably the y -intercept is not called a zero, because it does not make the value of the equation equal to zero.
5. **a.** By looking at the points at which the line crosses each of the axes.
- b.** Look for an ordered pair in the form $(0, ?)$ to find the y -intercept and one in the form $(?, 0)$ to find the zero.
-  **6.** In the following two problems, students might use graphing calculators to find a table of values and use the table to read off their answers. Be sure they associate the table values with the particular points on the plot.
- a.** A five-year-old car would cost \$8500.
- b.** When $A = 0$, $P = \$11,000$. This represents the price of a new car.
- c.** When $P = 0$, $A = 22$. This represents the age at which the car would have a value of \$0.

The scales and the relationship of the data to the axes are very important for interpreting the data. The range of values for x and y determines the part of the coordinate plane needed to plot the data. It can be called a viewing rectangle or window for the coordinate plane. For any ordered pair (x, y) , the x -value is usually graphed along the horizontal axis (the horizontal coordinate), and the y -value is usually graphed along the vertical axis (the vertical coordinate).

4. There are two points that a line may or may not have—the points where the line crosses the axes. The x -intercept, the coordinate where a line crosses the x -axis, is often referred to as a zero. The y -intercept is the coordinate of the point where a line crosses the y -axis.
- a.** Will a straight line always have x - and y -intercepts? Explain your answer.
- b.** Why do you think the x -intercept of an equation is called a zero?
- c.** Does it make sense to call the y -intercept a zero? Why or why not?

Suppose you are given an equation and asked to find the y -intercept and the x -intercept, or the zero. Just as you have used tables, graphs, and equations to tell whether or not two equations represent the same line, you can also use these same tables, graphs, and equations to identify the intercepts.

5. Consider the graph of a linear equation.
- a.** How can you find the zero and y -intercept of a linear equation from its graph?
- b.** How can you find the zero and y -intercept of a linear equation by studying a set of ordered pairs that satisfy the equation?
-  **6.** Consider the equation $P = 10,000 - 500(A - 2)$ where A represents the age of a used car and P represents the price.
- a.** How much will a 5-year-old car cost?
- b.** If $A = 0$, find P . What does the point $(0, P)$ represent when describing used cars?
- c.** If $P = 0$, find A . What does the point $(A, 0)$ represent when describing used cars?

7. a. Student choices of windows will vary but should include a scale on the y -axis from \$1000 to about \$11,000 or \$12,000. Choices for the scale on the x -axis will depend on students' experiences with the length of time cars maintain monetary value.

The particular points that students choose to use when drawing the line are not important. Students will probably use (2, 10000) with a rate of change of -500 to generate some points that will give them an appropriate range for each axis. If students have a graphing calculator, they might generate a table of values beginning with A (or x for the calculator) equal to 2, and use the values they generate to set the viewing window.

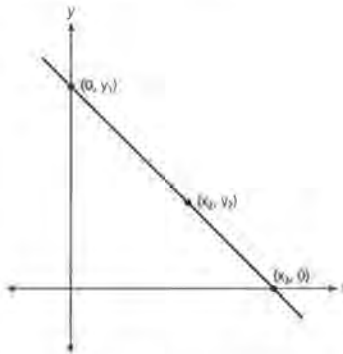


b. The slope is -500 . This means that the value of the car drops \$500 every year.



- 7.** Use the equation for (age, price) from Question 6 above.
- What are some values for A and P that will make sense in the problem? Use those values to select a viewing window, and sketch a graph of the line.
 - What is the slope of the line, and what does it represent?
 - Find the zero from the graph, and compare it to the zero you found in Question 6. Use the point and the slope to write the equation of the line.
 - Find the y -intercept and compare it to the y -intercept you found in Question 6. Use that point and the slope, to write another equation of the line.
 - Prove that the equations from Question 6 and c and d of this problem are all equivalent.

Consider the following graph of a line showing three labeled points and a slope m .



Any specific point (x_2, y_2) on the line can be used, along with the rate of change, m , to write the equation of the line:

$$y = y_2 + m(x - x_2)$$

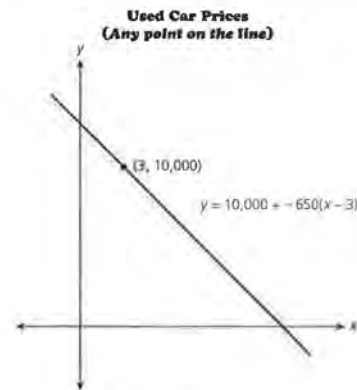
For example, this general equation can be used to describe the following situation: Suppose a 3-year-old car is worth \$10,000. If the rate of change in price is a decrease of \$650 per year, using (3, 10,000), then the equation of the line is

$$y = \$10,000 + -650(x - 3)$$
 as shown in the following graph.

STUDENT PAGE 60

7. c. $P = 0 - 500(A - 22)$, or
 $P = 11,000 - 500A$

The value of the zero from the graph should be close to 22.

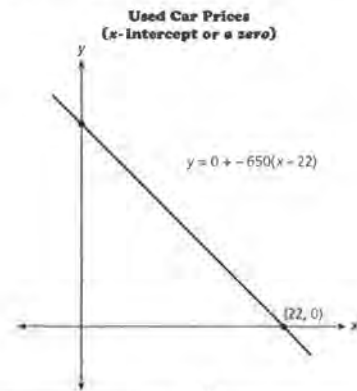


Suppose the point $(x_3, 0)$ is where the line crosses the horizontal axis. Then you can use this point (the x -intercept or zero), along with the slope, m , to write the equation of the line:

$$y = 0 + m(x - x_3), \text{ or}$$

$$y = m(x - x_3)$$

In the context of the example about used cars, the x -intercept or zero is $(22, 0)$. This is equivalent to saying that the used car is worth nothing when it is 22 years old. The equation of the line is $y = 0 + -650(x - 22)$, or $y = -650(x - 22)$ as shown on the following graph.



STUDENT PAGE 61

7. **d.** The value of the y -intercept should be close to 11,000.

$$P = 11,000 - 500(A - 0), \text{ or}$$

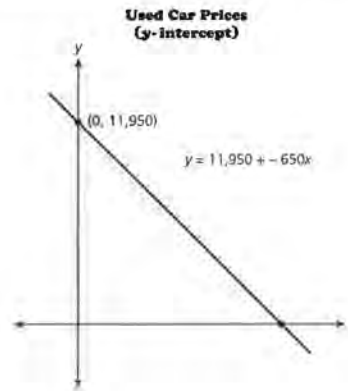
$$P = 11,000 - 500A$$

- e.** By using algebraic properties, the equations are all equivalent to $P = 11,000 - 500A$.

Suppose the point $(0, y_1)$ is where the line crosses the vertical axis. Then you could use this point (the y -intercept) to write the equation of the line:

$$y = y_1 + m(x - 0), \text{ or } y = y_1 + mx$$

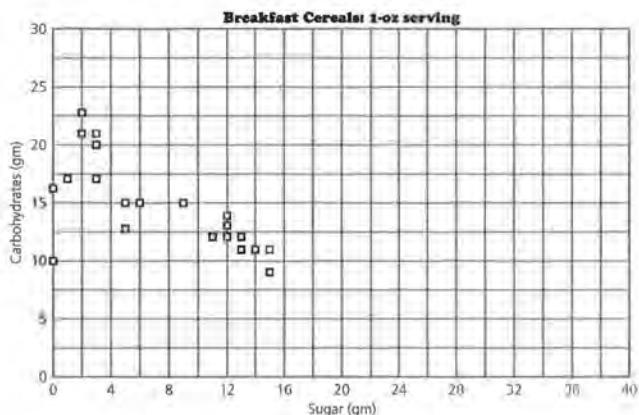
In the context of the used car example, the y -intercept is $(0, 11,950)$. This is equivalent to saying that when a car is brand new (zero years old), it is worth \$11,950. The equation of the line is $y = 11,950 + ^{-}650(x - 0)$, or $y = 11,950 + ^{-}650x$ as shown on the graph below.



STUDENT PAGE 62

8. a. Generally, the more sugar, the fewer carbohydrates.
- b. The zero is about 36. This means that one would expect cereal with 36 grams of sugar to have no carbohydrates.
- The y-intercept is about 18. This means one would expect cereal with no sugar to have about 18 grams of carbohydrates.

8. The following scatter plot shows the relationship between the grams of sugar and the grams of carbohydrates in a 1-ounce (oz) serving of various breakfast cereals.



- a. In general, describe the relationship between the amount of sugar and carbohydrates in the cereals.
- b. A line has been drawn on the following scatter plot to describe the relationship. Estimate the zero and the y-intercept from the graph. What does each represent with regard to the amount of sugar and the amount of carbohydrates in the breakfast cereals?

STUDENT PAGE 63

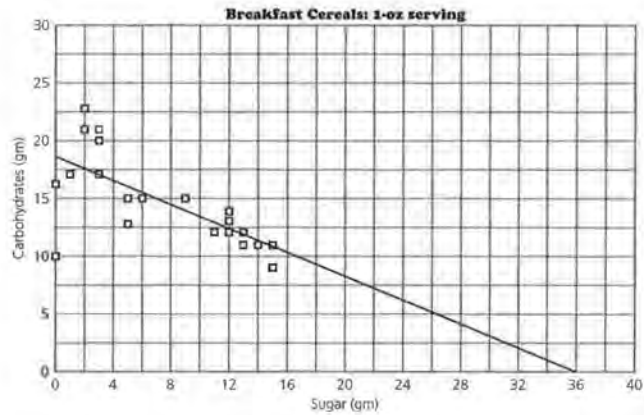
8. c. The equation should be close to $y = 18 - 0.5x$.

d. The value of the zero will depend on the equation students use. For example, when $y = 18 - 0.5x$, find the zero, or the value of x where $y = 0$.

$$0 = 18 - 0.5x$$

$$0.5x = 18$$

For this equation, the zero is 36.



c. Write the equation of the line.

d. Use your equation to find the zero. How does this value compare with the estimate you made in b? How does the zero relate to the data?

9. What is the relationship between the television viewing habits of men and of women? Do they watch the same programs? The chart on the next page shows the percentage of men and women who watched the top 30 TV programs during the 1992–1993 television season according to Nielsen Media Research.

STUDENT PAGE 64

9. a. Since there is a tie at 12, there is no 13. There is a three-way tie at 16, so there is no 17 or 18. This process ensures that the number of shows is the same as the number of rankings.

b. The outlier is *NFL Monday Night Football*. It has a much higher male rating than the female rating would predict, and this makes sense because, in general, watching football games is more popular with men. Students might also suggest *60 Minutes* as an outlier because it is far from the relationship shown by the data and by the line; in fact, this program is one of the few in which the percentage of men and women watching is about the same.

c. Ranges will vary slightly. One possibility is from 6 to 18 for both axes or $6 \leq W \leq 18$ and $6 \leq M \leq 18$.

d. The y -intercept is 1. This means that when no women are watching, 1% of men will be watching. This seems reasonable.

The zero is -2 . This means that when no men are watching, -2% of women will be watching. This is not reasonable because -2% has no meaning in this context.

This indicates that a reasonable maximum for the horizontal axis would be any number greater than zero. Because the values are percentages of people and, in this case, it is impossible to have the percentage greater than 100, the horizontal and vertical axes should both be defined as $0 \leq W \leq 100$, so that W is either the percentage of men or the percentage of women who watch television shows.

Television Viewing Habits

Rank	Program	% Women	% Men
1	<i>60 Minutes</i>	16.5	16.1
2	<i>Roseanne</i>	15.3	10.6
3	<i>Home Improvement</i>	14.1	12.0
4	<i>Murphy Brown</i>	14.7	9.6
5	<i>Murder She Wrote</i>	15.0	10.1
6	<i>Coach</i>	13.1	10.7
7	<i>NFL Monday Night Football</i>	7.6	15.3
8	<i>CBS Sunday Night Movie</i>	14.3	8.4
9	<i>Cheers</i>	11.6	10.4
10	<i>Full House</i>	10.7	6.4
11	<i>Northern Exposure</i>	11.8	9.0
12	<i>Rescue 911</i>	11.7	9.2
12	<i>20/20</i>	11.6	9.0
14	<i>CBS Tuesday Night Movie</i>	11.8	8.3
15	<i>Love and War</i>	11.9	7.7
16	<i>Prince of Bel-Air</i>	9.5	6.6
16	<i>Hangin' with Mr. Cooper</i>	9.9	6.1
16	<i>Jackie Thomas Show</i>	10.5	7.8
19	<i>Evening Shades</i>	12.4	8.2
20	<i>Hearts Afire</i>	12.1	7.7
20	<i>Unsolved Mysteries</i>	11.2	8.8
22	<i>Primetime Live</i>	10.7	9.1
23	<i>NBC Monday Night Movie</i>	11.2	6.4
24	<i>Dr. Quinn, Medicine Woman</i>	12.3	8.0
25	<i>Seinfeld</i>	9.9	8.7
26	<i>Blossom</i>	8.7	5.6
26	<i>48 Hours</i>	10.2	8.4
28	<i>ABC Sunday Night Movie</i>	10.2	8.2
29	<i>Matlock</i>	11.6	7.8
30	<i>Simpsons</i>	6.3	7.2
30	<i>Wings</i>	9.5	8.1

Source: data from *The World Almanac and Book of Facts*, 1994.

- a. Why do you think there were no TV programs that ranked 13th, 17th, and 18th on the chart?
- b. With the exception of at least one program, the pattern of the data appears to be linear as shown on the following scatter plot. Name the program(s), and tell why you think it is an outlier(s).

STUDENT PAGE 65

10. a. $M = 1 + \frac{2}{3}(W - 0)$

b. $M = 7 + \frac{2}{3}(W - 9)$

c. $M = 1 + \frac{2}{3}(W - 0)$

$M = 1 + \frac{2}{3}W$

$M = 7 + \frac{2}{3}(W - 9)$

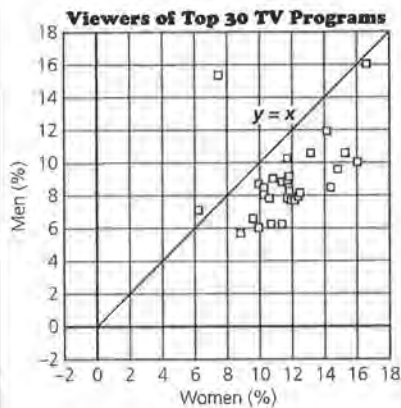
$M = 7 + \frac{2}{3}W - 6$


$M = 1 + \frac{2}{3}W$

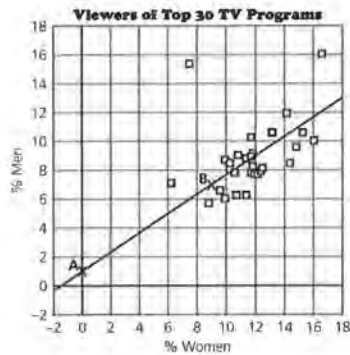
The equations are equivalent because they can be written in the same form. Students might also use the table of values, if M is the same, or the graphs to determine that the equations are equivalent.

d. Students might predict between 7% and 8% of men would watch.

11. Students answer on Activity Sheet 8.



-  a. A point on the line would mean the same percentage of women and men watched the show. A point above the line would mean a higher percentage of men than women watched the show. A point below the line would mean a higher percentage of women than men watched the show.



- c. Write a description in words or symbols of the range of values that make sense for the scale on each axis.
 d. What is the y-intercept and the zero or x-intercept of the line? Do these both make sense in terms of the data? Explain.

10. Refer to the table *Television Viewing Habits*.

- a. Find the rate of change, and use point A to write an equation of the line relating the percentage of men to the percentage of women who watched the top 30 TV programs.
 b. Use point B and your rate of change to write an equation of the line.
 c. Show that the two equations are equivalent.
 d. If you knew that approximately 10% of the women watched a given TV program, about how many men would you predict watched the same program?

11. Draw the line $y = x$ on Activity Sheet 8.



- a. Suppose a data point lies on this line. What does this data point represent? What does a data point above the line represent? What does a data point below the line represent?
 b. What does this line tell you about the percentage of men and the percentage of women who watched the TV programs?

b. The line indicates that for any point on this line (or close to the line), the percentage of men and women who watched that TV program are nearly the same.

STUDENT PAGE 66

11. c. The line $y = x$ or $(M = W)$ shows only how the percentage of men watchers compares to the percentage of women watchers. The line $M = 1 + \frac{2}{3}W$ represents the relationship between the percentage of men and percentage of women from the data. Using this equation, if you know the percentage of women watchers, then you can predict the percentage of men watchers because you have a rule governing the relationship.

12. a. $y = y_1 + mx$
 $y = m(x - x_3)$
 $y = y_2 + m(x - x_2)$

Alternative variables may be used as follows: $y = b + mx$; $y = m(x - a)$; and $y = q + m(x - p)$. Here m is the slope, b is the y -intercept, a is the zero (or x -intercept), and the point (p, q) is somewhere on the line.

b. The $y = m(x - a)$ form, where a is the zero when using 0 as the starting point.

13. a. It can be read from the form of the equation.

Or, if the point is used in the equation the result is true.

$$y = 15 - 5(x - 4)$$

$$15 \stackrel{?}{=} 15 - 5(4 - 4)$$

$$15 = 15 - 0$$

$$15 = 15 \checkmark$$

b. No. Once the equations are simplified, they must be exactly the same to be equivalent. Some students may observe that one slope is -5 and the other slope is 10 , so the equations could not possibly be equivalent and represent the same lines.

$$y = 10(x - 4)$$

$$= 10x - 40$$

$$= -40 + 10x, \text{ which is not equivalent to } y = 35 - 5x.$$

c. Suppose you used the line $y = x$ to predict the TV viewing habits of men and women. How is this different from using the equation in Question 10?

12. Recall that the form of an equation can help you find the y -intercept and zero.

- a.** Write the three general forms you can use to write a linear equation.
- b.** Which of the forms use the zero as the starting point?

13. Consider $y = 15 - 5(x - 4)$.

- a.** Suppose $(4, 15)$ is a point on the line. How can you verify this by using the equation?
- b.** If you use the Distributive Property and combine terms, then you can write the following equation:

$$y = 15 - 5(x - 4)$$

$$y = 15 - 5x + 20$$

$$y = 35 - 5x$$

Is $y = 35 - 5x$ equivalent to $y = 10(x - 4)$? Why or why not?

- c.** What is the slope of $y = 35 - 5x$? The y -intercept? How can you find them from this equation?
- d.** Given the equation $y = 20 + 3x$, what is the y -intercept?

The Distributive Property allows you to distribute a common multiplier to a sum or to write a sum as a product of a common factor and an expression. If the slope is a common factor of both terms, you can distribute the slope from the sum.

$$y = 35 + -5x$$

$$y = -5(-7) + -5(x)$$

$$y = -5(-7 + x)$$

$$y = -5(x + -7)$$

So, $x = 7$ is the zero of the equation.

14. Think about the zero of a linear equation.

- a.** When $x = 7$, what is the value of y in the equation $y = -5(x + -7)$?
- b.** Why is $x = 7$ called the zero?

c. The slope is -5 . Because -5 is the coefficient of x (or the multiplier of x), students can read it from the equation.

The y -intercept is 35 . Some students will read it from the equation (the constant term), although others will let $x = 0$ and solve.

d. The y -intercept is 20 .

14. a. $y = -5(x + -7)$
 $= -5(7 + -7)$
 $= -5(0)$
 $= 0$

b. It is the value of x that makes $y = 0$. Note: this assumes the equation is solved for y .

STUDENT PAGE 67

14. c. No. $x = 2$ does not make the equation equal to 0, only the value within the parentheses will equal 0. Making the term $5(x - 2)$ equal to 0 is not sufficient because of the constant term 10. Therefore, when $x = 2$, $y = 10$.

15. a. The zero for both is 4.

$$\begin{array}{ll} y = 6(x - 4) & y = 6(4 - x) \\ 0 = 6x - 24 & 0 = 6(4 - x) \\ 6x = 24 & 0 = 24 - 6x \\ x = 4 & 6x = 24 \\ & x = 4 \end{array}$$

b. They have opposite slopes, 6 and -6 . They intersect at $(4, 0)$.

$$\begin{array}{ll} y = 6(x - 4) & y = 6(4 - x) \\ = 6x - 24 & = -6x + 24 \end{array}$$

c. The statement is true only for $x = 4$.

$$\begin{array}{l} 6(x - 4) = 6(4 - x) \\ 6x - 24 = 24 - 6x \\ 12x = 48 \\ x = 4 \end{array}$$

16. The methods for finding the values will differ. Some students may use the graphs to make estimates, whereas others may substitute 0 for either x or y . Still, others may be able to read the zero and the intercept from the form of the equation. Encourage students to discuss how they found the answers.

a. The zero = 5; the y -intercept = -50 . The zero can be read by noting the form of the equation; the y -intercept can be found by substituting 0 for x and solving.

b. The zero = 50; the y -intercept = 1000. The zero can be found by substituting 0 for y and solving for x ; the y -intercept can be read by noting the form of the equation.

c. The zero = 8; the y -intercept = 48. The zero can be found by substituting 0 for y and solving for x ;

e. Jenny thinks the zero for $y = 10 + 5(x - 2)$ is $x = 2$. Is she right? Why or why not?

15. Find the zeros of each of the following.

a. $y = 6(x - 4)$ and $y = 6(4 - x)$

b. Compare the lines represented by the equations in a.

c. Is $6(x - 4) = 6(4 - x)$ true or false? Verify your answer.

16. For each of the following equations, identify the zeros and the y -intercepts. Indicate how you found your answer.

a. $y = 10(x - 5)$

b. $y = 1000 + -20x$

c. $y = 6(8 - x)$

d. $y = 100x$

SUMMARY

To understand the relationship between a line and its graph, it is helpful to consider several characteristics.

- To make a scatter plot from the data, choose appropriate scales including maximum and minimum values for both axes.
- To make a graph from an equation, choose an appropriate viewing window.
- To choose an appropriate window, inspect the equation for a reasonable starting point and ending point, or generate a set of ordered pairs that satisfies the equation.

Sometimes, two special points can be useful.

- For the y -intercept at $(0, y)$, you can find the coordinates of this point by doing the following: substituting 0 for x in the equation; reading the point where the graph crosses the y -axis; or writing the equation in the form $y = y_1 + mx$ and recognizing that y_1 is the y -intercept.
- For the x -intercept at $(x, 0)$, you can find the coordinates of this point by doing the following: substituting 0 for y in the equation; reading the point where the graph crosses the x -axis; or writing the equation as a product in factored form and finding the value for x that makes the factor 0.

the y -intercept can be found by substituting 0 for x and solving.

d. The zero = 0; the y -intercept = 0. The zero can be found by substituting 0 for y and solving for x ; the y -intercept can be found by substituting 0 for x and solving. If students have difficulty with this, encourage them to plot ordered pairs and sketch the line.

Practice and Applications

- 17. a.** The zero = $-\frac{4}{3}$, or $-1\frac{1}{3}$; the y -intercept = 20.
- b.** The zero = 1990; the y -intercept = 19,900.
- c.** The zero = -15; the y -intercept = 3.
- d.** The zero = 6; the y -intercept = -30.
- e.** Although student responses will differ, be sure that in each case they suggest a viewing window that would contain the graph. One suggestion might be for students to use the zeros and y -intercepts to obtain the maximum and minimum values for each axis. Another suggestion is to generate a set of ordered pairs and use these to define the maximum and minimum values.
- 18. a.** $10(x - 3)$
- b.** $5(3 + x)$
- c.** $20(5 + x)$

- Sometimes the intercepts make sense for the data; often they do not. For a given slope m , understanding the relation between the starting point used to write the equation and the form of the equation can be useful. If m is the slope:

If (x_1, y_1) is any point on the line, then $y = y_1 + m(x - x_1)$.

If $(0, y_2)$ is the y -intercept, then $y = y_2 + mx$.

If $(x_3, 0)$ is the zero, then $y = m(x - x_3)$.

Practice and Applications

- 17.** Find the zero and the y -intercept for each of the equations.
- a.** $y = 20 + 15x$
- b.** $n = 200 - 10(x - 1970)$
- c.** $a = 6 + 0.2(x - 15)$
- d.** $t = 5(x - 6)$
- e.** What viewing window or set of scales for the axes would make sense for each of the equations above?
- 18.** Use the Distributive Property to rewrite each of the expressions as a product with a common factor.
- a.** $10x - 30$
- b.** $1.5 + 5x$
- c.** $100 + 20x$
- 19.** The following table shows the cost of used $\frac{3}{4}$ -ton Chevrolet pickup trucks as a function of age.

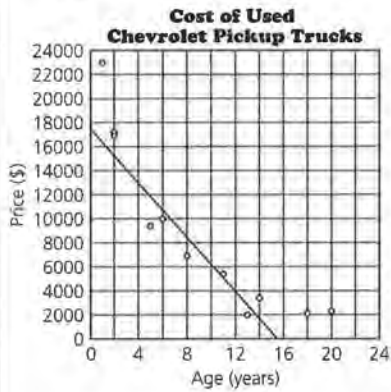
Used Chevrolet Pickup Trucks

Year	Age (years)	Price (\$)
1974	20	2,500
1976	18	2,200
1980	14	3,650
1981	13	2,000
1983	11	5,388
1986	8	6,900
1988	6	9,995
1989	5	9,300
1992	2	17,595
1992	2	17,500
1993	1	23,000

Source: *The Milwaukee Journal*, December 12, 1993.

STUDENT PAGE 69

19. a. The lines will vary greatly because the data are not very linear.



One possible equation is $y = 6000 - 1170(x - 10)$.

b. For the line from a, $y = 17,700 - 1170x$; y_1 or \$17,700 represents the price of a new pickup truck; m is the slope, in this case -1170 , which represents the amount that the price drops (changes) each year.

c. For the line, about 15. This is the predicted age at which the pickup truck will have no value. However, the data show that the line is not a very accurate predictor because 18- and 20-year-old pickup trucks have values in the data.

20. There will be variation in the students' ranges, so check for reasonableness. One possibility is given for each situation.

a. The x-axis should range from 0 to the maximum number of attempts by a single person. The y-axis should range from 0 to the maximum number of free throws made by a single person. The y-intercept represents the number of free throws made if none are attempted. The zero represents the number of free-throw attempts before a basket is made. A typical window might be $0 \leq x \leq 35$; $0 \leq y \leq 35$.

- a. Make a scatter plot (*age, price*) of the data. Draw a line that you think best represents the relationship in the data, and write the equation of that line.
 - b. Locate the point at which the line you drew intersects the vertical axis or y-axis. Write the equation in the form $y = y_1 + mx$. What do y_1 and m represent in the context of the data?
 - c. Estimate the point at which the line intersects the horizontal or x-axis. What does this point mean in the context of the data?
20. Write a description of appropriate scales for the axes or viewing window for each of the following situations. In each case, describe what the y-intercept and the zero would tell you about the data.
- a. The number of free throws attempted and the number of free throws made by a basketball player
 - b. The cost of a camera over time
 - c. The percentage of rainy days and the percentage of sunny days for cities in the United States
 - d. The fats and calories in fast foods
21. Describe a real-world situation and an appropriate viewing window for each of the equations.
- a. $n = 30 + 5(x - 1970)$
 - b. $t = 120 - 0.8x$

b. The x-axis should show slightly more than the years of interest. The y-axis should cover the range of prices. The y-intercept represents the price of the camera in the year 0. The zero represents the year when the camera cost is \$0. A typical window might be $1950 \leq x \leq 2000$; $\$5 \leq y \leq \2000 if a very good camera is considered.

c. Both axes should range from 0% to 100%. The y-intercept represents the percentage of sunny days in a city, with no rainy days.

The zero represents the percentage of rainy days in a city, with no sunny days.

d. The x-axis should range from 0 to the maximum amount of fat. The y-axis should range from 0 to the maximum number of calories. The y-intercept represents the number of calories in a fast food item with no fat. The zero represents the amount of fat in a fast food with no calories. A typical window might be $0 \leq x \leq 40$; $0 \leq y \leq 1000$.

STUDENT PAGE 70

21. Situations will vary. Important components are listed.

a. The answer should include the point (1970, 30) and a slope of 5. A likely situation would involve prices: The item cost \$30 in 1970 and increased by \$5 per year. The viewing window will depend on the context.

b. The answer should include a y -intercept of 120 and a slope of 0.8. The viewing window will depend on the context.

22. a. The fuel consumption of large trucks for different average speeds.

b. $0 \leq s \leq 80$; $0 \leq \text{mpg} \leq 30$

c. The zero is 110 mph; this means that a truck averaging 110 mph will get 0 miles per gallon. This is not likely to be true, but it is also not likely that a truck would average 110 mph. The y -intercept is about 13 mpg; this means that a truck with an average speed of 0 mph will get 13 mpg. This is also not likely to be true, but large construction trucks that travel close to a speed of 0, such as 5 mph, might get as much as 8 or 10 mpg.

23. a. The window should include an x -value of 120 and a y -value of 60.

b. $-18.2 \leq y \leq 41.8$, or $-19 \leq y \leq 42$

c. $-2 \leq x \leq 0$ and $0 \leq y \leq 20$

d. $490 \leq y \leq 590$

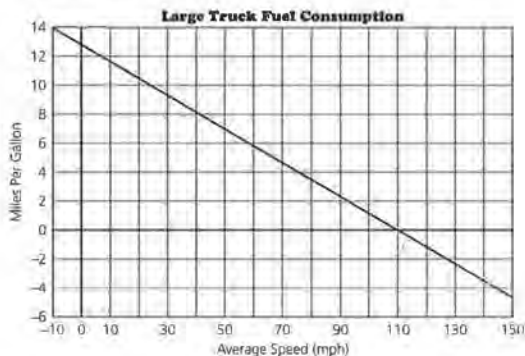
24. a. Students should be able to describe a variety of ways for determining the zero and y -intercept. They may describe: reading the values from the equations in various forms; substituting 0 for x and y ; or using a point represented in the equation with the slope to approximate the values.

22. Refer to the graph below.

a. What does the graph represent?

b. What do you think would be a more appropriate range of values for speed? For miles per gallon?

c. Identify the zeros and the intercepts from the graph and tell what they might mean in the context of the data.



23. Determine an appropriate viewing window for each of the following:

a. To see the y -intercept and zero for $y = 50 - 0.5(x - 20)$

b. To see the line $c = 4.30 + 1.5(x - 1975)$ when $1960 \leq x \leq 2000$

c. To see the y -intercept and zero for $y = 20 + 10x$

d. To see the line $y = -110 + 4x$ for $150 \leq x \leq 175$



24. How well can you make a quick sketch of the graph of a linear equation? Work in partners on the problems in Sets A and B listed at the top of the next page.

a. Suppose you use the zero and y -intercept for each line. With your partner, discuss how to make a quick sketch of the line for each equation.

b. Sketch the line for each equation in Set A by hand while your partner uses a graphing calculator. Compare your results. Change roles and repeat the process using Set B.

b. Sketches should be general, and lines can be checked using a graphing calculator. This table shows the zero and y -intercept for each equation.

Set A: Equation	Zero	y -int
$y = 10 - 5(x - 1970)$	1972	9,860
$y = 50 + (1.10)x$	-45.45	50
$y = 50 + (1/10)(x - 0)$	-500	50
$y = 12 + 5(x - 2)$	-0.4	2
$y = 2 + 5x$	-0.4	2
$y = 65 + 0x$	none	65
$y = 1200 + 0.5(x - 1980)$	-420	210

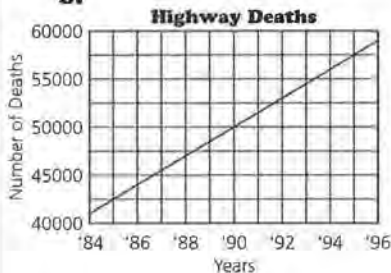
STUDENT PAGE 71

Set B:

Equation	Zero	y-int
$y = 210 + 0.5x$	-420	210
$y = 87 - (3/8)x$	232	87
$y = 81 - (3/8)(x - 16)$	232	87
$y = 50 + 10(x - 0)$	-5	50
$y = 50 + 10(x - 1950)$	1945	-19,450
$y = 80 + (5/7)(x - 5)$	-107	76.43
$y = 75 + (5/7)(x - 12)$	-93	66.43

- 25. a.** The zero of the equation is -10.5; when $y = 0$, $x = -10.5$.
- b.** The zero of the equation is 85; when $y = 0$, $x = 85$.
- 26. a.** The initial value is (1988, 47000), and the slope is 1445. This means that in 1988 there were 47,000 deaths on highways, and the number of deaths increases by 1445 per year.

b.



- c.** There were about 51,335 deaths in 1991. Most students will use the equation.
- d.** The zero is about 1955. This means that in 1955 there were no highway deaths, which does not seem likely.
- 27. a.** The slope is -0.36 or $-0.36/1$. For every year that a girl is older, her qualifying time to run the mile decreases by 0.36 of a minute.
- b.** An appropriate window would be from about 4 to 16.
- c.** The y-intercept is 13.06. This

Set A

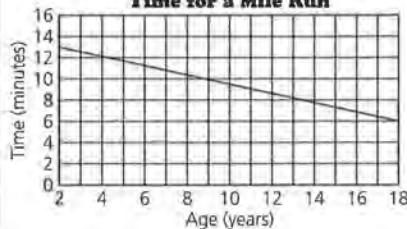
$y = 10 - 5(x - 1970)$
 $y = 50 + (1/10)x$
 $y = 50 + \frac{1}{10}(x - 0)$
 $y = 12 + 5(x - 2)$
 $y = 2 + 5x$
 $y = 65 + 0x$
 $y = 1200 + 0.5(x - 1980)$

Set B

$y = 210 + 0.5x$
 $y = 87 - \frac{3}{8}x$
 $y = 81 - \frac{3}{8}(x - 16)$
 $y = 50 + 10(x - 0)$
 $y = 50 + 10(x - 1950)$
 $y = 80 + \frac{5}{7}(x - 5)$
 $y = 75 + \frac{5}{7}(x - 12)$

- 25.** For each equation, find x when $y = 0$. What does the result tell you?
- a.** $y = 50 + 4(x - 2)$
- b.** $y = 17 - 0.2x$
- 26.** The number of deaths (d) on highways for a given year (t) can be approximated by the equation $d = 47,000 + 1445(t - 1988)$.
- a.** What are the starting point and the slope? What do they tell you about the number of deaths on the highway?
- b.** Draw a sketch of this equation.
- c.** Estimate the number of highway deaths in 1991. How did you make your estimate?
- d.** Find the zero and interpret it in the context of the data. How did you find the zero?
- 27.** The Presidential Physical Fitness Award Program is offered in some United States schools. For the Qualifying Standards, the relationship between a girl's age (16 and under) and the time (in minutes) it takes for a girl to run one mile can be estimated by the equation $T = 13.06 + -0.36A$.
- a.** What is the slope of the line, and what does the slope tell you about the time it takes a girl to run a mile?
- b.** Find an appropriate window for the graph of the equation. Make a sketch of the line.
- c.** Find the y-intercept and the zero. Write a description of each in terms of the situation.
- d.** Why do you think the girls' ages are restricted to 16 and under?

Girl's Qualifying Time for a Mile Run



indicates that a girl who is 0 years old would run the mile in 13.06 minutes. This does not make sense. The zero is about 36. This means that a 36-year-old woman would

run the mile in 0 minutes; again this does not make sense.

d. Student responses will vary. Some might say that the ages were probably restricted to 16 and under because the time might not continue to decrease in the same way. (The qualifying time actually increases for older girls.) Others might say that the test is not given to older girls or that older girls do not take part in the test.

ASSESSMENT

Vital Statistics

Materials: graph paper, pencils or pens, rulers

Technology: the same technology used during previous lessons

Pacing: 1 class period or homework

Overview

This assessment enables you to evaluate students' understanding of *Lessons 5* and *6* in Unit II. Students should demonstrate the ability to read and interpret a scatter plot. Given a set of data, they should be able to plot the data, find and write the equation of a line for the scatter plot, and interpret the slope and intercepts. Given an equation of a line, they should also be able to find and interpret the slope and intercepts.

Teaching Notes

Students might inquire about the 2 on the scatter plot; this represents a coordinate that is the same for two countries—Germany and the Netherlands.

Students must understand either the graph or the form of the equation to respond to the questions as well as understand the data and the scatter plot to interpret the values they find. Observe the way in which students answer Question 3b. Some students may graph the equation and use the graph to find their answers, whereas others may use algebraic representations to find their answers. If possible, show both approaches to the solutions or any other strategies students offer, noting the advantages and disadvantages of each strategy. Students who use the graph of the line may have estimates, particularly for the slope, that will be difficult to obtain from points on the graph. Students who use the equation might make an error that would be difficult to find without seeing the graph.

Follow-Up

The life expectancies of men and women and for different ethnic groups can be found in an almanac or the *Statistical Abstract*. Students might find it interesting to investigate scatter plots of these data, looking for patterns, trends, and relationships.

Solution Key



1. a. Japan had 8 marriages for every 1000 persons and 5 divorces for every 1000 married women.

b. By reading the graph, the United States had the largest rate for both marriages and divorces at 15 marriages for every 1000 persons and 21 divorces for every 1000 married women.

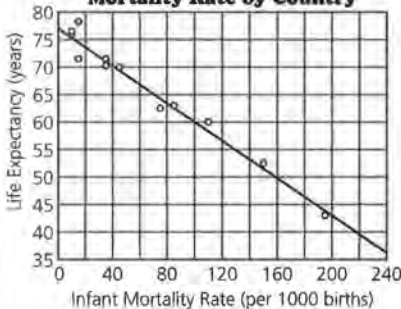
c. Italy had the lowest divorce rate at 2 for 1000 married women.

d. Denmark and the United Kingdom had the same divorce rate at 13 for every 1000 married women; the United Kingdom had 10 marriages for every 1000 persons while Denmark had only 9 marriages for every 1000 persons.



2. a. In 1991, Ethiopia had the highest infant mortality rate at 193 deaths for every 1000 births. Life expectancy is an average of the ages at death. If infant mortality is high, then there are a large number of deaths at very young ages which would lower the life expectancy.

b. Life Expectancy vs. Infant Mortality Rate by Country



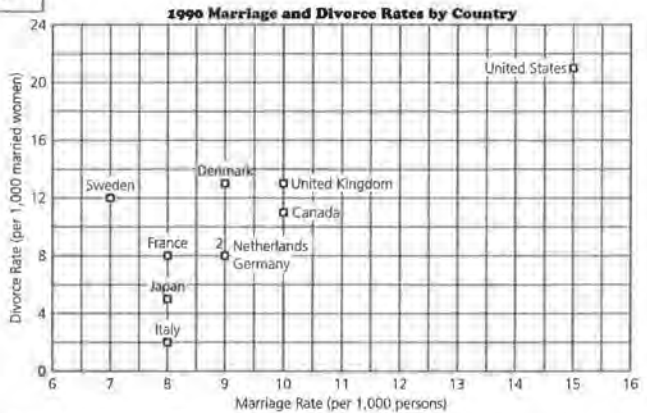
ASSESSMENT

Vital Statistics

OBJECTIVES

Use intercepts, rate of change, and lines to analyze a situation.

1. The 1990 marriage and divorce rates by country are shown in the following scatter plot. Refer to the scatter plot to answer each question.



Source: data from American Almanac, 1994-1995

- In 1990, what was the marriage and divorce rate in Japan? Explain what the values indicate.
- Which country had the greatest marriage rate and the greatest divorce rate? How can you tell?
- Which country had the fewest divorces?
- In 1990, how did the marriage and divorce rates in Denmark compare with those in the United Kingdom?



2. The following table shows the life expectancy at birth (in years), daily calorie supply for adults, and the infant mortality rate (per 1000 births) for selected countries in 1991. (Infant mortality is the number of deaths for children less than one year old, exclusive of fetal deaths.)

The equations will vary slightly, based on the lines students draw. One possible equation is $L = 60 - 0.17(M - 100)$. In this equation, the slope is -0.17 . The slope indicates life expectancy will decrease by 0.17 years if infant mortality increases by one more death per 1000 births. Stated another way, life expectancy will decrease by nearly 2 years (10×0.17 or 1.7) for every 10 more deaths for every 1000 births.

STUDENT PAGE 73

2. **c.** The zero of the equation in **b** is about 453. This can be found by transforming the equation to the form $y = m(x - a)$, by substituting 0 for L and solving, or by careful inspection of a larger graph.

The y -intercept for the equation $L = 77 - 0.17M$ in **b** is 77. This can be found by transforming the equation to the form $y = b + mx$, by substituting 0 for M and solving, or by careful inspection of the graph.

d. The zero means that if infant mortality reaches 453 deaths for every 1000 persons, the life expectancy would be zero. The y -intercept means that if infant mortality were reduced to 0, life expectancy would be 77 years. These both indicate that the linear model is not very reliable beyond the data given ($8 \leq M \leq 200$).

3. **a.** The zero of the equation is 3563. This means that if there are no deaths per 1000 births, each infant would require 3563 calories per day.

The y -intercept is 285. This means that if an infant has 0 calories per day, there will be 285 deaths for every 1000 births. (This does not make sense; if an infant has 0 calories per day, the infant will die. This means that the line and equation representing the relationship are not appropriate for a small number of calories.)

The slope is -0.08 or $-\frac{8}{100}$, which means that for every 100 calorie increase per day, there are 8 fewer infant deaths. (This is an example where the ratio form for the slope makes the interpretation easier and more sensible.)

1991 Life Expectancies, Daily Calories, and Infant Mortality by Country

Country	Life Expectancy (years)	Daily Calorie Supply (for adults)	Infant Mortality (per 1000 births)
Ethiopia	48	1,667	193
Zaire	52	1,991	150
Argentina	71	3,113	34
Bolivia	60	1,916	115
Mexico	70	3,052	45
United States	76	3,671	11
China	70	2,639	33
Indonesia	62	2,750	78
United Kingdom	76	3,149	10
Hungary	71	3,644	19
Switzerland	78	3,562	8
Libya	63	3,324	88

Source: data from *The Universal Almanac*, 1994.

- a.** In 1991, which country had the highest infant mortality rate? Explain how you think the mortality rate affects life expectancy.
- b.** Plot the data (*infant mortality, life expectancy*). Then draw a line on your scatter plot to summarize the data, and write its equation. What does the slope of your line tell you about the data?
- c.** Find the zero and the y -intercept. Explain how you found each.
- d.** What do the zero and the y -intercept represent in terms of the data?
3. Suppose the equation $y = 285 + -0.08x$ summarizes the relationship (*calories, infant mortality rate*) as shown in the table above.
- a.** Find each of the following: the zero, the slope, and the y -intercept, and then indicate what each represents in terms of the data.
- b.** Describe how you found your answers for **a**.

b. Students can estimate the values from their graph, using the zoom feature on the calculators, if necessary. Others may substitute 0 for the x -value, find the corresponding y , and vice versa.

The various methods available are described in Question 1c. You should notice which students are

using which strategies so that you can encourage them to use a variety of strategies. If students know many strategies, they can use the one most appropriate to each problem.

LESSON 7

Lines on Scatter Plots

Materials: graph paper, pencils or pens, rulers, *Activity Sheets 9–11*, *Lesson 7 Quiz*

Technology: calculators, graphing calculators (optional)

Pacing: 3 class periods

Overview

This lesson introduces students to finding a measure of error by estimating the ages of famous people and comparing their estimates with the actual ages. The concept of the difference between the actual age and the estimated age leads to the concept of residual, which is developed later in the lesson. Students find the differences between the actual and predicted values for a line they draw for the (*height, weight*) scatter plot and use these differences to determine who in the class has a “good” line. These differences or residuals are used to find either the mean absolute error or the root mean squared error. By using one of the measures of error, students decide which line is the “best.”

Although residual is a statistical concept, the difference between two values of a function, $f(b)$ and $f(a)$ for a given a and b is a fundamental idea in calculus, and slope is often defined as: $(f(b) - f(a))/(b - a)$. This lesson and the remaining lessons in the module lay the groundwork for understanding and thinking about the difference between two y -values as a vertical distance in the coordinate plane.

Teaching Notes

Question 1 can be done with the entire class, and you may view Questions 2 and 3 as optional depending on how the lesson is constructed. Questions 4–6 are necessary if students seem confused by the concept of finding error. Students usually enjoy estimating ages.

If the suggested persons do not seem appropriate for your students, choose others and use an almanac to find their birth dates.

After students have estimated the ages, have them make scatter plots and analyze the scatter plots before they perform any calculations (preferably using their calculators). Have students estimate individually and not share information. This increases the variability and makes the activity more interesting. For those famous persons that students do not know, have them guess the ages. The line $y = x$ can be used to see how accurate the estimates are. Asking students whether they overestimated or underestimated the ages enables students to interpret the scatter plot. Many students may indicate that points representing overestimates will be above the line, which shows that perhaps they are not really thinking carefully about the scatter plot.

Have students work in groups to find the best estimator for their group and ask them to describe how they made their choices. Encourage students to base their choices on mathematical concepts rather than indicating the best estimator as the one whose graph looks good, or has several points close to the line. Point out that it is difficult to compare two groups unless there are numerical descriptions. Some students will count the number of points on the line, whereas others will try to find a measure of closeness. Still others may have imaginative solutions for determining the best estimator. Usually, students arrive at using the absolute value of the difference between the actual and predicted ages. Some students may require explanation for the absolute value, such as: A single large

outlier above the line can cancel out a series of data points below the line, making it appear that the total difference is 0.

Students may find the mean absolute difference, the total difference, or the median. (A calculator can be very helpful here.) A careful analysis of the ways in which outliers affect error might suggest to some students that the sum of the squared differences will actually meet most of the objections raised about other measures of error. (The squaring magnifies the outliers.) Students should come to some agreement, but they should avoid making an issue about using any given procedure.

In the next activity students draw their own lines for a set of paired data, not a $y = x$ line, and use the same procedure to find the differences between the actual values and the values predicted by the line.

Graphically, they are still reading the vertical difference between the predicted point and the actual point. Numerically, students must use their equations to make predictions. This can be done by hand, which becomes very tedious, or by using the LIST function from a graphing calculator. Students find the sum of the residuals from their particular lines and use these to decide who has a good line.

Students can choose either the root mean squared error or the mean absolute error. For many students, the mean absolute error is intuitive, easy to find, and seems reasonable. Actually, the process of finding the absolute value, while simple, does not lend itself as well to analysis as the root mean squared error. (This is analogous to finding the standard deviation for single variable data rather than the mean absolute deviation.) If, however, the process becomes too complicated to find the root mean squared error, encourage students to use the mean absolute error in order to help them make sense of their work.

Technology

Initially, students can use technology to plot their points in the age activity and to do any number crunching. They should, however, draw the (*height, weight*) line on their own although they can do so using the draw command on calculators as discussed

earlier. The point of this lesson is to have a variety of line, some good and some not good so that students can see how a measure of error can be used to help them organize their thinking.

Follow-Up

The *Decisions Through Data* video series includes a lesson on the manatees discussed in the exercises. It would make a good resource for the problem. The video was edited by David Moore and is available in Hour Three: Units 11–14: Data Analysis for Two Variables, Lexington, Mass: Consortium for Mathematics and Its Applications (COMAP). You can contact COMAP by mail, fax, telephone, or the internet at

COMAP	1-800-77COMAP (tele)
Suite 210	1-617-863-1202 (fax)
57 Bedford St.	3332959@MCIMAIL.COM
Lexington, MA	(internet)
02173	

Avoid spending too much time on these activities because the next lesson introduces technology for performing the calculations.

Solution Key

Discussion and Practice

- Student estimates will vary. It is important that each student record an estimate for each person. See *Teaching Notes* for this lesson. Scatter plots will vary greatly. The following are the birthdays for the persons listed.

Nancy Reagan	1924
Mister Rogers	1926
Sandra Day O'Connor	1930
Chelsea Clinton	1980
Eddie Murphy	1961
Tom Brokaw	1940
Roseanne	1952
Ringo Starr	1940
Frank Sinatra	1915
Oprah Winfrey	1954
Jon Bon Jovi	1962
Garth Brooks	1962
Jane Fonda	1937

Source: *The World Almanac and Book of Facts*, 1994.

LESSON 7

Lines on Scatter Plots

How do you know if the line relating the percentage of sugar to the amount of carbohydrates in cereals, or the line relating the cost of a car to its age, is a good line?

If you can draw several different lines to summarize the data, how do you know if one line is better than another?

OBJECTIVE

Find a *good line* for a scatter plot by considering a measure of error.

In earlier lessons, you investigated drawing a line to summarize a relationship between two variables. You learned to write an equation or rule for the line you drew and learned how to tell if different algebraic representations of your line were equivalent. Also, you studied some special characteristics of a line and that line's equation. Questions still remain, however. How good is your line? How well does it fit the data? The activities in this lesson will help you to answer these questions.

INVESTIGATE

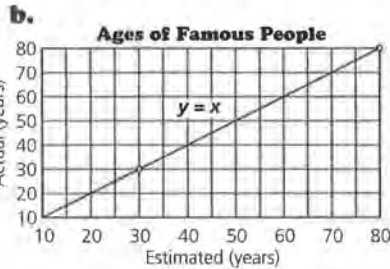
Ages of the Rich and Famous

In 1997, Walt Disney World celebrated its 25th anniversary. Often people are surprised when they learn the ages of famous people or of things that are in the news or are part of their daily lives. This lesson will give you an opportunity to find out how well you can estimate the ages of some famous people.

Discussion and Practice

- Here is a list of famous people. Make a table and estimate how old you think each person is. Then your teacher will give you the ages of these famous people.

2. a. Student responses will vary. Most will indicate that someone is a good estimator if most of that person's estimates are close to the actual ages. Encourage students to try to find a mathematical way to define *close*. Again, see the *Teaching Notes* for this lesson.



If an estimate is correct, the point will have the same x - and y -values. The equation of the line representing accurate estimates is $y = x$.

- c. If a point is above the line, then a student has estimated that the famous person is younger than the person actually is.
- d. This will depend on students' scatter plots. Students should use the concept of points above and below the line to determine whether they are overestimators or underestimators.
3. Answers will vary. Have students explain how they determined the best estimator. The rest of the lesson develops a formal way to judge. If the method described emerges from the discussion and student work, omit Questions 4–6.

Ages of Famous People

	Estimated Age (years)	Actual Age (years)
Nancy Reagan	_____	_____
Mister Rogers	_____	_____
Sandra Day O'Connor	_____	_____
Macaulay Culkin	_____	_____
Eddie Murphy	_____	_____
Tom Brokaw	_____	_____
Roseanne	_____	_____
Ringo Starr	_____	_____
Frank Sinatra	_____	_____
Oprah Winfrey	_____	_____
Joni Bon Jovi	_____	_____
Garth Brooks	_____	_____
Jane Fonda	_____	_____



2. How well were you able to estimate the ages of these people? To help answer this question, make a scatter plot with your estimates of the ages on the horizontal axis and the actual ages on the vertical axis, (*estimated age*, *actual age*).
- a. How do you think you should decide if someone is a good estimator of the ages of these famous people?
- b. Where will a point lie if your estimate is correct? Draw a line on your scatter plot representing estimates that are 100% accurate. Write the equation of the line.
- c. What does it mean if a point is above this line?
- d. In general, are you an overestimator or an underestimator? How can you tell?
3. Look at the scatter plots of other students. Decide who among you is the best estimator, and give a reason why. Be prepared to explain your choice to the class.

STUDENT PAGE 76

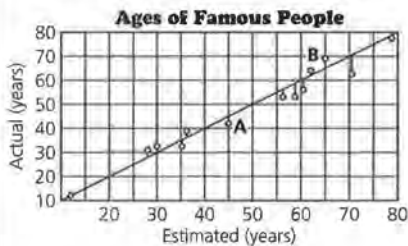
4. a. Leah estimated a person was 45 years old, and the person was actually 41 years old.

b. The vertical distance represents how many years off she was in her estimate.

c. (70, 62). Leah's worst estimate was when she guessed someone was about 70 years old, and the person was actually 62 years old. This point can be found from the graph by looking for the point farthest above or below the line.

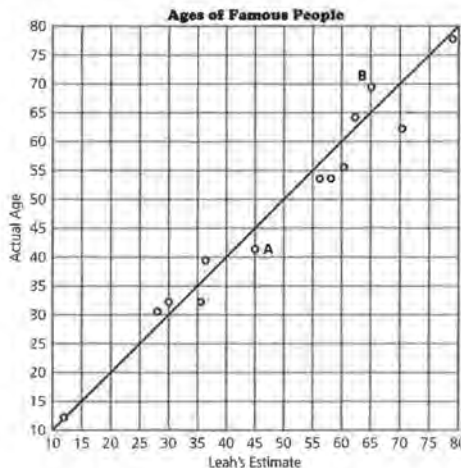
d. The error for point B is about 4 years. This can be found by looking at the vertical distance from B to the line. The error for point A appears to be close to the error for point B; however the errors are in different directions.

5. a. Students might need to review what the symbol Σ represents.



b. Leah must have assigned a positive value to the error for a point below the line and a negative value to the error for a point above the line. Then, when she added the values, some of the errors canceled out each other, leaving a total error of about 14.

4. Following is a scatter plot of Leah's estimates and the actual ages for another group of famous people.



- What does A represent?
 - What does the vertical distance from A to the line represent?
 - Name the ordered pair that represents the person for whom Leah had the worst estimate. How can you find that ordered pair using the graph?
 - Suppose the difference between Leah's estimate and the actual age is called her "error" in estimating. What was Leah's error for the person represented by B? Describe how to find this error using her scatter plot. What is the difference between the error for B and the error for A?
5. Leah decided to find out how far off all of her estimates were, or to find her total error. She claimed that overall her total error was only 14 years, and she wrote $\Sigma \text{ errors} = 14$ (Σ means "sum").
- Find all of the differences between her estimated ages and the actual ages, and record them in a table.
 - What do you think Leah did to find $\Sigma \text{ errors} = 14$?

STUDENT PAGE 77

- 5. **c.** This method is not really appropriate because when the errors cancel out each other, you can get a very small value for Σ error and yet be very far off with individual values.
- 6. **a.** Answers will vary, based on students' scatter plots.
b. The average value gives some indication of how accurate the estimates were in general.
c. The answer depends on the class data.

- c.** Do you think her method was a good one? Why or why not?
- 6. Use your estimates of age and the scatter plot you made in Question 2.
 - a.** How far off was each of your estimates? What is the sum of your errors?
 - b.** On average, how far off were you for each estimate? What does this tell you about your ability to estimate ages of this group of famous people?
 - c.** If you define the "best" estimator as the person with the least error, who is the best estimator in your class?

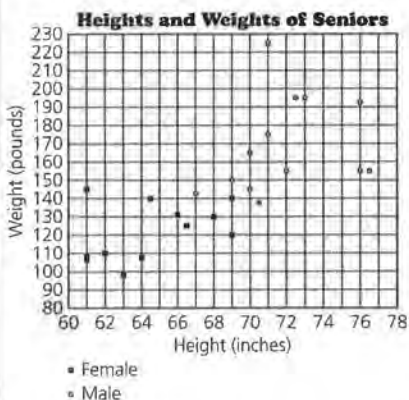
In an earlier lesson, you investigated the relationship between the heights and weights of football players. Do you think the same relationship exists for students who are not football players? The following data show the heights and weights of 25 high school seniors, both male and female. A scatter plot of the data is shown on the next page.

High School Seniors' Heights/Weights

Males' Height (inches)	Weight (pounds)	Females' Height (inches)	Weight (pounds)
72.5	195	66	132
70.5	137	63	97
72	156	61	145
70	145	61	108
71	175	64	106
70	165	66.5	125
73	195	64.5	140
76	155	69	120
67	143	68	130
76.5	155	61	105
76	192	69	140
69	149	62	110
71	225		

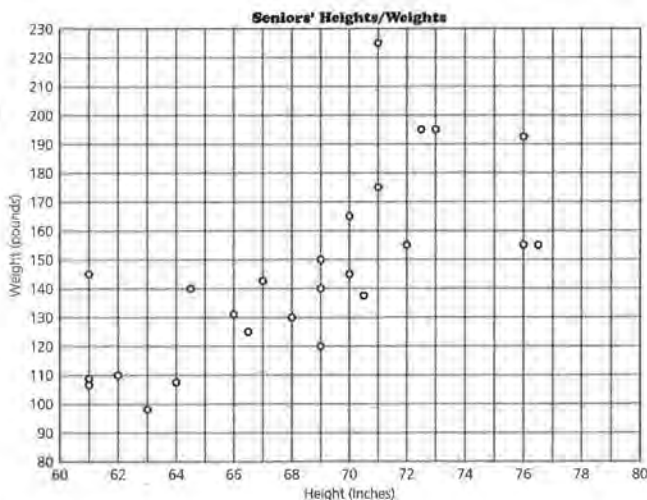
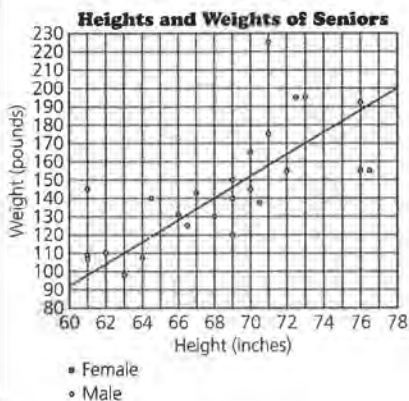
STUDENT PAGE 78

7. **a.** There appears to be a linear relationship, but there is a lot of variation in the data. It is difficult to tell how much variation there is without some mathematical measure, which motivates the primary objective of this lesson.
- b.** Students should answer on *Activity Sheet 9*.



Almost all of the females are shorter than almost all of the males. There appears to be slightly less variation among the females than among the males.

- c.** Because the populations (male/female) are different, the lines will probably differ. There seems to be more variation in these data than for the football players, but that may be due to scale factors. Again, point out that some measure of variation is useful in thinking about how well a line summarizes a relationship.



7. Refer to the scatter plot above.
- a.** Describe the pattern you see in the seniors' heights and weights.
- b.** Use *Activity Sheet 9* to star the points representing the heights and weights of females. What observations can you make?
- c.** Draw a line on the scatter plot that you think will summarize or fit the data for all students, male and female. Find the equation of your line.
- d.** How does your equation for the heights and weights of a sample of seniors compare with the equation relating the heights and weights of football players in Lesson 5, Question 5?
- e.** Look at the line you drew in Question 7. Working with your partner, decide who has the "better" line. How did you decide?
- f.** Which line is the best for predicting a given height? One way to find out is to test your line using the data points you know. A line has been drawn on the scatter plot that follows. The point (68, 140) is on the line.

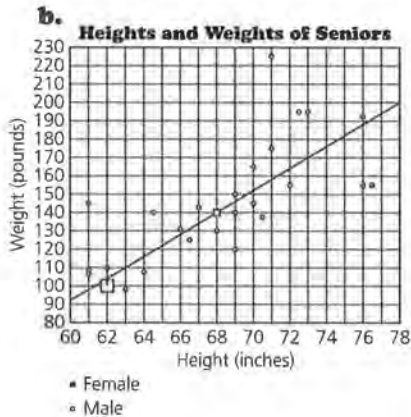
One possible equation is $W = 160 + 5.6(H - 72)$.

- d.** There will be variation in these answers depending on students' answers for **c** and Question 5d in Lesson 5. For the answers given here, the slopes of the lines are quite different. The football players gain more weight per inch in height than seniors who are not football players. Students may also use individual points to make comparisons.

- g.** Students may use some sort of Σ errors method or another method. Have them think about the procedures they used in estimating the ages to see if that procedure might be useful here. Encourage students to share their methods.

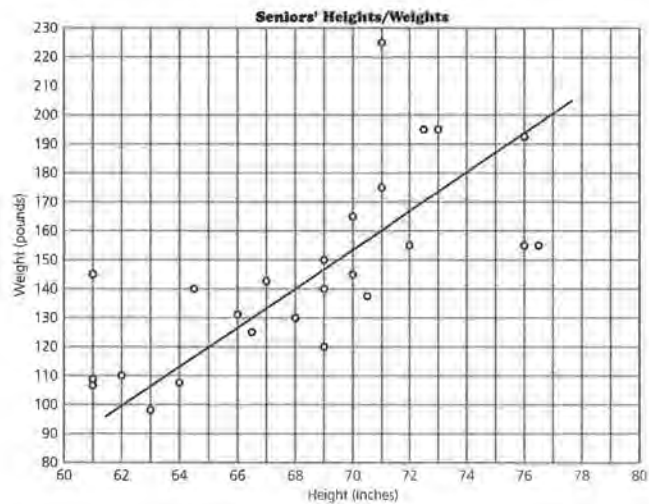
STUDENT PAGE 79

9. a. Students should answer a and b on *Activity Sheet 10*.



- c. 10 pounds

10. a. The answer depends on lines drawn by students. Some predictions may be close.
- b. It should be a student whose prediction of weight for a height of 72 inches is either above or below the line by the least amount or is the shortest vertical distance.
11. a. For a height of 76 inches, the line predicts a weight of 192 pounds, which is an actual data point.
- b. The line appears to underestimate weights in general because there are more points above the line than below, and the points above the line seem to be a greater distance from the line. Again, without some numerical measure, it is difficult to make a decision. Students might try to find a numerical way to justify their answers.



- a. Mark this point on the scatter plot on *Activity Sheet 10*.
- b. Look at the table of data to find the weight of the senior who is 68 inches tall. Use *Activity Sheet 10* to mark the point on the plot.
- c. What is the difference between the weight that is predicted by the line drawn on the scatter plot and the actual weight from the data in the table?
10. Refer to Question 7 and *Activity Sheet 9*.
- a. How well did your line predict the weight for a height of 72 inches?
- b. Who in your group was the best predictor of weight for a height of 72 inches?
11. Refer to the scatter plot (*height, weight*) shown above with Question 9.
- a. For which height(s) does the line predict the actual weight(s)?
- b. Overall, does the line overestimate the weight or underestimate the weight? How can you tell?

STUDENT PAGE 80

11. c. For the actual weight of 225 pounds for a height of 71 inches, the predicted weight will be the furthest off. This can be seen from the graph because the distance from this point to the line is the greatest.

d. Draw the vertical distance from (62, 110) to the line.

12. a. Approximate lengths are
 $AB = 8$ $CD = 25$
 $EF = 15$ $GH = 36$
 Each represents the error for a particular point.

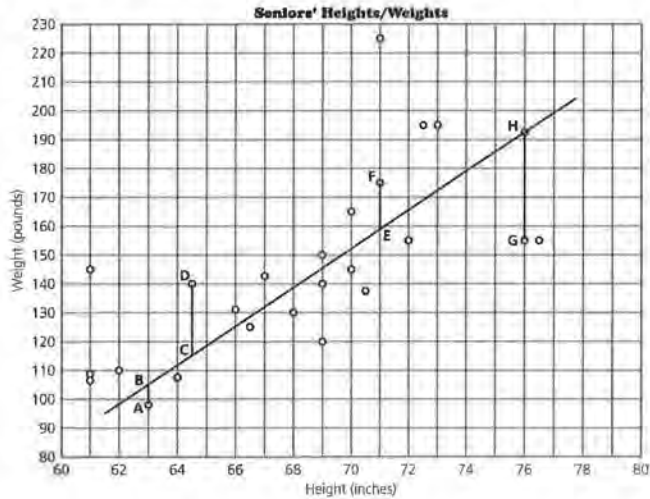
b. 6.7 is the slope of the line. (68, 140) is a point on the line.

c. The equation predicts that a senior who is 66 inches tall would weigh 126.6 pounds. The actual 66-inch senior weighed 132 pounds. The difference (132 - 126.6) is 5.4 pounds.

d. $AB = 9.5$ $CD = 23.45$
 $EF = 14.9$ $GH = 38.6$

- c.** For which point will the weight that is predicted from the line be farthest from the actual weight? How can you use the scatter plot to decide?
- d.** Find the point (62, 110). Describe how you can show on the scatter plot the difference between the actual and predicted weight.

12. Consider the line segments shown on the scatter plot below.



- a.** Using the scatter plot, estimate the length of each segment: AB , CD , EF , and GH . What does each length represent?
- b.** Suppose the equation of the line shown in the scatter plot is $W = 140 + 6.7(H - 68)$. What do the numbers in the equation represent in terms of the data?
- c.** Use this equation to predict the weight of a senior who is 66 inches tall. How much does this senior actually weigh? How close is the weight of this senior predicted by the equation to this senior's actual weight?
- d.** Use the data in the table to find the coordinates of A , D , F , and G . Then use the equation to determine the length

- 13.** Students should use *Activity Sheet 10*. Students can use a graphing calculator to find these predictions by graphing the line and using the CALC menu, by storing the equation in Y1, and finding Y1(Xi) on the home screen for a particular x. They might also use the LIST feature and define the list to be the predicted values. This strategy will be explored in the next lesson. At this point, students should probably see how the individual values are generated to enable them to think about what the values represent and how the result is shown on the scatter plot.
- a.** A possible table of values follows.

of the segments *AB*, *CD*, *EF*, and *GH*, as shown in the scatter plot.



- 13.** Recall that you can generate a table of values for any equation.
- Use the equation for the line you drew in Question 7 to predict the weight for each height. Record your data in the table on *Activity Sheet 10*.
 - Find $y_i - y$, the difference between any given actual and predicted weight. What does a negative difference in weight represent?
 - How are the predicted weights shown on the scatter plot? Give two examples.
- 14.** Use the table on *Activity Sheet 10*.
- Find a method to determine the average error in your predictions of weight. Be prepared to explain your method.
 - Compare your error with the errors of your classmates. Who has the *least* error and thus, the *best* line?
- 15.** To find an *average* error, you need to find the difference between the actual weight and the predicted weight. These differences are called *residuals*.
- Does it make sense to add the differences, or residuals, to find an average error? Why or why not?
 - If y_i is any actual value and y is any predicted value for a given height, what does $\sum(y_i - y)$ represent?
 - Recall the interval regarding the median height on the infant growth charts in Lesson 5, Questions 2 and 3. Using *Activity Sheet 10*, sketch on the scatter plot a band that you think shows the typical error in using your line to predict weight.

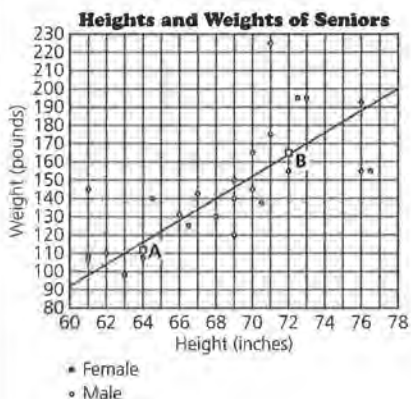
There are two ways to avoid the problem of negative residuals canceling positive residuals. Use the absolute value of each residual or use the square of each residual before adding them. Squaring is more typical, but taking the absolute value may seem more logical. You can estimate your error in making a prediction by finding an “average” error:

Height	Actual Weight	Predicted Weight	Difference
72.5	195	170.15	24.85
70.5	137	156.75	-19.75
72	156	166.8	-10.8
70	145	153.4	-8.4
71	175	160.1	14.9
70	165	153.4	11.6
73	195	173.5	21.5
76	155	193.6	-38.6
67	143	133.3	9.7
76.5	155	196.95	-41.95
76	192	193.6	-1.6
69	149	146.7	2.3

Height	Actual Weight	Predicted Weight	Difference
66	132	126.6	5.4
63	97	106.5	-9.5
61	145	93.1	51.9
61	108	93.1	14.9
64	106	113.2	-7.2
66.5	125	129.95	-4.95
64.5	140	116.55	23.45
69	120	146.7	-26.7
68	130	140	-10
61	105	93.1	11.9
69	140	146.7	-6.7
71	225	160.1	64.9

13. b. A negative difference means the prediction was too high.

c. The predicted weights are points on the line. Students can mark any two points.



14. Students should answer on *Activity Sheet 10*. Recall that tables will depend on the students' equations for the lines they drew. Students may enjoy comparing their predictions to see how far off they are from given data points.

a. There are many possibilities. Some students may add, using both positive and negative changes, and then divide by the number of points. Others may use absolute values. As students discuss their methods, relate these to the procedures discussed in the activity for estimating ages.

b. The answers depend on students' work and the criteria they established. The differences are the length of the vertical segments from each point to the line.

15. a. Some students may be concerned about some residuals that will cancel out each other due to positive and negative values. Avoid making an issue of the vocabulary and allow students to use a reasonable and efficient method to communicate their ideas.

- Find the differences between your estimate and the actual value.
- Square or take the absolute values of the differences.
- Find the sum of the squared or absolute differences.
- Find the average by dividing the sum by the number of differences you have.
- If you use the squared differences, divide to find the average and then take the square root of the average.

If you square the differences, the final result is called the *root mean squared error*. If you take the absolute value of the differences, the result is called the *mean absolute error*.

16. Calculate the root mean squared error or the mean absolute error for your line in Question 7. What does this value tell you?

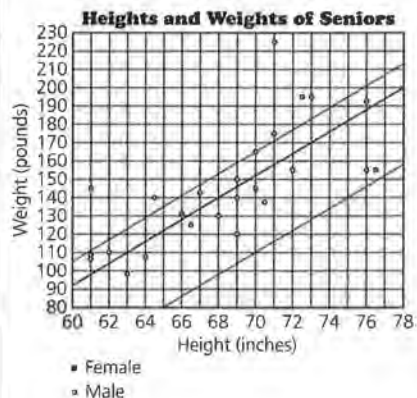
You may recall the standard deviation or mean absolute deviation from earlier work. The root mean squared error is a measure of variability similar to standard deviation. The mean absolute error for a line is similar to the mean absolute deviation for a data set.

SUMMARY

- If there is a linear pattern in a set of data, you can summarize the relationship by drawing a line.
- You can determine how well a line fits a set of data by looking at the differences between the actual points and the predicted points on the graph.
- The difference between a predicted y -value and an actual y -value is called a *residual*. This difference is represented on the graph by the line segment that is the vertical distance from the point to the line.
- The overall error in predicted values can be measured by calculating the *mean absolute error* (the average of the absolute values of the differences or residuals) or the *root mean squared error* (the square root of the average of the squared differences or residuals).

b. It represents the sum of the residuals (the sum of the vertical distances).

c. Students should answer on *Activity Sheet 10*. Students' bands will vary. It may be interesting to discuss whether all points should be included in the band. One possible set of bands is shown.

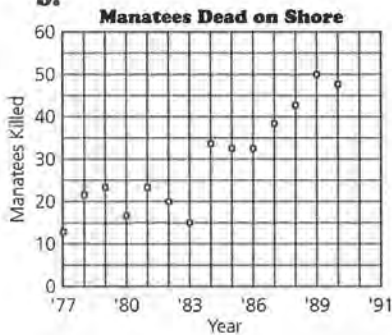


16. Some students may have done this in Question 14. If not, they should compute the error now. The result will give students some measure of error in making predictions from their lines.

Practice and Applications

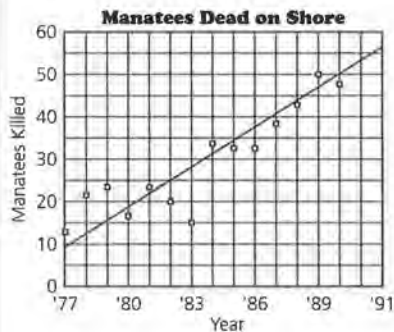
17. a. There are a number of possibilities, including the following: The number of manatees found dead on shore increases each year; as the number of powerboat registrations increases, the number of manatees found dead on shore increases.

b.



In general, the number of manatees found dead on shore has increased over time.

c. Answers will vary.



One possible equation is $y = 25 + 3.3(x - 1982)$. The slope indicates that every year 3.3 more manatees are found dead on shore than were found in the previous year.

Practice and Applications

17. In Florida, conservationists are concerned about the diminishing numbers of manatees, mammals similar to dolphins, that live in coastal waters. They are friendly and playful and seem to enjoy being near humans. During the late 1980s, the number of manatees whose dead bodies washed onto the shore increased dramatically. Examinations revealed that the manatees' bodies appeared to have been scraped by powerboat propellers. The Florida Department of Natural Resources investigated the number of powerboat registrations and found the following data.

Manatees and Powerboat Registrations in Florida

Year	Powerboat Registrations (thousands)	Manatees Found Dead on Shore
1977	447	13
1978	460	21
1979	481	24
1980	498	16
1981	513	24
1982	512	20
1983	526	15
1984	559	34
1985	585	33
1986	614	33
1987	645	39
1988	675	43
1989	711	50
1990	719	47

Source: data from *Decisions Through Data*, 1992

- a. Describe any relationships or trends you can see from the data in the table.
- b. Make a scatter plot over time of the number of manatees found dead on shore. What does the scatter plot show?
- c. Draw a line that will describe the deaths of the manatees as a function of time. Write the equation of your line. What does the slope of your line tell you?

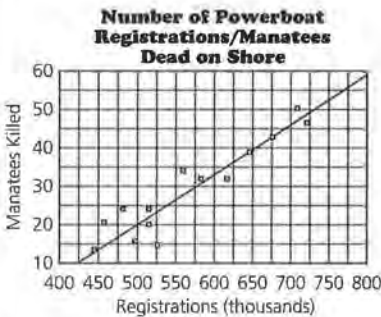
STUDENT PAGE 84

18. a. About 29 manatees were found dead. Students can use the 1983 and 1984 data in the table to estimate. There appears to be a linear trend in the plot.

b. From the scatter plot, you can see a relationship between the increase in registrations and the increase in manatee deaths. With the scatter plot over time, you can observe only the increase in deaths.

c. About 27 manatees. Students should be able to estimate, using a point that is close to the linear pattern.

19. Students answer on *Activity Sheet 11*.



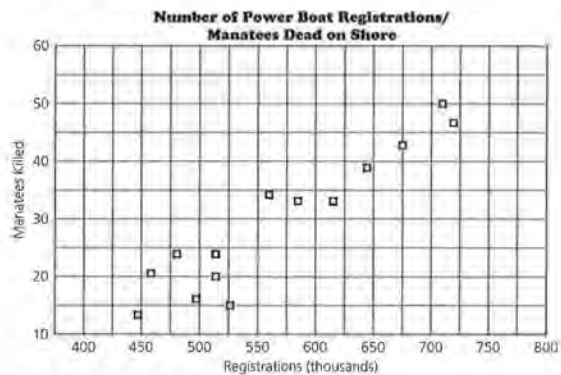
a. Equations will vary slightly. One possible equation is $K = 20 + 0.13(R - 500)$. The slope indicates that for every 100 thousand increase in powerboat registrations, there will be 13 more manatees found dead on shore. The decimal form of the slope (0.13) is not as meaningful as the fraction: 13/100.

b. The equation predicts about 26.5 manatees found dead on the shore if there are 550 thousand powerboats registered.

18. The Florida conservationists observed that there seems to be a relationship between the number of powerboat registrations and the number of manatee deaths.

a. Using the data in the table, estimate the number of manatees found dead on shore as related to 550 thousand powerboat registrations.

b. Look at the following scatter plot to see if there really are any patterns as the conservationists claim. Compare the inferences you can make from the scatter plot over time in Question 17 with the inferences from the following scatter plot.



Source: data from *Decisions Through Data*, 1992

c. Use this scatter plot to estimate the number of manatees found dead on shore if there are 550 thousand powerboat registrations. How did you make your estimate?

19. Using *Activity Sheet 11*, draw on the scatter plot a line that you think summarizes the relationship between the number of manatee deaths and the number of powerboat registrations.

a. Write the equation of your line. What is the slope of your line, and what does it tell you about manatee deaths?

b. Using the equation of your line, predict the number of manatees found dead on the shore if there are 550 thousand powerboat registrations.

STUDENT PAGE 85

19. c. Students will most likely choose the equation because there is no further estimation required by the time the equation is written. Students should explain their preferences.

d. For the equation $K = 20 + 0.13(R - 500)$, when there are 0 powerboat registrations, there will be -45 manatees found dead on shore. When there are 346 thousand powerboats registered, there will be 0 manatees found dead on shore. The y -intercept is -45, and the zero is 346.

20. Answers depend on students' lines. Students may compare by the root mean squared error or the mean absolute error.

21. a. A is (526, 15). It represents the data point of 526 thousand registrations and 15 manatees found dead on shore. B is (725, 50). It represents the prediction point on the line of 725 thousand registrations and 50 manatees found dead on shore.

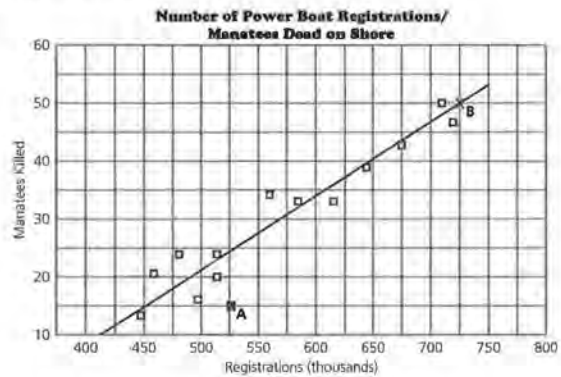
b. He would predict too many for point A, because point A is below the line.

c. Tua forgot to look at the vertical scale, which would have reminded her that 1 square represents 5 deaths; therefore, she should have multiplied the number of squares by 5.

- c.** Which is the easiest to use to make a prediction: the table, the plot, the line, or the equation? Explain.
- d.** Find the y -intercept and the zero of your line. Use each in a sentence to describe the relationship between the number of powerboat registrations and the number of manatees found dead on shore.

20. Compare your line with the lines of others in your class. Who seems to have the *best* line? How did you decide?

21. Tua's line is shown on the following scatter plot.



- a.** What are the coordinates of A and B? Tell what each pair of coordinates represents.
- b.** If Tua uses her line to predict the number of manatees found dead on shore, would she predict too many or too few deaths for A? How can you tell?
- c.** When she made her predictions, Tua estimated her error by just counting the number of squares in the grid to represent the distance from a data point to her line. For example, she determined that A is about 2 squares away from the line so she concluded that her prediction was off by about 2 deaths. What would you tell Tua about her method?

22. a. Students should answer on *Activity Sheet 11*.

Number of Powerboat Registrations (thousands)	Predicted Number of Manatees Found Dead on Shore
447	13.11
460	14.8
481	17.53
498	19.74
513	21.69
512	21.56
526	23.38
559	27.67
585	31.05
614	34.82
645	38.85
675	42.75
711	47.43
719	48.47

b. Most students will use the equation, such as $K = 20 + 0.13(R - 500)$ from 3a, to make predictions, whereas others may use their graph.

c. The answer depends on student data. Some may compare selected values or begin to look at differences or average differences.

d. For the preceding data, the root mean squared error is 4.2. A predicted number of dead manatees would typically be within 4 of the actual number found dead.

e. The answer depends on students' lines and errors.

22. Use the table, similar to the one below, on *Activity Sheet 11*.

a. Predict the number of manatees found dead on shore for the given number of powerboat registrations. Record your predictions in the table on *Activity Sheet 11*.

Powerboat Registrations (thousands)	Predicted Number of Manatees Found Dead on Shore
447	_____
460	_____
481	_____
498	_____
513	_____
512	_____
526	_____
559	_____
585	_____
614	_____
645	_____
675	_____
711	_____
719	_____

b. How did you make your predictions?

c. Who seems to have the best predictions in your group? How can you tell?

d. Calculate the root mean squared error or the mean absolute error for your predictions. What does the error indicate about your line?

e. Compare your error with the errors of your classmates. Who has the least error?

23. Write a letter to the Florida Department of Natural Resources outlining the problem involving powerboats and their negative effect on manatees as you have identified it. Provide statistical evidence to support your conclusion, and make some suggestions for resolving the issue.

24. Consider the perpendicular distance from a data point in a scatter plot to the line you have drawn to represent the relationship in the data. Do you think it would be useful to use this distance to measure a *best* line? Why or why not?

23. When evaluating students' letters, take into consideration students' abilities to make convincing arguments using the information they have discovered. A student may make an argument that his or her line is a good predictor because it has a small error and then make an argument using the slope of the line. Students should use their graphs and their data to prepare a convincing argument.

24. **Challenge** The perpendicular distance is difficult to find. While the vertical distance measures the difference between the actual value and the predicted value, the perpendicular distance has no such contextual basis. (It will, however, produce the same best line—a good geometry problem!)

LESSON 8

Technology and Measures of Error

Materials: graph paper, pencils or pens, rulers

Technology: graphing calculators or computers with a spreadsheet software, overhead projection panel (optional)

Pacing: 1 class period

Overview

The focus of this lesson is to have students use technology that minimizes error in the line for the data. Step-by-step instructions provide students with help in using either a spreadsheet software such as Microsoft Works or a TI-83 graphing calculator to find the error for a given linear equation for the data. Most spreadsheet software programs will generate the new error for an equation fairly automatically as the equation is changed. Some graphing calculators require that a new equation be entered and the error recalculated each time; others now work like spreadsheet. In either situation, the work is still much easier when technology is used.

Teaching Notes

Work through one of the examples with the class. The instructions given are for Microsoft Works, but they should be fairly similar for any spreadsheet program. If students have used a spreadsheet software previously, they will be comfortable with the process. If not, let students experiment with the procedure until they understand how to make it work. If necessary, you might have someone with knowledge of the software help students become more comfortable in working with it.

The graphing calculator is easy to use. Some calculators will not process a change in the equation without

repeating the commands to find the predicted values and then the differences between the actual and predicted values. The predicted values can be found by using the LIST function and storing the equation in Y1, or by using the equation from the home screen and defining the list from that perspective.

You can modify the instructions in the student book to fit other spreadsheet software or graphing calculators.

Follow-Up

Be sure students understand how to use the technology; without which the steps can become overpowering and students may not understand the purpose of the exercises that follow.

LESSON 8

Technology and Measures of Error

Finding residuals by hand is tedious and time consuming. How can you find them without so much work?

Technology makes doing many calculations that are difficult or time consuming to do by hand easier. It is important, however, that you take time to understand the concepts involved.

OBJECTIVE

Use technology to find a measure of error in predicting by using an equation.

INVESTIGATE**Using a Spreadsheet or Graphing Calculator**

Refer to the data regarding the height and weight of seniors in Lesson 7, page 77. You can find the root mean squared error for the line $w = 170 + 7(h - 72)$, using either a spreadsheet software like *Microsoft Works* or a TI-83 graphing calculator.

If you are using *Microsoft Works*, open up the application to a new spreadsheet.

- In the first row, A1 through E1, enter the headings as follows:

A1	B1	C1	D1	E1
Height	Weight	Predicted Weight	Difference	Difference Squared

- Then enter the values for the height in column A (beginning in cell A2) and the corresponding values for weight in Column B (beginning with cell B2).
- In cell C2, enter your prediction equation, using A2 in place of h , with an equals sign (=) in front of the formula, $=170+7*(A2-72)$.
- In cell D2, enter the formula $=B2-C2$.

STUDENT PAGE 88

- In cell E2, enter the formula $=D2^2$.

To label the results for the final computations:

- In D27, enter **Sum diff squared**.
- In D28, enter **Sum diff squared/ n** . (n is the number of data points)
- In D29, enter **Root mean squared error**.

To enter the formulas for the final computations:

- In E27, enter $=\text{Sum}(E2: [\text{location of last value in column E}])$. In this example, there are 25 data points, so the entry in E27 is $=\text{Sum}(E2:E26)$. (Recall that cell E1 does not contain a data point.)
- In cell E28, enter $=E27/25$.
- In cell E29, enter $=\text{sqrt}(E28)$.

STUDENT PAGE 89

	A	B	C	D	E
1.	Height	Weight	Predicted Weight	Difference	Difference Squared
2.	72.5	195	=170+7*(A2-72)	=B2-C2	=(D2)^2
3.	70.5	137			
4.	72	156			
5.	70	145			
6.	71	175			
7.	70	165			
8.	73	195			
9.	76	155			
10.	67	143			
11.	76.5	155			
12.	76	192			
13.	69	149			
14.	71	225			
15.	66	132			
16.	63	97			
17.	61	145			
18.	61	108			
19.	64	106			
20.	66.5	125			
21.	64.5	140			
22.	69	120			
23.	68	130			
24.	61	105			
25.	69	140			
26.	62	110			
27.				Sum diff squared	=Sum(E2:E26)
28.				Sum diff squared/n	= E27/25
29.				Root mean squared error	=sqrt(E28)

The spreadsheet software will perform all of the operations for you, but you have to set it up. To make the formulas work in each of the columns C, D, and E, you must highlight each column individually. For example, highlight cell C2 and drag the highlight to the last data line. Under the **Edit** menu select **Fill Down**. This command will use the formula $=170+7*(A2-72)$ in cell C2 to predict the weight for each height in cells A2 to A26 and store each result in cells C2 to C26, respectively. Repeat this process for columns D and E. The result in cell E29 will be the root mean squared error. Your final spreadsheet should look like the following one.

Solution Key

Discussion and Practice

1. a. On the spreadsheet, entry C3 shows that the predicted weight for a person 70.5 inches tall is 159.5 pounds.
- b. The -43 in D9 means that the actual weight of a person 76 inches tall was 43 pounds less than the predicted weight of 198 pounds.
- c. The entries in column C represent the y -values (weights) predicted from the line for the x -values (heights) in column A. The entries in column D represent the vertical distances between the actual y -values (weights) and the predicted y -values (predicted weights) for the heights given in column A.

	A	B	C	D	E
1.	Height	Weight	Predicted Weight	Difference	Difference Squared
2.	72.5	195	173.5	21.5	462.25
3.	70.5	137	159.5	-22.5	506.25
4.	72	156	170	-14	196
5.	70	145	156	-11	121
6.	71	175	163	12	144
7.	70	165	156	9	81
8.	73	195	177	18	324
9.	76	155	198	-43	1,849
10.	67	143	135	8	64
11.	76.5	155	201.5	-46.5	2,162.25
12.	76	192	198	-6	36
13.	69	149	149	0	0
14.	71	225	163	62	3,844
15.	56	132	128	4	16
16.	63	97	107	-10	100
17.	61	145	93	52	2,704
18.	61	108	93	15	225
19.	64	106	114	-8	64
20.	66.5	125	131.5	-6.5	42.25
21.	64.5	140	117.5	22.5	506.25
22.	69	120	149	-29	841
23.	68	130	142	-12	144
24.	61	105	93	12	144
25.	69	140	149	-9	81
26.	62	110	100	10	100
27.				Sum diff squared	14,757.25
28.				Sum diff squared/n	590.29
29.				Root mean squared error	24.295884425

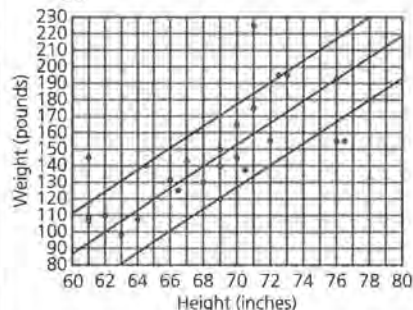
To find the mean absolute error, in cell E1 enter **Absolute Difference**, in E2 enter the formula, =abs(D2), in D27 enter **Sum abs diff**, and in D28 enter **Mean abs error**. You can delete the entries in D29 or in E29. The mean absolute error will appear in cell E28 when you use the same process you used to find the root mean squared error.

Discussion and Practice

1. Look at the preceding spreadsheet or the spreadsheet you generated.
 - a. What does the entry in cell C3 represent?

2. a. 24.296, or 24.3

b.



$$w = 170 + 7(h - 72)$$

$$w = -334 + 7h + 24$$

$$w = -334 + 7h - 24$$

c. The root mean squared error gives a range for each prediction. This means the predicted weight for a height of 70.5 inches would be 159.5 ± 24.3 or between 183.8 and 135.2.

3. a. Students should experiment to discover that changing different parts of the equation affects the error.

b. Students should experiment to find a small error. As students make discoveries, they should share them to help facilitate the process. Encourage students to think about what the changes are doing to their line: A change in the slope changes the steepness of the line, while a change in the point shifts the line vertically. It should take only a few guesses before students have found an equation that gives a small error.

c. The error gives the typical difference between the actual weight and the weight predicted by the line for a given height.

d. The smaller the error, the better prediction the line gives.

b. What does the entry in cell D9 represent?

c. Refer to the original scatter plot of the data in Lesson 7, Question 7, on page 78. What do the entries in columns C and D of the spreadsheet represent on the scatter plot?

2. Look at the spreadsheet on the previous page.

a. What is the root mean squared error for the equation $w = 170 + 7(h - 72)$?

b. Add the root mean squared error to $w = 170 + 7(h - 72)$. Then subtract the root mean squared error from the same equation. Use these two new equations to draw two lines on your scatter plot of the data (Activity Sheet 9).

c. What can the root mean squared error tell you about the predicted weight for a height of 70.5 inches?

When using a spreadsheet software, you can change the equation in your spreadsheet by entering a new slope and a new point into the equation in cell C2. Press **return**, then highlight C2 down to the last row in the C column in which you have data. Use the **Fill Down** command under **Edit** menu, and the recalculated results should appear on your spreadsheet. (Note: You may want to print your results each time to keep a record of your changes.)

3. Continue working with your spreadsheet.

a. Try a new equation in your spreadsheet to see how that affects the error.

b. Keep changing your equation to find as small a root mean squared error as you can.

c. What does the error you found in b tell you?

d. Why do you want as small an error as possible?

When using a TI-83 graphing calculator, press **STAT**, select **1:Edit**, press **ENTER**. Key in the heights in the **List 1** column and the weights in the **List 2** column. Press **Y=**, and at **Y1=**, key in $170+7(X-72)$ as shown on the calculator screens at the top of the next page.

STUDENT PAGE 92

L1	L2	L3
72.5	195	---
70.5	137	
72	156	
70	145	
71	175	
70	165	
73	195	

PLOT1	PLOT2	PLOT3
Y1=	170 + 7(x - 72)	
Y2 =		
Y3 =		
Y4 =		
Y5 =		
Y6 =		
Y7 =		

The equation stored in Y1= will use the heights in List 1 for the X-values to generate the predicted weights. You can store the predicted weights in List 3 by following these steps.

- Press STAT, 1, to return to the Lists. Move the cursor to the top of the List 3 column. Press ALPHA ".
- Press VARS, Y-VARS, 1:Function, 1:Y1 (2nd L1) ALPHA " ENTER.

L1	L2	L3
72.5	195	---
70.5	137	
72	156	
70	145	
71	175	
70	165	
73	195	

L1	L2	L3	*3
72.5	195	173.5	
70.5	137	159.5	
72	156	170	
70	145	156	
71	175	163	
70	165	156	
73	195	177	

The values in the List 3 column should be the weights predicted by using the equation stored in Y1=.

You can use List 4 in which to store the difference between each predicted weight and the actual weight by following these steps.

- Move the cursor to the top of the List 4 column. Press ENTER.
- At the bottom of the screen, at L4= (the location of the cursor) press ALPHA " 2nd L2 - 2nd L3 ALPHA " ENTER as shown on the following calculator screens.

STUDENT PAGE 93

L2	L3	L4
195	173.5	21.5
137	159.5	-22.5
156	170	-14
145	156	-11
175	163	12
165	156	9
195	177	18
L4 = "L2 - L3"		

To find the *absolute value* or the *squared difference*, define List 5 as either L5 = "abs L4" or L5 = "L4²" as shown on the following calculator screens. The absolute value of the differences are shown in the left screen. The squared differences are shown in the right screen.

L3	L4	L5
173.5	21.5	21.5
159.5	-22.5	22.5
170	-14	14
156	-11	11
163	12	12
156	9	9
177	18	18
L5 (1) = 21.5		

L3	L4	L5
173.5	21.5	462.25
159.5	-22.5	506.25
170	-14	196
156	-11	121
163	12	144
156	9	81
177	18	324
L5 (1) = 462.25		

To find the mean absolute difference, press 2nd, QUIT. Then press 2nd LIST MATH 3:mean. At mean (, the location of the cursor, press 2nd L5) (to specify the list you would like to use), and then press ENTER. The result will be the mean of the values in List 5 or the mean absolute difference as shown in the following calculator screens.

mean(L5)	18.54
----------	-------

STUDENT PAGE 94

4. **a.** The entry 156 is the predicted weight for the height of 70 inches in L1(4).
- b.** The entry 14 is the difference between the actual weight of 156 pounds and the predicted weight of 170 pounds for the person who is 72 inches tall.
- c.** The entries in L3 are the weights predicted by the line for the given heights. L4 represents the vertical distance from the data point to the line in each case, or the difference between the actual weight and the predicted weight for a given height.

If you choose to use the squared difference, press **2nd** $\sqrt{}$ **2nd** **LIST MATH**. Select **3:mean(**. Press **ENTER**. Press **2nd** **L5** **)** **ENTER**. The result will be the mean of the squared differences in List 5, or the root mean squared error as shown on the following calculator screens.

NAMES OPS	MATH
1: min(
2: max(
3: mean(
4: median(
5: sum(
6: prod(
7: stdDev(

mean(L5)	24.29588443
----------	-------------

4. Refer to the calculator screens shown below.
- a.** What does the entry in L3(4) represent?
- b.** What does the entry in L4(3) represent?

L3	L4	L5
173.5	21.5	21.5
159.5	22.5	22.5
170	-14	14
156	-11	11
163	12	12
156	9	9
177	18	18
L3(4) = 156		

L3	L4	L5
173.5	21.5	21.5
159.5	22.5	22.5
170	14	14
156	-11	11
163	12	12
156	9	9
177	18	18
L4(3) = -14		

- c.** Refer to the original scatter plot of the data, repeated on the next page. What do the entries in Lists L3 and L4 represent on the scatter plot?

STUDENT PAGE 95

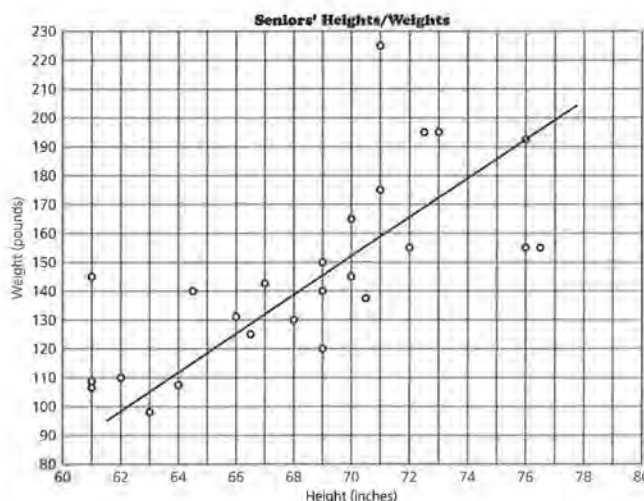
4. **d.** The root mean squared error is 24.3. This means that the weight would probably be within 24.3 pounds above or below the predicted weight. The predicted weight for a height of 70.5 inches is 159.5 pounds. Therefore the weight would probably be between 183.8 pounds and 135.2 pounds.

5. **a.** Students should experiment to discover that changing different parts of the equation affects the error.

b. Students should experiment to find a small error. Have students share their discoveries to help facilitate the process. Encourage students to think about what the changes do to their line: A change in the slope changes the steepness of the line, while a change in the point shifts the line vertically. It usually does not take many guesses before students have found an equation that gives a small error.

c. The error gives the average difference between the actual weight and the weight predicted by the line for a given height.

d. The smaller the error, the better prediction the line gives.



d. What is the root mean squared error for the equation $w = 170 + 7(h - 72)$? What does this tell you about your predicted weight for a height of 70.5 inches?

5. To find the error for a new equation, enter the new equation in Y1. Look at the graph. The new predicted values will be in L3. The difference between the observed and predicted values will be in L4. Press 2nd ENTER and ENTER again to replay the mean error.

- a.** Try a new equation, and see how that affects the error.
- b.** Keep changing your equation to find a smaller error.
- c.** What does the error you found in **b** tell you?
- d.** Why do you want the smallest error possible?

SUMMARY

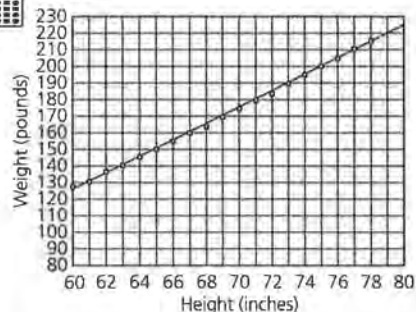
Spreadsheet software or a graphing calculator can be used to quickly find a measure of error for a prediction equation.

- Once you have the equation of the line, you can generate predicted y-values.
- The root mean squared error will give you an "average" interval above and below a predicted y-value.

Practice and Applications



6. a.



The pattern of the points appears close to linear; therefore a line is appropriate. Equations will vary slightly. One possible equation is $W = 145 + 5(H - 64)$. Encourage students to write the height in inches rather than in feet and inches.

b. For the equation given, the root mean squared error is 1.19. This means that typically you would expect a predicted weight for a given height to be within 1.19 of the actual weight, or the actual weight plus or minus 1.19 pounds.

- With spreadsheet software, you can change one of the values in the equation and fill down. The resulting new error appears automatically. This feature lets you easily experiment with different equations to find one that reduces the error.
- With a TI-83 graphing calculator, you have to change the equation in $Y1=$ each time and recalculate the error from the lists generated by that equation.

Practice and Applications

6. The following table shows the recommended weight for females and males as a function of height for ages 19 through 34.

Recommended Weight for Females and Males, Ages 19–34

Height (feet and inches)	Weight (pounds) Female	Weight (pounds) Male
5'0"	97	128
5'1"	101	132
5'2"	104	137
5'3"	107	141
5'4"	111	146
5'5"	114	150
5'6"	118	155
5'7"	121	160
5'8"	125	164
5'9"	129	169
5'10"	132	174
5'11"	136	179
6'0"	140	184
6'1"	144	189
6'2"	148	195
6'3"	152	200
6'4"	156	205
6'5"	160	211
6'6"	164	216

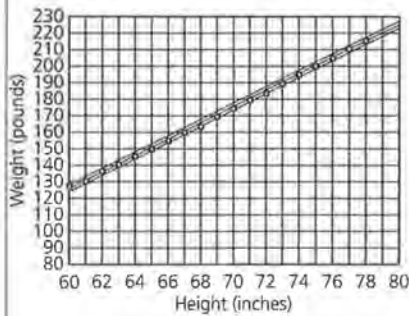
Source: data from *Nutrition and Your Health: Dietary Guidelines for Americans*

- a.** Plot the suggested weight for males as a function of height (*height, weight*), and determine whether a line would be appropriate to describe the relationship. If so, draw the line and find its equation.

STUDENT PAGE 97

- 6. c.** Using the equation $W = 145 + 5(H - 64)$, you would expect the guidelines to predict 105 pounds ± 1.19 , or between 103.81 pounds and 106.19 pounds.

d.



$$W = 145 + 5H - 320$$

$$W = -175 + 1.19 + 5H$$

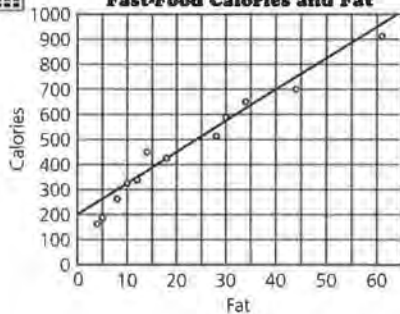
$$W = -175 - 1.19 + 5H$$

The first three points lie outside the band, which may be difficult for students graphing by hand. This indicates that these points are outside of the typical variation of the data from the line. Because the points are close together, it may indicate that a different line may be a better overall predictor.



7. a.

Fast-Food Calories and Fat



Equations will vary. One possible equation is $C = 400 + 12.5(F - 16)$.



- b.** Use spreadsheet software or a graphing calculator to find the root mean squared error for your equation. What does the root mean squared error indicate about any prediction you make using your equation?
- c.** If someone is 4 feet 8 inches tall, what suggested weight would you expect to appear in the *Dietary Guidelines*?
- d.** Add the root mean squared error to your equation, and graph the new equation on your scatter plot. Subtract the root mean squared error from the original equation, and graph that equation on your scatter plot. How many points lie outside this band? What does this indicate?
- 7.** What is the relationship between calories and the amount of fat in foods from fast-food restaurants? The following table shows the number of calories and grams of fat in food items offered at several fast-food restaurants.

Fast-Food Restaurant Items

Restaurant	Food Item	Fat (grams)	Calories
McDonald's	McLean Deluxe without cheese	10	320
	Quarter Pounder with cheese	28	510
	Chicken Salad	4.5	162
Burger King	BK Broiler (no sauce)	8	267
	Chunky Chicken Salad	5	172
	Whopper with cheese	44	706
Pizza Hut	Cheese pizza (two slices)	18	492
	Pan Supreme Pizza	30	589
Taco Bell	Bean Burrito (no cheese)	14	447
	Chicken Burrito (no cheese)	12	334
	Taco Salad (with shell)	61	905
	Nachos-Bell Grande	35	649

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- a.** Plot the calories as a function of the grams of fat (*fat, calories*), and draw a line that seems to represent the relationship. Find the equation of your line.
- b.** Find the y-intercept and zero of your line, and indicate how to interpret each in the context of fat and calories.
- c.** Use spreadsheet software or a graphing calculator to find the mean absolute error.

b. For $C = 400 + 12.5(F - 16)$, the y-intercept is 200. This means that if a fast-food item has 0 grams of fat, it would have 200 calories.

The zero is -16. This means that if a fast-food item has -16 grams of fat, it would have 0 calories—an impossible situation.

c. For the equation in **b**, the mean absolute error is 54.2.

STUDENT PAGE 98

- 7. d.** Students can compare their answers to **c** to find the “best” line.
- e.** Students should include information about the slope and intercepts and the accuracy of the line based on the error.
- 8.** Students’ descriptions should clearly state the steps used to determine the error and should use an example as an illustration, explaining how the steps apply to the specific example.

- d.** Compare your line with the lines of your classmates, and determine who has the *best* line.
- e.** Write a paragraph summarizing what your equation means and what the error indicates about using your equation to predict values.
- 8.** Describe how you can determine a measure of error for a prediction equation. Give an example, and explain how it works.

LESSON 9

Lines, Lines, and More Lines

Materials: graph paper, pencils or pens, rulers, *Activity Sheets 12–14, Lesson 9 Quiz*

Technology: graphing calculators (optional)

Pacing: 3 class periods

Overview

In this lesson, students learn to make a median fit line for a set of data as a standard process for finding a line that fits a set of data. Students discover that the median fit line is not sensitive to extreme values, or outliers. They also learn how to find the value that might have yielded a given outcome by solving an equation or reversing the process they use to find such an outcome. This lesson provides students with practice in finding a median fit line in a variety of contexts.

Teaching Notes

The initial example of finding a median fit line can be done as a demonstration for the entire class. Students can then find a median fit line of their own, using the head circumference/height data. You can use an overhead transparency of the data with a median fit line drawn on the scatter plot to check students' work. If the scatter plots are nearly the same size, students can place the transparency on their scatter plots to see how close their median fit lines are when compared with the line on the transparency. Be sure students use two points on the median fit line they have drawn, not two data points, to find the equation.

The median fit line will not necessarily produce the smallest error, using either the mean absolute error or root mean squared error. The procedure does not have characteristics that will minimize the differences. The procedure will, however, produce a line that is

not dependent on outliers and one that will give a relatively small error.

Students may have trouble solving the equation for an x -value given the y -value, or they may have enough experience from earlier work for this procedure to make sense. Provide students with several ways to think about their solutions, and stress the fact that they should be sure the numbers make sense in the context before they agree with the answer.

In practice, statisticians find an x -value for a given y -value by graphing ordered pairs in reverse order (y, x) and finding the line that seems to describe that relationship. In order to provide students with practice in solving equations and then thinking about their solutions, the questions are written using the (x, y) format. The alternate approach might be interesting to students and might reveal the emphasis that statisticians place on thinking about which variable they use as the response variable. Students may be surprised to discover that the median point in a region of (x, y) points will not necessarily be the same as the median point in the corresponding (y, x) region.

Students may not need to answer all of the questions in order to understand the concept of a median fit line. At this stage, students can safely use the median fit line as a standard procedure to find a relatively good line to summarize the data. The least squares linear regression line uses another procedure for finding the equation of a line that will fit the data according to a set of criteria. The least squares line is a function of the mean and is sensitive to outliers. As students learn about the least squares regression line,

they will learn what it represents and what characteristics it will possess in another module in this series.

Technology

Students should make their median fit lines by hand for at least the first two examples. After they understand the procedure, they might use the formula generated by their calculators. Encourage interested students to write a program to find the root mean squared error. Have them share their procedures with the class.

Follow-Up

Students may be familiar with some of the techniques for curve fitting that will occur in other classes. You might want to encourage them to find data in newspapers or in special-interest magazines and try to model the relationship by finding the median fit line. They might also use the data they collected in *Lesson 7* to find a median fit line as a way to summarize the relationship.

LESSON 9

Lines, Lines, and More Lines

Do you have to draw several lines and test each one for error?

How can you draw a fairly good line to begin with?

If you look at some of the possible lines summarizing the relationship of the data, how can you be sure that the lines are fairly similar?

There are many possible lines that can be used to describe a set of data. There are some common techniques that are used to draw different lines. One typical line for a set of data is called a *median fit line*. The technique used to draw the median fit line is based on ordering the data points and counting to find median points that represent the data in different sections of the scatter plot.

OBJECTIVES

Summarize data by drawing a median fit line. Solve a linear equation.

INVESTIGATE**Seniors' Heights and Weights**

Consider the seniors' height/weight data once more as reproduced on the following page.

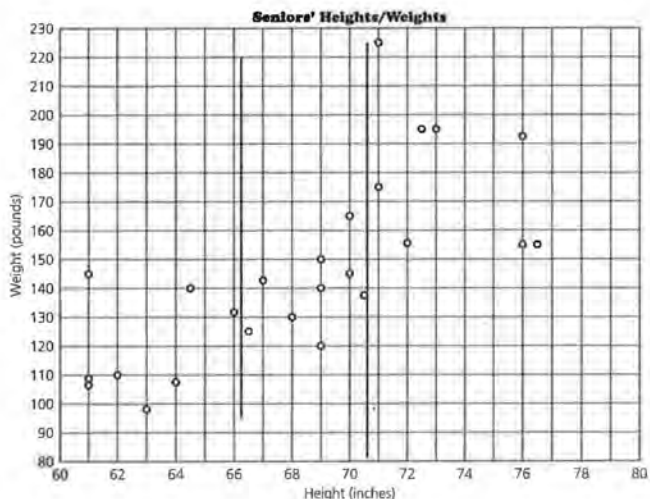
STUDENT PAGE 100

Seniors' Heights/Weights

Males' Height (inches)	Weight (pounds)	Females' Height (inches)	Weight (pounds)
72.5	195	66	132
70.5	137	63	97
72	156	61	145
70	145	61	108
71	175	64	106
70	165	66.5	125
73	195	64.5	140
76	155	69	120
67	143	68	130
76.5	155	61	105
76	192	69	140
69	149	62	110
71	225		

Recall that you only need two points to draw a line, but sometimes it is important to use a third point as a "checkpoint." To help you find these three points, draw vertical lines perpendicular to the horizontal axis separating the data points into three regions of the scatter plot. (The vertical lines you draw should not contain any data points.) Each of the three regions should contain, as nearly as possible, an equal number of points. In this example there are 25 points, as shown in the following scatter plot, and because $25 \div 3 = 8$ with a remainder of 1, put 8 points in the first region, 9 in the middle, and 8 in the third.

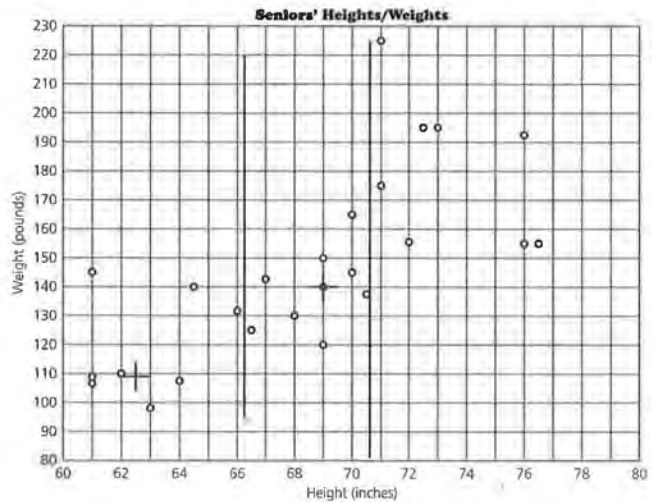
STUDENT PAGE 101



You can determine a representative, or median, point for each region by finding a median value for the height, the x -value, and a median value for the weight, the y -value.

One way to find these median points is to look at the scatter plot. For this example, in the first region (to the left), the median height will be halfway between the fourth and fifth horizontal coordinates, or at 62.5. (Notice that there are 4 points to the left of 62.5 and 4 points to the right of 62.5.) The median weight will be halfway between the fourth and fifth vertical coordinates, or at 109. (Notice that there are 4 points above 109 and 4 points below 109.) Thus, the median point for the first region has coordinates (62.5, 109), as shown in the next scatter plot. (Notice that in this example, for the first region, the median point is *not* one of the data points.)

STUDENT PAGE 102



Another way to find these median points is to make an ordered list of the coordinates of the points in each region and find the median x - and y -values as shown in the table below.

First Region (height, weight)	Heights (in order)	Weights (in order)
(61, 145)	61	97
(61, 108)	61	105
(61, 105)	61	106
(62, 110)	62	108
	Median = 62.5	Median = 109
(63, 97)	63	110
(64, 106)	64	132
(64.5, 140)	64.5	140
(66, 132)	66	145

In the second or middle region, the median height is an actual horizontal coordinate because there is an odd number (9) of horizontal coordinates for the points in this region. The fifth horizontal coordinate is at 69. (Having several points with horizontal coordinates of 69, does not change your result.) The fifth vertical coordinate is 140; therefore the coordinates of the

Solution Key

Discussion and Practice

- 1. a.** There are 9 points: (66.5, 125), (67, 143), (68, 130), (69, 120), (69, 140), (69, 149), (70, 165), (70, 145), (70.5, 137).

Ordered Heights	Ordered Weights
66.5	120
67	125
68	130
69	137
69	140 Median
69	143
70	145
70	149
70.5	165

- b.** There are 8 points: (71, 175), (72.5, 195), (72, 156), (73, 195), (76, 155), (76.5, 155), (76, 192), (71, 225).

Ordered Heights	Ordered Weights
71	155
71	155
72	156
72.5	175
72.75	183.5 Median
73	192
76	195
76	195
76.5	225

- c.** Mark off 9 points in the left and right regions and 8 points in the middle region.

representative or median point for the second region is (69, 140).

The median point for the third, or right, region is found in the same way as the point for the first, or left, region.

Discussion and Practice

- 1.** Refer to the table of *Seniors' Heights and Weights*.
- a.** Make an ordered list of the coordinates of the data points in the middle region, and verify that the median height is 69 inches and the median weight is 140 pounds.
 - b.** What are the coordinates of the median point in the right region?
 - c.** How would you separate the data points into three regions if there are 26 points altogether?

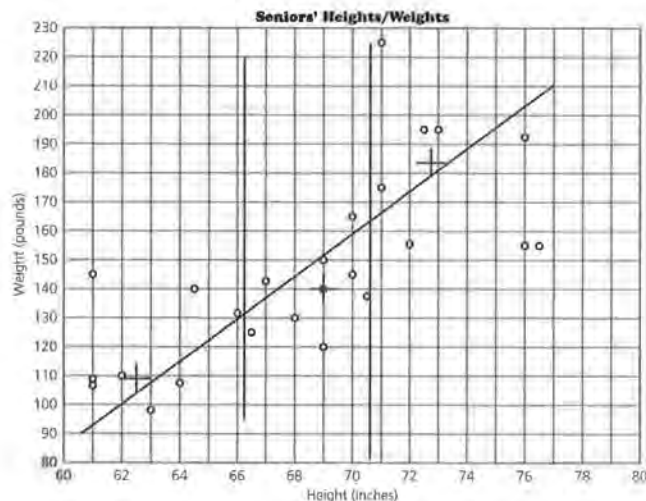
You can use the median points in the left and right regions of the scatter plot to determine the slope of the median fit line. Place your ruler on the two median points, and while keeping it parallel to the line between them, slide your ruler $\frac{1}{3}$ of the vertical distance toward the median point in the middle region. Now draw this line on your scatter plot, as shown on the next page. (Even though you are approximating $\frac{1}{3}$ of the distance, your line will still be fairly accurate.)

STUDENT PAGE 104

2. **a.** Student responses will vary. One equation might be $W = 180 + 7.6(H - 73)$.
- b.** The slope is 7.6; this means that for every additional inch in height there are 7.6 additional pounds.
- c.** The predicted weight is about 188 pounds.
- d.** The y -intercept is -375 . This means that a person who is 0 inches tall will weigh -375 pounds. This does not make sense. First of all, you cannot have a person 0 inches tall, and secondly, there cannot be a negative weight.



3. a. For the preceding equation, the mean absolute error is 19.5, and the root mean squared error is 25.6. These values might be less than those found earlier. The median fit line does not guarantee the smallest error; however, it does provide a procedure that you can use to find a line that will give a relatively small error and one that is not sensitive to outliers.



The line you have drawn is called a *median fit line*, or a *median-median line*, and can be used to summarize the relationship between the heights and weights of the 25 seniors. To find the equation of the median fit line, use any two points on the line.

2. Consider the preceding scatter plot.
- Find an equation for the median fit line shown in the preceding scatter plot.
 - What is the rate of change, or slope of the line, and what does it tell you?
 - Use the equation of your line to predict the weight of a person who is 74 inches (6 feet, 2 inches) tall.
 - What is the y -intercept of the line? What does the y -intercept mean in terms of the data? Does this make sense?

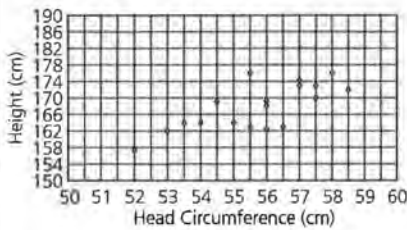


3. Refer to the median fit line of the preceding scatter plot.
- Earlier you found the root mean squared error or the mean absolute error for a line. Find either of these values for the median fit line. How does the error for the

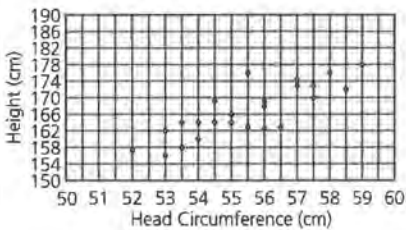
STUDENT PAGE 105

3. **b.** The predicted weight is about 142 pounds. If you use the mean absolute error, the prediction typically could be off by about 20 pounds, or range from 122 pounds to 162 pounds. If you use the root mean squared error, the prediction typically could be off by about 26 pounds, or range from 116 pounds to 168 pounds.
4. **a.** The points (54, 182), (56, 162.5), (56.5, 163), and (58.5, 153) appear to be outliers because they look as if they would be at a greater distance than any other data points from any line drawn to summarize the relationship. Students may include other points as well.

b. Students should answer on *Activity Sheet 12*.

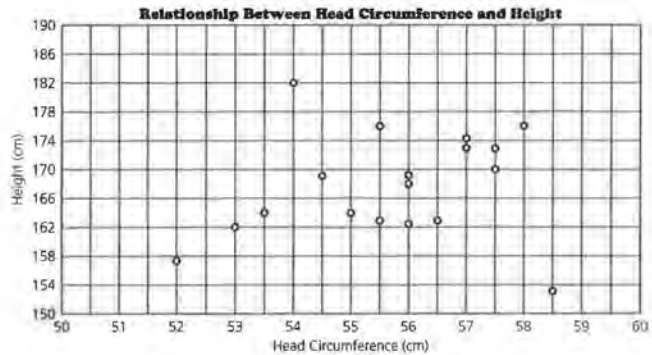


c. Students should answer on *Activity Sheet 12*.



median fit line compare with the error for the line you drew by eye at the beginning of Lesson 8.

- b.** Find the weight of a person who is 68 inches tall. What does the error indicate about your prediction?
4. Following is a scatter plot showing (in centimeters) both the circumference of the head and the height of some high-school freshmen.



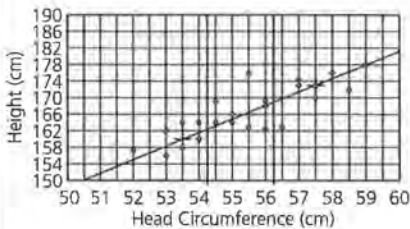
- a.** Identify any of the points that look as though they might be outliers. Why do you think these points might be outliers?
- b.** The class found that two of the class members had converted inches to centimeters incorrectly when they were measuring their height. The correct points should be (58.5, 172) and (54, 164). Using *Activity Sheet 12*, adjust the scatter plot accordingly.
- c.** The measurements for the rest of the class are shown in the table below. Add these points also to the scatter plot on *Activity Sheet 12*.

Freshmen's Head/Height Measurements

Head Circum. (centimeters)	Height (centimeters)	Head Circum. (centimeters)	Height (centimeters)
54	160	54.5	164
55	166	53	156
59	178	53.5	158.5

STUDENT PAGE 106

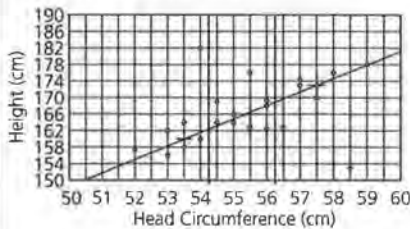
4. **d.** There are several data points that lie on the same vertical line because they have the same height. This makes it difficult to divide the scatter plot into three regions so the first and third regions have an equal number of points. Let students choose how they would like to make the division, but try to keep the number as close to the same as possible for all three regions. The example was done with 7/9/8 points in the respective regions.



One possible equation is $H = 158 + 3.25(C - 53)$ or $H = -14.25 + 3.25C$. The slope is 3.25. This means that for every additional centimeter in head circumference, you could expect 3.25 additional centimeters in height.

e. Using the equation in **d**, the height would be 166.125. Students might use the mean absolute error or the root mean squared error to give an interval for their predictions. This would give a band that on the average should contain the actual data points.

5. **a.** Students should answer on *Activity Sheet 13*.



- d.** Draw a median fit line on *Activity Sheet 12* to summarize the data in the corrected scatter plot. Write the equation of your median fit line. What is the slope, and what does it tell you in terms of the data?
- e.** Use your median fit line to predict the height of a person with a head measure of 55.5 centimeters. How confident are you about your prediction? Describe what adjustments you could make to improve your confidence in the accuracy of your prediction.
5. Look at the scatter plot in Question 4 showing the two incorrect data points. The scatter plot is also reproduced on *Activity Sheet 13*.
- a.** Plot the six extra points on this scatter plot and draw a median fit line. Write the equation for this median fit line. How does this equation compare with the one you found in Question 4d?
- b.** Comment on this statement: A median fit line will not be changed much by points that are outliers.
6. Is there any relationship between the size of a person's wrist and the size of that person's neck? A class of students measured their wrists and necks in centimeters as shown in the following table.

Wrist/Neck Measurements

Wrist (centimeters)	Neck (centimeters)	Wrist (centimeters)	Neck (centimeters)
15	30	17.5	33.5
15.7	31	15	33
14	34.5	16	35
15	34	14	32
15.5	31	17	40
18	35	16.5	39.5
15.3	31.5	17.5	37.5
14	34.5	15.3	33.8
19	40	18	42
14.5	35.5	21	42.5
16	36.5	20	39
18	38.5	14.5	36.5
15.5	33.5		

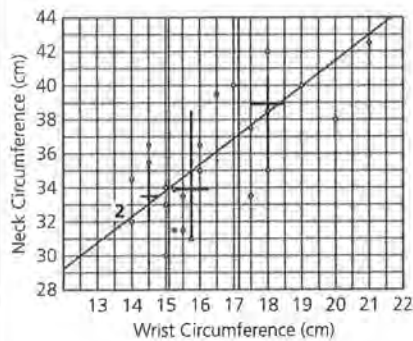
One possible equation is $H = 158 + 3.25(C - 53)$ or $H = -14.35 + 3.25C$. The equation should be close to the one found using corrected data.

b. Because median points are used, the median fit line does not significantly change when there are outliers in the data.

STUDENT PAGE 107

- 6. a.** Using centimeters will make many of the values whole numbers or decimals that are easily graphed. If you measure in inches, almost all measurements will cluster around the same few values.

b. Students should answer on *Activity Sheet 14*. This example was done with 8/9/8 points in the respective regions.



A possible equation is $N = 37 + 1.5(W - 17)$. The rate of change is 1.5; this means an increase in wrist size of 1 centimeter would predict an increase in neck size of 1.5 centimeters.

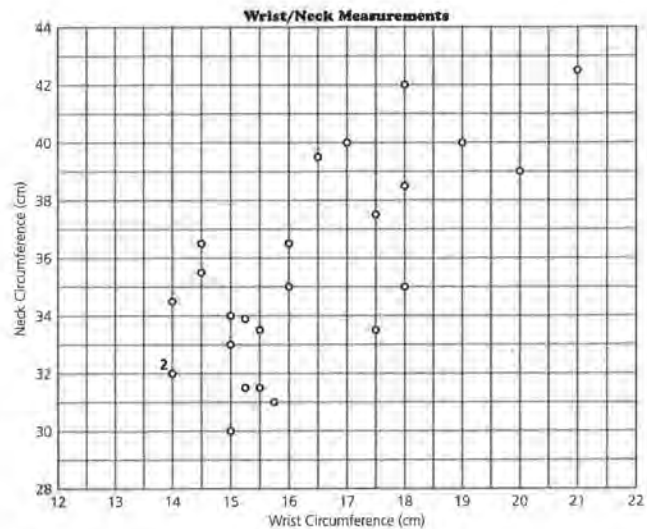
c. $N = 37 + 1.5(17 - 17)$

The neck size would be 37 centimeters.



d. For the equation given in **b**, the mean absolute error is 1.996 and the root mean squared error is 2.47. The line is within about 2 centimeters of the actual measurement. There is a considerable variability in the predictor, but it is fairly reliable.

- a.** Why do you think the measurements are in centimeters and not in a larger unit of measure?
- b.** The data are shown on the following scatter plot and also on *Activity Sheet 14*. Using the activity sheet, draw a median fit line on the scatter plot of the data. Write the equation of the median fit line. Describe the rate of change, and indicate what this tells you in the context of the data.



- c.** Predict the neck size of a person who has a 17-centimeter wrist measurement.
- d.** Find either the mean absolute error or root mean squared error for the median fit line you drew. What does this tell you about your prediction? How well do you think the line summarizes the data?

Sometimes you want to know what wrist size would predict a given neck size. To find out, you can use the graph of your line on the scatter plot, a table of values, or the equation of your line.

STUDENT PAGE 108

- 7.** Note that students are only asked to describe methods. Numerical values are provided for reference.
- a.** You could look at the table of values for a neck size close to 35. There are two of them, 16 and 18. From this you could estimate about 17 inches, but this is not based on the overall trend.
- b.** From the graph, locate 35 on the y -axis and move right to the line. Then go down to the scale on the x -axis to read the wrist size of about 16 inches.
- 8.** A wrist size of 17.2 centimeters would predict a neck size of 37 centimeters.

- 7.** Suppose the equation relating the wrist/neck data is $N = 33 + 1.5(W - 14.5)$. What wrist size would predict a neck size of 35 centimeters?

- a.** Explain how you can use a table of values to find the solution.
- b.** Explain how the graph will help you find the solution.

Suppose you use algebraic properties to find the wrist size that would predict a neck size of 35 centimeters. You can rewrite the equation in an equivalent form and solve.

If the predicted neck size is 35, let $N = 35$ in the following equation:

$$N = 33 + 1.5(W - 14.5)$$

$$35 = 33 + 1.5(W - 14.5)$$

Distribute 1.5 and combine like terms.

$$35 = 33 + 1.5(W - 14.5)$$

$$= 33 + 1.5W - 1.5(14.5)$$

$$= 33 + 1.5W - 21.75$$

$$= 11.25 + 1.5W$$

Since $35 = 11.25 + 1.5W$, you must find a quantity that when added to 11.25 is 35.

$$35 = 11.25 + ?$$

Thus 23.75 has to equal $1.5W$ because

$$23.75 = 11.5 + 23.75$$

$$\text{So: } 1.5W = 23.75$$

$$W = 23.75 \div 1.5$$

$$W = 15.83$$

Therefore, a person with a wrist size of about 16 centimeters would have a neck size of 35 centimeters.

- 8.** Using the equation in Question 7, what wrist size would predict a neck size of 37 centimeters?

SUMMARY

The median fit line for data points is one way to find a *good* line to represent the data.

Practice and Applications

9. a. Answers will depend on class data. The relationship should approximate the line $h = a$. The slope is 1; for each inch increase in height, arm span is 1 inch longer. Students enjoy thinking of those who fit the equation nearly exactly as being squares and like to identify students who are squares as opposed to those who are rectangles. You might ask students to identify the “squares” on their scatter plots. Be sure students measure arm span from the back of the person.

b. The arm span is about 63 inches.

10. a. $y = 172x - 32$
 $14 = 172x - 32$
 $46 = 172x$
 $x = 46/172$, or about 0.27

b. $y = 172x - 32$
 $y = 172(22) - 32$
 $y = 3784 - 32$
 $y = 3752$

c. $y = 172x - 32$
 $0 = 172x - 32$
 $32 = 172x$
 $x = 32/172$ or about 0.19

d. $y = 172x - 32$
 $y = 172(0) - 32$
 $y = -32$

11. a. $15 = 4 + 3(x - 8)$
 $15 = 4 + 3x - 24$
 $15 = -20 + 3x$
 $3x = 35$
 $x = 35/3$, or about 11.67

b. $8 = 14 + ^{-}3(x - 2)$
 $8 = 14 - 3x + 6$
 $8 = 20 - 3x$
 $3x = 12$
 $x = 4$

- You can find the median fit line by separating the data points into three regions and finding the median point that represents the data points in each region.
- The median fit line is not sensitive to outliers because the median of a data set is not affected by extreme values.
- The median fit line can be used to predict y from x , to interpolate or read between the known data points, to extrapolate or read beyond the known data points (recognizing the assumptions made in using the value), or to act as a summary equation for the data.
- You can predict outcomes by using the graph of the median fit line, by inspecting sets of ordered pairs generated by the equation of the median fit line, or by substituting a known value into the equation and solving for the unknown value.

Practice and Applications

- 9.** Measure the arm span (in inches) and the height of each member of your class. (Arm span is the distance from the fingertip of your left hand to the fingertip of your right hand when your arms are outstretched parallel to the floor.)
- Plot the data (*height, arm span*), and draw a line. Find an equation to describe the relationship.
 - Use your equation to predict the arm span of someone who is 63 inches tall.

10. Suppose $y = 172x - 32$. Find each of the following.

- x , when y is 14
- y , when x is 22
- x , when y is 0
- y , when x is 0

11. Find the value for x in each equation.

- $15 = 4 + 3(x - 8)$
- $8 = 14 + ^{-}3(x - 2)$
- $750 = 182 + 7x$
- $330 = ^{-}120 - 7x$

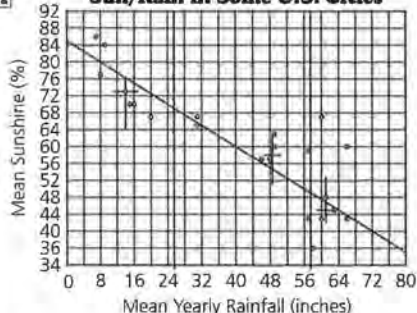
c. $750 = 182 + 7x$
 $568 = 7x$
 $x = 81.14\dots$, or about 81.14

d. $330 = ^{-}120 - 7x$
 $450 = ^{-}7x$
 $x = ^{-}64.2857\dots$, or about $^{-}64.29$



12. a.

Sun/Rain in Some U.S. Cities



One possible equation is $S = 60 - 0.6(R - 40)$. This example was done with 7/8/7 points in the respective regions.

- b.** The slope indicates that for a 0.6% decrease in the mean amount of sunshine, you would expect a 1-inch increase in the mean amount of rainfall per year. The y -intercept, 84%, predicts the percentage of sunshine that can be expected in a place with no rainfall. The zero, 140 inches, is the mean amount of rainfall in a year expected in a place with no sunshine.
- c.** For 75% sunshine, you would predict about 15 inches of rainfall.
- d.** The line appears to be rather good for the cities with less than 50 inches of rainfall because all of the points are close to the line. The places with more than 50 inches of rainfall are more scattered, and the line does not fit as well.

Students can compute the root mean squared error or mean absolute error for a measure of the fit.



12. The following table shows the mean rainfall per year and the mean percent of sunshine in selected cities around the United States.

Sun/Rain in U. S. Cities

City	Mean Rainfall (inches)	Mean % Sun	City	Mean Rainfall (inches)	Mean % Sun
Los Angeles, CA	14	73	New Orleans, LA	57	59
Salt Lake City, UT	15	70	Nashville, TN	46	57
Phoenix, AZ	7	86	Jackson, MS	49	60
Las Vegas, NV	9	84	Mobile, AL	60	67
San Francisco, CA	20	67	Atlanta, GA	61	48
Denver, CO	16	70	Charlotte, NC	66	43
Wichita, KS	31	65	Raleigh, NC	60	43
Oklahoma City, OK	31	67	Miami, FL	66	60
Albuquerque, NM	8	77	St. Louis, MO	58	36
Houston, TX	48	57	Louisville, KY	57	43
Little Rock, AR	49	63	Norfolk, VA	63	45

Source: data from *The Greening of America*, 1970

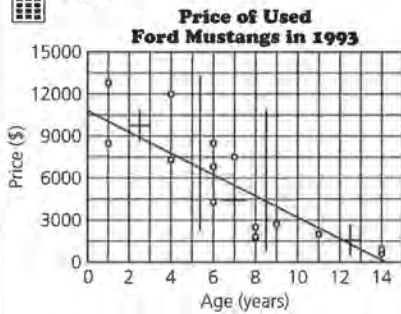
- a.** Plot (*rainfall, sunshine*) and find the median fit line. Write its equation.
- b.** What do the slope, y -intercept, and zero represent in terms of the data?
- c.** What amount of rain would you expect for an average of 75% sunshine?
- d.** How well do you think the line represents the data? Explain your answer.



13. For the following sets of data, plot the points and find a median fit line for each. Write a paragraph, describing the relationship between the variables for each set of data. Include in your paragraph a discussion of the slope, y -intercept, and zero of the median fit line.

STUDENT PAGE 111

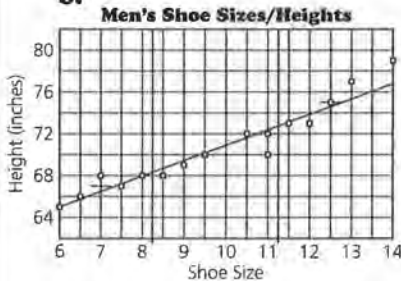
13. a.



One possible equation is $P = 10,500 - 807(A - 1)$.

The slope is about -807° , the y -intercept is about 11,307, and the zero is about 14. Student discussion should include interpretation of the slope (the price falls \$807 every year); the y -intercept (a new Mustang costs \$11,307); and the zero (a 14-year-old Mustang has no value). Students might also find a measure of error to determine how well the line seems to fit the data. The mean absolute error is \$5311, and the root mean squared error is \$6582. The points that are quite far from the line cause the root mean squared error to be somewhat larger.

b.



One possible equation is $y = 75 + 1.5(x - 13.5)$. This example was done with 5/6/5 points in the respective regions.

The slope is about 1.5, the y -intercept is about 55.75, the zero is about -37.17 . Student discussion should include interpretation of the slope (with an increase of one shoe size there will be an increase in

a. The prices of used Ford Mustangs are shown in the following table.

Prices of Used Ford Mustangs from Classified Ads in 1993

Year	Age	Price
1980	14	\$900
1980	14	575
1983	11	1,950
1985	9	2,695
1986	8	1,795
1986	8	1,695
1986	8	2,500
1987	7	7,495
1988	6	4,300
1988	6	6,800
1988	6	8,495
1990	4	7,295
1990	4	11,995
1993	1	8,493
1994	1	12,799

b. The following table, which has been used by the Federal Bureau of Investigation in shoe print studies, shows the heights and the shoe sizes of males.

Male Height and Shoe Size

Height (inches)	Shoe Size	Height (inches)	Shoe Size
65	6	70	11
66	6.5	72	11
68	7	72	10.5
67	7.5	73	11.5
68	8	73	12
68	8.5	75	12.5
69	9	77	13
70	9.5	79	14

Source: Footwear Impression Evidence, 1990.



14. Collect a data set with at least 15 pairs of data that you think may have a linear relationship, and then plot the data. Using what you learned in this unit, answer each of the following questions.

a. Draw a line to summarize the relationship, and explain how it can be used to predict values.

height of 1.5 inches); the y -intercept (a person with shoe size 0 is 55.75 inches tall); and the zero (a person 0 inches tall would wear shoe size -37). Note that the zero and y -intercept do not have real meaning in this context. Students might find a measure of error to determine how well the line seems to fit the data.

The root mean squared error is 1.06, while the mean absolute error is 0.73. On the average, an

estimated height based on shoe size will have an error of about 1 inch.

STUDENT PAGE 112



14. These answers will depend on the data students collect.

- b.** Do you think your hypothesis about a linear relationship is correct? Why or why not?
- c.** How reliable do you think a prediction based on your line will be? Explain your answer.
- d.** Find an equation for the line you drew. Write two questions that could be answered by using your equation.

LESSON 10

A Measure of Association

Materials: graph paper, pencils or pens, rulers, *Activity Sheets 15–16*

Technology: graphing calculators (optional)

Pacing: 2 class periods

Overview

This lesson introduces finding a measure of correlation between two sets of data by using a simplified method to approximate the correlation coefficient. It is important for students to recognize that this number is a measure of the strength of the relationship between two variables and not a measure of how good a linear model is for the data. Students explore positive, negative, and zero correlation in a variety of contexts. They also investigate situations where correlation might be confused with cause and effect in order to understand the relationships within a situation.

Teaching Notes

The activities are intended merely to give students some understanding of correlation using a method of approximation. Students should not formalize the concept of correlation at this stage but keep the concept at an intuitive level. Some students may confuse correlation with slope, but remind them that slope can be of any magnitude while the correlation coefficient is from -1 to 1 . A data set that is not linear can have a very high correlation while a data set that has another pattern, for example, a quadratic curve, can have zero correlation. The first step in thinking about correlation is to inspect a scatter plot of the data to determine whether it is even reasonable to fit a straight line. Correlation can indicate which of two data sets seems to have the stronger measure of association between the two variables; it can help quantify

the strength of that association. Correlation does not justify that a line you drew is the line of “best” fit. For further information about correlation, see *Exploring Least Squares Regression*, another module in the *Data-Driven Mathematics* series.

Correlation is easily misinterpreted. Negative correlation is often treated the same as zero correlation. For both negative and positive correlation, there is a definite pattern: For negative correlation, as one variable increases, the other decreases; and for positive correlation, as one variable increases, the other increases also. Zero correlation indicates that there is no pattern: Some small values are paired with large values, and some small values are paired with small values.

Correlation is also often confused with cause and effect. When two variables are correlated, the relationship can be due to some other factor: one of the variables might cause the other variable, or the relationship between the two could be coincidental. A classic case of the cause-and-effect confusion occurred many years ago: The relationship between the number of storks and the number of newborn babies in Sweden showed a high correlation. Therefore, it was thought that storks caused an increase in the number of babies. However, in fact, as more babies were born and the population increased, more houses were built and therefore more chimneys were present—and storks lived in chimneys. The media often report a causal relationship at schools (high rates of violence correlate with increased stress) when, in fact, both variables are connected by another factor such as an increase in population.

Technology

Students can make the scatter plots using technology but should do the counting by hand to estimate the correlation coefficient.

Follow-Up

Students might check newspapers and magazine articles for instances in which correlation is used. Often the term *association* is used or it is said that one factor causes another. Ask students to think about other factors that might be involved in such cases.

LESSON 10

A Measure of Association

*"Grades are correlated with homework!" "The use of Vitamin E is correlated with a decrease in strokes."
"There is a correlation between exercise and human longevity."*

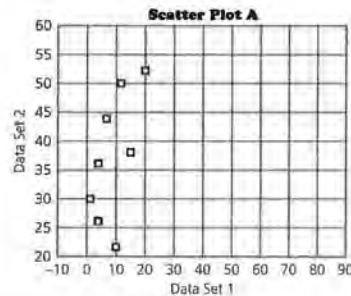
What do these statements mean?

What does it mean when two variables are correlated?

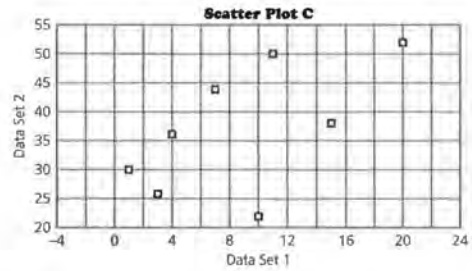
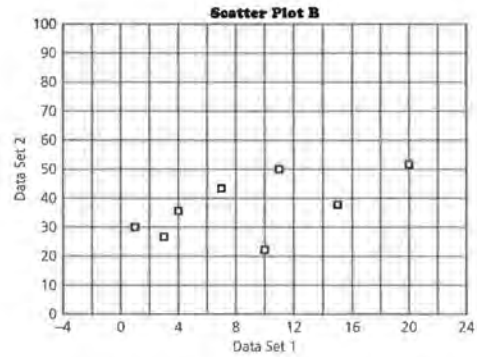
The scales on the axes can distort your perception of the pattern in a scatter plot. Scatter Plots A, B, and C show the same data graphed on grids with different scales. Which of the scatter plots looks most linear? Although it is important to look at the scatter plot to see if the data seem linear, a numerical measure can help you make a judgment about the relationship between the variables that is not dependent on the scales used in the scatter plot.

OBJECTIVES

Determine the strength of a linear relationship by finding a measure of correlation. Understand the connection between correlation and cause/effect.



STUDENT PAGE 114



Correlation measures the strength of a linear relationship. If the data points form a pattern that looks very much like a straight line, the correlation is called *strong*. If the data points are scattered or form a circle or large oval, the correlation is called *weak*.

What is the strength of the association or correlation between height and weight? Should you use a line to predict the weight of a person if given a height?

INVESTIGATE

Correlation Between Height and Weight

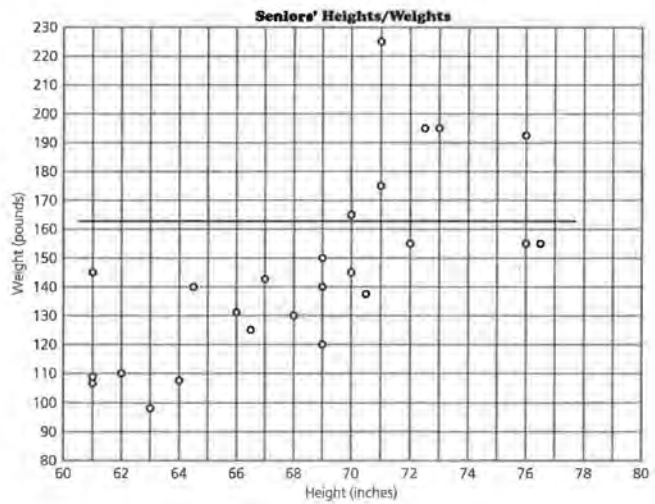
In Lesson 9, you fit a line to the data by separating a scatter plot into three regions. To estimate the value of the correlation coefficient, you also begin by separating the scatter plot into

STUDENT PAGE 115

regions. This time, however, you will separate the scatter plot into nine regions, like a tick-tack-toe grid.

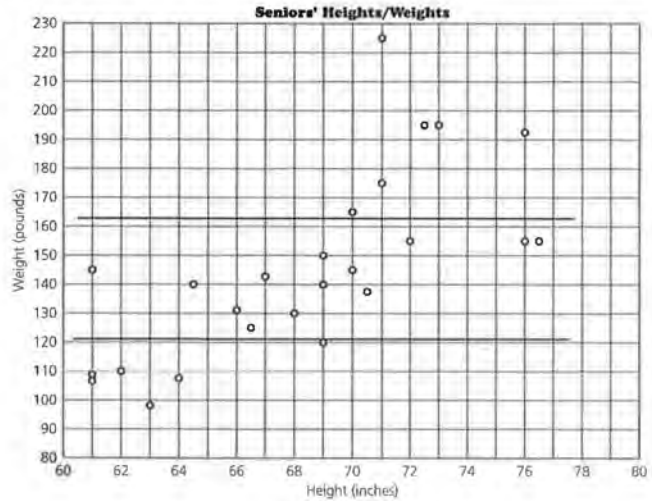
First, count the number of data points (N) and divide N by 4 (because you are interested in the 4 corner regions). Recall that there were 25 people in the (*height, weight*) scatter plot, so in this example, $25 \div 4 = 6.25$. Disregard the decimal part (0.25) of the number and use the integer part, called I . In this example $I = 6$. (This function I is called the *greatest integer function* and can be written as $[6.25] = 6$.)

Count 6 or fewer points from the top of the scatter plot and draw a horizontal line as shown here. (If there are "ties," or two points with the same y -coordinate, count fewer than the value of I .)



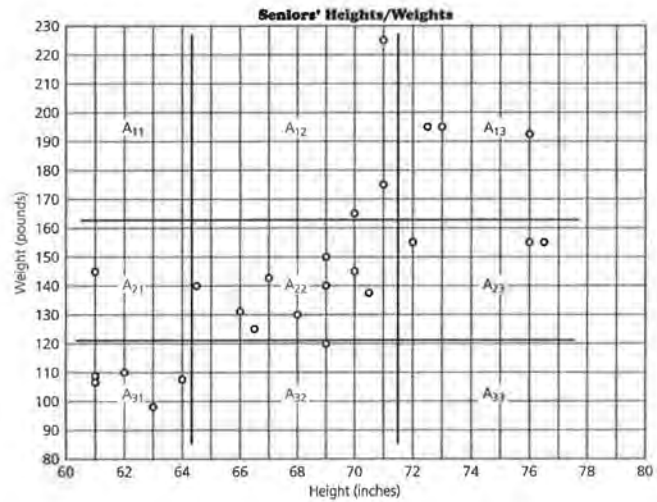
STUDENT PAGE 116

Now count 6 or fewer points from the bottom of the scatter plot and draw another horizontal line as shown in the following scatter plot.



Count 6 or fewer points from the left and 6 or fewer points from the right, and draw two vertical lines. Any line you draw should not pass through a data point. Now you have a tick-tack-toe grid on your scatter plot as shown on the next page.

STUDENT PAGE 117



You can label cells in your tick-tack-toe grid, or entries in your matrix, by indicating the positions using rows and columns. (Rows go across and columns go up and down.) Cell A_{21} on your scatter plot indicates the second row and the first column on the grid. In the matrix, your entry for A_{21} is 1 because there is one data point in the A_{21} cell.

A_{11}	A_{12}	A_{13}	For your example,	0	3	3
A_{21}	A_{22}	A_{23}	the number of points	1	9	3
A_{31}	A_{32}	A_{33}	in each cell is	5	1	0

Note that A_{11} is 0 because there are no data points in the A_{11} cell of your tick-tack-toe grid.

r is used to represent the correlation. To estimate the correlation r , use this formula:

$$r = \frac{(A_{13} + A_{31}) - (A_{11} + A_{33})}{21}$$

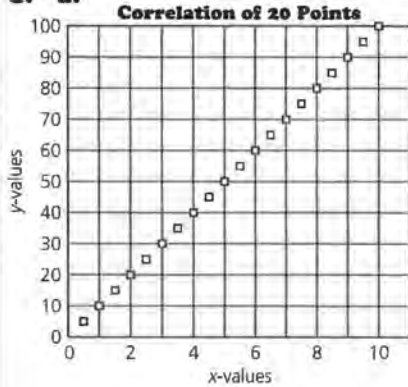
$$\text{So, } r = \frac{8 - 0}{2(6)} \\ = 8 \div 12 = 0.6\dots, \text{ or about } 0.67$$

Suppose you have to interpret a correlation of 0.67. You might first think about some extreme cases.

Solution Key

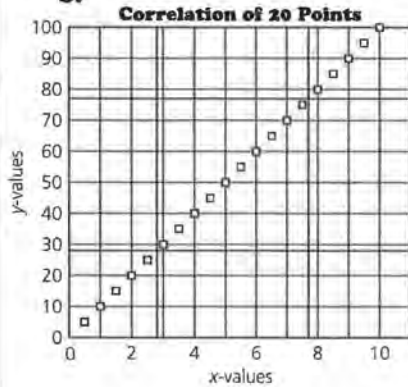
Discussion and Practice

1. a.



In this example, $I = 5$.

b.



$A_{13} = A_{31} = 5$

$A_{11} = A_{33} = 0$

c. $r = [(5 + 5) - (0 + 0)] \div 10 = 1$

d. No, the calculation would be $r = [(8 + 8) - (0 + 0)] \div 16 = 1$.

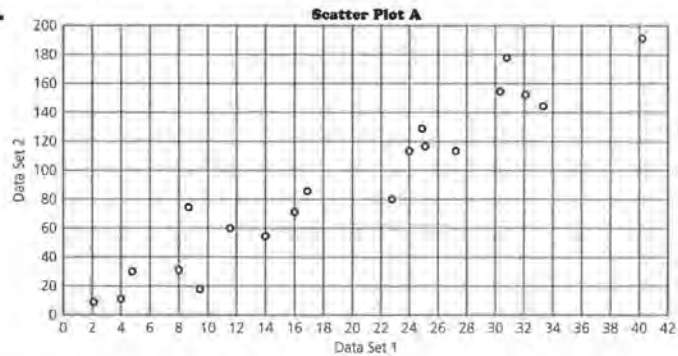
- 2. a.** True. It is clear that if the points are in a line with a positive slope, all the points will be in A_{31} , A_{22} , and A_{13} . This means the numerator will be $A_{31} + A_{13} - 0$ which will be $2I$ or 2 times the number of points in the corners. Thus r will be 1.

b. True, the argument is the same as in **a**.

Discussion and Practice

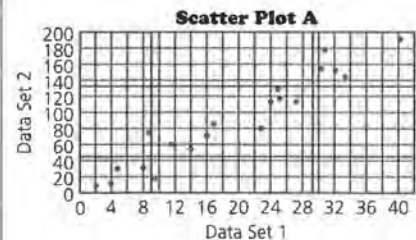
- Suppose you are given 20 points that form a straight line with a positive slope.
 - Make a sketch of what the scatter plot might look like. What is I ?
 - How many points will lie in A_{13} ? In A_{11} ? In A_{31} ? In A_{33} ?
 - Find r .
 - Will r change if you are given 32 points to determine the line instead of 20?
- Jo-Jo plotted points for three straight lines and found the correlation for each. The conclusions he drew are shown here. Decide whether or not he was correct in each case, and explain why you agree or disagree with him.
 - If the points are in a straight line with a positive slope, then $r = 1.00$.
 - If there are no points in cells A_{11} and A_{33} , then $r = 1.00$.
 - If the points are in a straight line with a negative slope, then $r = -1.00$.
 - If the total number of points in A_{11} and A_{33} is the same as the total number of points in A_{13} and A_{31} , the correlation is 0.1.
- Estimate the correlation for each of the following two scatter plots. Use *Activity Sheet 15* for your work.

a.

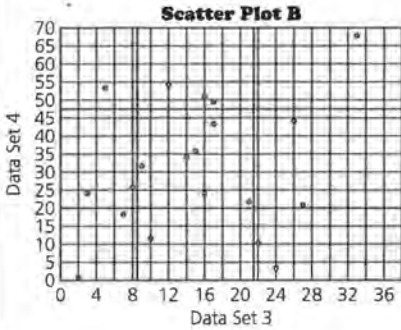


- c.** True, because when $A_{11} + A_{33}$ is subtracted from 0, the numerator is negative. The rest is similar to **a**.
- d.** No, in this case r will be 0 because $0 - 0 = 0 \div 2I$, or 0.
- 3.** Students should answer on *Activity Sheet 15*.

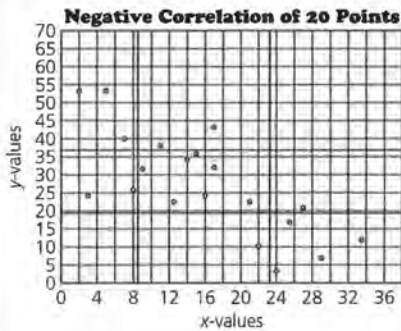
a. Scatter plot A: $r = [(5 + 4) - (0 + 0)] \div 10 = 0.9$



3. b. Scatter plot B: $r = [(1 + 2) - (1 + 2)] \div 10 = 0$

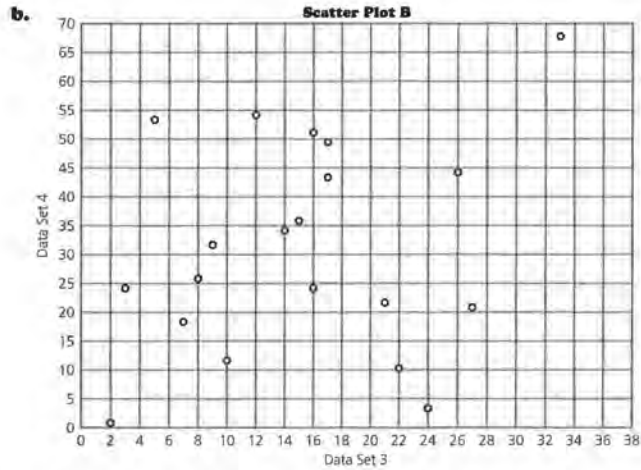


4. a. For a set of points with a negative correlation, the line of fit would have a negative slope. There would be more total points in cells A_{11} and A_{33} than in A_{13} and A_{31} .
- b. The following is one possible set. Students should understand that data with a negative value of r will tend to go from upper left to lower right.



$$r = [(0 + 0) - (3 + 4)] \div 10 = -0.7$$

- c. A set of data with a negative correlation falls from left to right. A set of data with a positive correlation rises from left to right.



4. Consider a set of points with a negative correlation.
- If a set of points has a negative correlation, describe a possible line of fit for those points. How would a negative correlation affect the numbers in the cells of the matrix?
 - Give a set of points with a negative correlation and estimate r .
 - Describe the difference between positive correlation and negative correlation.
- A correlation close to 1 indicates a strong positive relationship between the variables. The data points show a pattern close to a straight line with a positive slope.
 - A correlation close to -1 indicates a strong negative relationship between the variables. The data points show a pattern close to a straight line with a negative slope.
 - If the correlation is close to 0, there is no relationship between the variables. The data points show a circular pattern or a pattern that is not linear.

STUDENT PAGE 120

5. a. The following table contains all of the whole-number possibilities for the rectangle. Students may use rational numbers also.

Length	Width	Area
1	24	24
2	23	46
3	22	66
4	21	84
5	20	100
6	19	114
7	18	126
8	17	136
9	16	144
10	15	150
11	14	154
12	13	156
13	12	156
14	11	154
15	10	150
16	9	144
17	8	136
18	7	126
19	6	114
20	5	100
21	4	84
22	3	66
23	2	46
24	1	24

b. $P = 2(5 + 20) = 50$, thus the perimeter is 50 as required.



- 5.** Refer to the table below.
- Find at least 18 sets of possible values for the length, width, and area of a rectangle with a perimeter of 50 feet. Then add your values to the table started below.

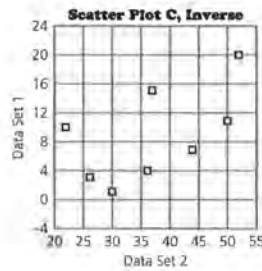
Rectangle with P = 50 feet

Length (feet)	Width (feet)	Area (square feet)
5	20	100

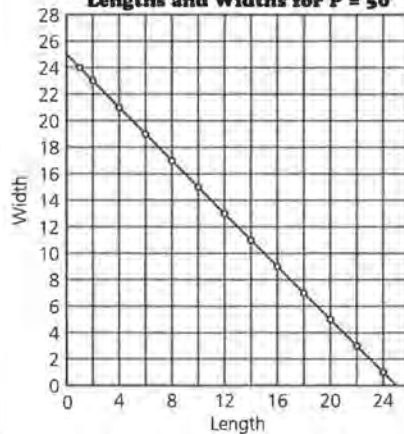
- Explain why 5 and 20 are possible values.
- Plot each of the following sets of ordered pairs: (*length*, *width*) and (*length*, *area*). Then estimate the correlation. If the data appear linear with a correlation close to 1, draw a line that fits the data and write its equation.
- What conclusion can you make about correlation based on your findings in c?



- 6.** Refer to the scatter plots at the beginning of this lesson. The approximate correlation for Scatter Plot A is 0.25.
- What do you think the correlation will be for Scatter Plots B and C? Explain your answer.
 - The following scatter plot is the *inverse* of Scatter Plot C. The inverse is formed by reversing the *x*- and *y*-values in each of the ordered pairs so that (10, 22), for example, has been plotted (22, 10). What is the estimated correlation coefficient for the data in this inverse scatter plot?



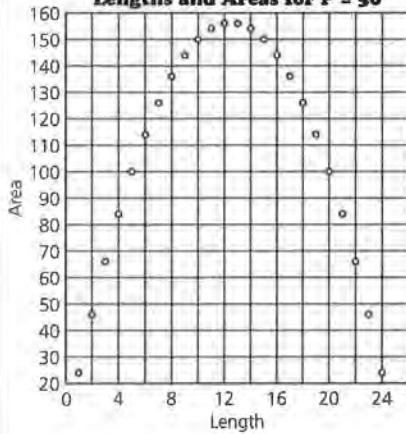
C. Lengths and Widths for P = 50



The correlation is -1 ; the equation is $W = 25 - L$.

5. c.

Lengths and Areas for P = 50



The correlation is close to 0 for the scatter plot shown.

d. If the data are close to linear, the correlation is close to 1 (or -1). If the data are less linear, the correlation is close to 0. You can have 0 correlation even if there is a clear pattern in the data as long as the pattern is not linear.

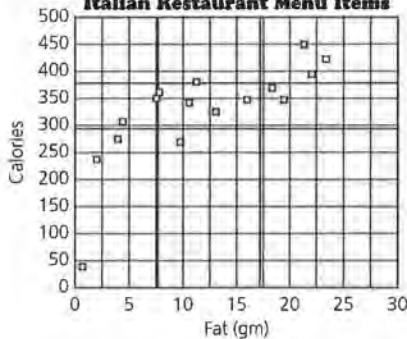


6. a. The correlation in scatter plots B and C is about 0.5. The scatter plots are the same, but just rescaled.

b. The correlation coefficient is the same, 0.5.

7. Students should answer on Activity Sheet 16.

Italian Restaurant Menu Items



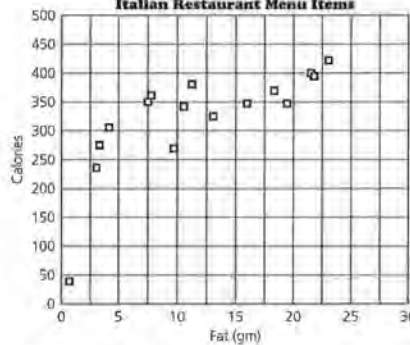
$r = [(3 + 3) - 0] \div 8 = 3 \div 4$. The correlation is about 0.75.

7. The following table shows the grams of fat and the number of calories for several entrees at an Italian restaurant. These data points are graphed on the scatter plot that follows the table.

That's Amorò Restaurant

Menu Item	Fat (grams)	Calories	Menu Item	Fat (grams)	Calories
Linguini Primavera	2.9	235	Chicken Piccata	16.1	348
Linguini with Scallops	3.1	276	Italian Frittata	23	424
Linguini with Shrimp	4.1	304	Sicilian Pork	11.2	379
Classic BLT	19.6	347	Florentine Chicken	7.9	362
TLT (Turkey)	13.1	328	Veal Piccata	21.9	394
Chicken Primavera	7.5	350	Sweet and Sour Chicken	10.4	341
Eggplant Parmigiana	9.7	269	Veal Parmigiana	21	450
Poached Roughy	18.4	370	Breadsticks	0.6	40

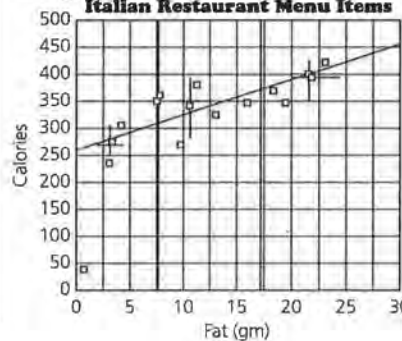
Italian Restaurant Menu Items



- Estimate the correlation.
- Describe the relationship between the grams of fat and the number of calories in the menu items shown in the scatter plot.
- Find the median fit line and write the equation. What does the slope of the median fit line indicate about the data?
- If you know the correlation coefficient, what can you say about the slope of the line for the data?

b. In general, the more fat in the food, the higher the calories in the food.

Italian Restaurant Menu Items



One possible equation is $C = 325 + 6.67(F - 10)$. The slope of 6.67 means that for every additional gram of fat, the number of calories tends to increase by about 7.

STUDENT PAGE 122

7. **d.** The slope of a line and the correlation coefficient can be the same only if all of the data are in a line and the slope of that line is either 1 or -1 . Otherwise, the slope and the correlation coefficient will have the same sign, but no other connection.
8. **a.** The association has to do with age. Young people have small feet and can read little if any, but then children grow, go to school, and learn to read. Once they reach a certain age, their reading ability and shoe size should not be related at all, but since the relationship is strong in the early years, there is a correlation.
- b.** This is close to true. Students who do homework spend more time on school work and learn by doing their homework. These factors contribute to their doing well in school. It is not clear whether just doing homework without thinking would improve school performance.
- c.** The statement that the more education you have, the better job you can get and the more money you can make, appears to be true. In this case, there seems to be a direct correlation.
- d.** This is most likely because the players who make a lot of points play longer than other players and are more likely to be aggressive players. For this reason, these players also make more fouls. However, it is possible to make a lot of points and not make a lot of fouls. Both could be a function of the time played.

Correlation is often confused with *cause and effect*. A strong correlation between two variables does not necessarily mean that in the relationship one variable caused the other one to change. The changes in the variables could have been caused by some other factor or the correlation could be coincidence.

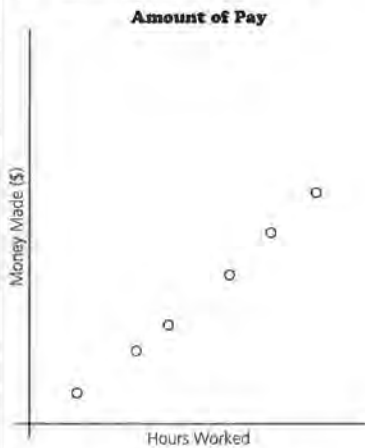
8. There is a strong correlation in each of the following. Discuss what you think might cause the association, and discuss whether the statement in **c** makes sense. Is there a third factor in statements **c** and **d** that could have caused both variables to change?
- a.** Small children have small feet and cannot read well. As they grow older, the size of their feet and their reading abilities increase, so there is a strong correlation between foot size and reading ability. Therefore, big feet cause people to read well.
- b.** Students who do homework learn what they are supposed to learn for a class. There is a strong correlation between the amount of homework students do and the grades they get in a class. Therefore, doing homework causes students to get good grades.
- c.** *"Get a good education and you'll get a good job. . . . a CNI study of U.S. Census data suggests that there is a direct correlation between education and income levels. The suburbs with the wealthiest population and the highest property values are also the ones with the highest percentage of college graduates . . . the community that has the most adults without a high school diploma is West Milwaukee . . . ranks dead last in median household income and median home value."*
Source: *Mi City Hub*, October 21, 1993.
 Does having an education cause you to have a higher income?
- d.** In a certain game, there was a high positive correlation between the number of field goals basketball players made and the number of fouls they made. Therefore, if you would like to make a lot of points, you should make a lot of fouls.

SUMMARY

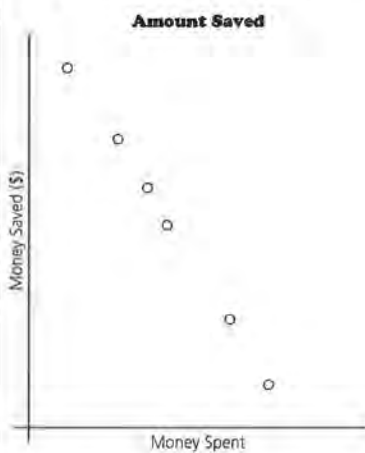
Correlation is a measure of the strength of the linear association between two variables.

Practice and Applications

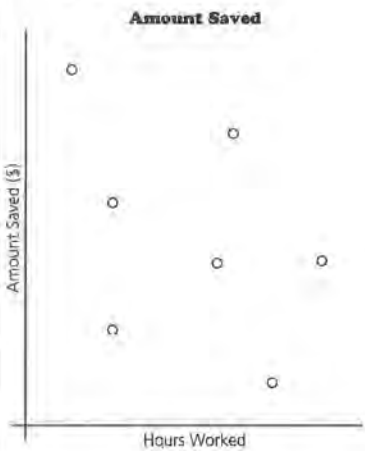
9. a. positive correlation



b. negative correlation



c. zero correlation

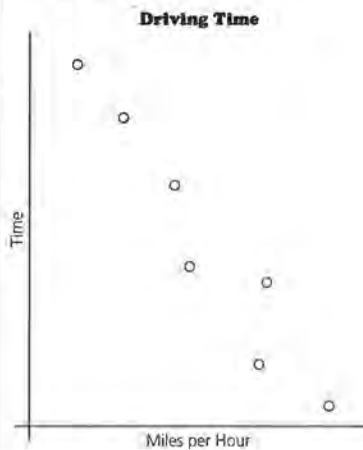


- Correlation is always between 1 and -1: $-1 \leq r \leq 1$.
- If the pattern in a scatter plot is close to a straight line, the correlation will be *strong*, and the absolute value of r will be close to 1.
- If the pattern in a scatter plot is scattered and not a straight line, or if the pattern is not linear, the correlation is *weak* and the value of r is close to 0.
- The scales used in a scatter plot do not affect the correlation.
- Correlation is only a measure of linear association. It will not tell you about any other relationship that may exist between the variables.
- For a perfect positive correlation of 1 or a perfect negative correlation of -1, if you know one variable, you can exactly predict the value of the other.
- A strong correlation between two variables does not necessarily indicate that there is a cause-and-effect relationship between the variables. There are often other variables that are involved in the association.

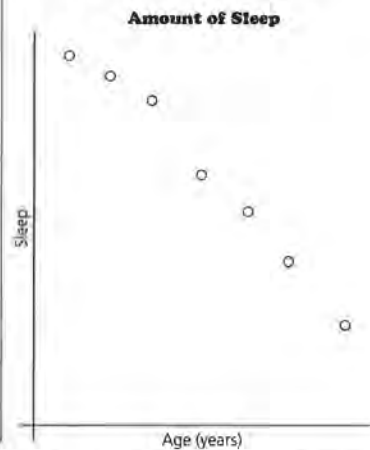
Practice and Applications

9. Sketch a scatter plot that you think reflects each of the following statements. Indicate either a positive, negative, or zero correlation for each.
- The more hours you work, the more money you make.
 - The more money you spend, the less you save.
 - Some people work long hours and save a lot of money; some people work long hours and do not save a lot of money.
 - The faster you drive, the less time it takes to arrive at your destination.
 - The older you get, the less sleep you need.
 - The more hours you spend exercising, the more calories you burn.
 - Some people study for many hours and get good grades; some people study very little and get good grades. Some people study many hours and get poor grades.

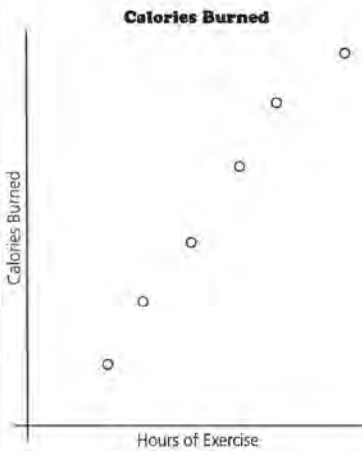
d. negative correlation



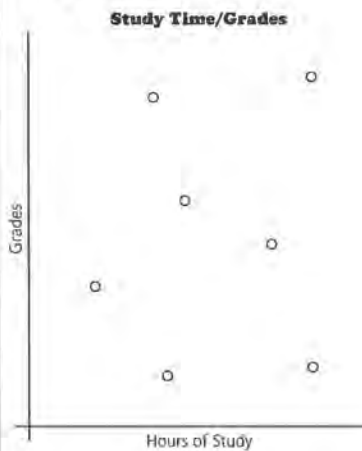
e. negative correlation



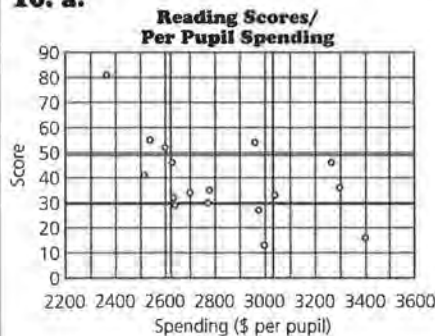
9. f. positive correlation



g. no correlation



10. a.



$$r = [(0 + 0) - (3 + 1)] \div 8 = -0.5$$

10. The following data show the amount spent per pupil and the reading scores of seventh graders in each middle school.

Milwaukee Middle School Per Pupil Spending and Reading Scores

Middle School	Spending (per pupil)	Reading Scores
Fulton	\$3,408	16
Robinson	3,306	36
Wright	3,274	46
Kosciuszko	3,049	33
Parkman	3,006	13
Edison	2,975	27
Roosevelt	2,970	54
Walker	2,787	35
Muir	2,783	30
Bell	2,710	34
Sholes	2,649	29
Burroughs	2,642	32
Webster	2,637	46
Audubon	2,609	52
Steuben	2,548	55
Fritsche	2,525	41
Morse	2,374	81

Source: data from *Milwaukee Journal*, May 25, 1992.

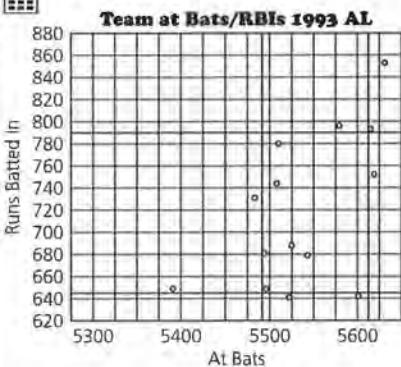
- a. Plot the reading scores as a function of per-pupil spending (*spending, reading scores*), and find the correlation.
- b. According to the *Milwaukee Journal*, "... the correlation isn't always there." What do you think this statement means?



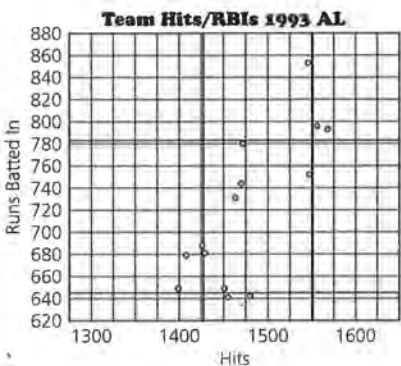
11. Is there any association between the various statistics collected about baseball players and teams? If a team has a high number of hits, will it have a high number of runs batted in? Following are data for the 1993 American League Championship Season. Divide the following pairs of variables among your group members: (*at bats, runs batted in*), (*hits, runs batted in*), (*hits, home runs*), (*hits, batting averages*), (*at bats, home runs*), and (*home runs, runs batted in*).

- b. The correlation is not very strong, but the correlation is opposite to that which might be expected. One would think that if there were a correlation, more money would improve test scores. This correlation indicates more money decreases test scores.

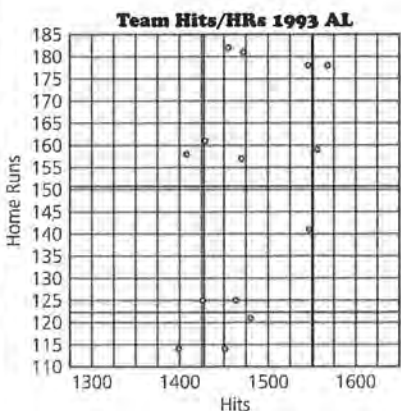
11. a.



$r = [(2 + 0) - (0 + 0)] \div 6 = 0.33$.
 There is not a very strong linear relationship between the number of at bats and the number of runs batted in. (See scatter plot above.)



$r = [(2 + 0) - (0 + 0)] \div 6 = 0.33$.
 There is not a very strong linear relationship between the number of hits and the number of runs batted in. (See scatter plot above.)



$r = [(0 + 1) - (0 + 0)] \div 6 = 0.17$.
 There is not a very strong linear relationship between the number of hits and the number of home runs. (See scatter plot at left.)

$r = [(2 + 2) - (0 + 0)] \div 6 = 0.67$.
 There is a moderately strong linear relationship between the number of hits and the batting averages. (See scatter plot at right.)

American League Championship Season: 1993 Team Ratings

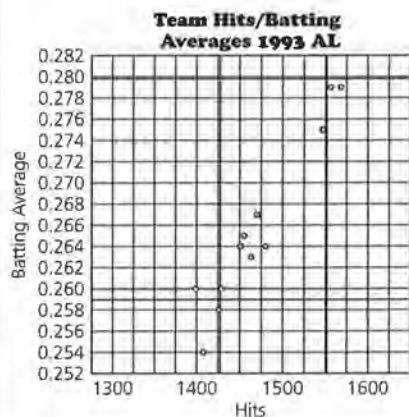
Team	Avg	AB	R	H	HR	RBI
New York	0.279	5,615	821	1,568	178	793
Toronto	0.279	5,579	847	1,556	159	796
Cleveland	0.275	5,619	790	1,547	141	747
Detroit	0.275	5,620	899	1,546	178	853
Texas	0.267	5,510	835	1,472	181	780
Baltimore	0.267	5,508	788	1,470	157	744
Chicago	0.265	5,483	776	1,454	182	731
Minnesota	0.264	5,601	693	1,480	121	642
Boston	0.264	5,496	686	1,451	114	644
Kansas City	0.263	5,522	675	1,455	125	641
Seattle	0.260	5,494	734	1,429	161	681
California	0.260	5,391	684	1,399	114	644
Milwaukee	0.258	5,525	733	1,426	125	688
Oakland	0.254	5,543	715	1,408	158	679

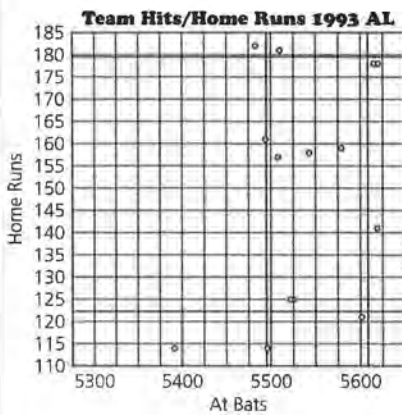
Source: data from *World Almanac and Book of Facts, 1994*.
 (R = hit, batter gets on base; R = run; player scores; RBI = runs batted in; other run-ners scored on player's hit; HR = home run; batter scores on own hit; AB = at bat; batter has opportunity to bat; Avg = average; hits divided by at bats)

- a. Make a scatter plot, find the correlation, and describe what it tells you about the association between the variables.
- b. If you look at all the scatter plots, between which pair of variables is the association strongest? The weakest?

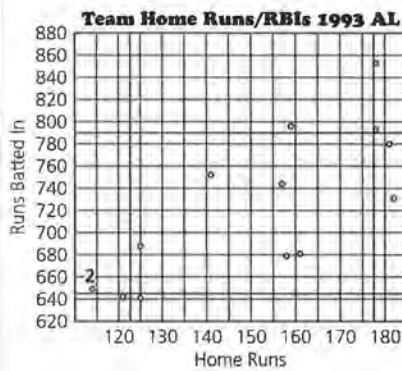


12. Federal Proposition 48 raised the academic requirements for participation in sports for athletes entering college in 1986. The college graduation rates in the Big Ten and the Pac Ten colleges for students who entered college in 1985 and 1986 are shown in the table shown on the next page. For example, in 1986, 78% of the students who entered the University of Illinois graduated, whereas only 74% of the athletes who entered that year graduated.





$r = [(0 + 1) - (1 + 0)] \div 6 = 0$. There is no linear relationship. (See scatter plot above.)



$r = [(1 + 1) - (0 + 0)] \div 4 = 0.17$. There is not a very strong linear relationship between the number of home runs and the number of runs batted in. (See scatter plot above.)

b. The association is strongest between hits/batting averages and home runs/RBIs. The association is weak for all other scatter plots.



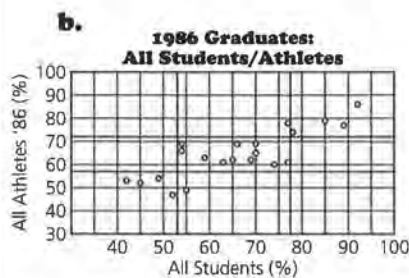
12. a. Arizona State, Oregon State, and Washington State appear to have had the worst records for athletes graduating. Northwestern, Stanford, and Penn State appear to have had the best records for athletes graduating.

College Graduation Rates

College	Graduation Percentage of Students entering in 1986	Graduation Percentage of Athletes entering in 1985	Graduation Percentage of Athletes entering in 1986	Graduation Percentage of Football Players entering in 1985	Graduation Percentage of Football Players entering in 1986
Illinois	78	64	74	71	75
Indiana	65	66	62	72	50
Iowa	59	64	63	58	63
Michigan	85	63	79	61	80
Michigan State	69	65	62	48	56
Minnesota	42	53	53	42	32
Northwestern	89	82	77	75	62
Ohio State	54	67	69	63	72
Penn State	77	75	78	81	78
Purdue	70	61	65	47	55
Wisconsin	70	64	69	63	81
Arizona	49	50	54	53	57
Arizona State	45	40	52	24	30
California	77	62	61	57	44
Oregon	54	57	66	60	63
Oregon State	52	49	47	52	70
Southern Cal	66	53	69	60	71
Stanford	92	89	86	84	79
UCLA	74	58	60	55	42
Washington	63	56	61	35	54
Washington State	55	53	49	38	50

Source: data from USA TODAY, July 8, 1993.

- Which college seems to have the worst record for athletes? The best?
- Consider the four associations that follow. Divide the problems among your group members. Estimate the correlation using the tick-tack-toe method.
 - Compare the percentage of all students who entered in 1986 and graduated from the college to the percentage of athletes who entered in 1986 and also graduated.
 - Compare the percentage of all students who entered in 1986 and also graduated from the college to the percentage of football players who entered in 1986 and also graduated.



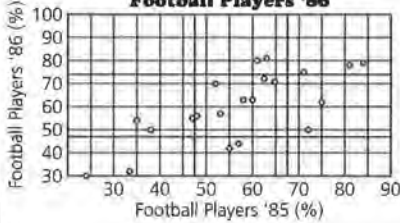
$r = [(4 + 4) - (0 + 0)] \div 10 = 0.8$



$r = [(3 + 2) - (0 + 0)] \div 10 = 0.5$

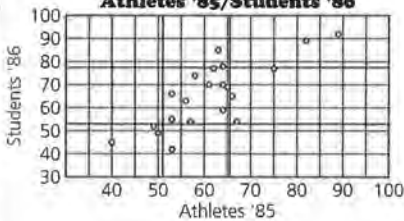
(12b)

**Football Players '85/
Football Players '86**



$$r = [(3 + 2) - (0 + 0)] \div 10 = 0.5$$

Athletes '85/Students '86

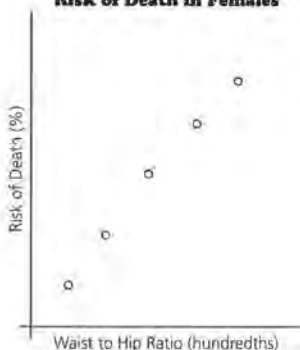


$$r = [(2 + 3) - (0 + 0)] \div 10 = 0.5$$

c. In general, the percentage of graduating athletes is correlated with the percentage of all students who graduate. The strongest correlation is between all students and all athletes who entered in 1986. Students should make claims that are supported by the scatter plots. Students may include the line $y = x$ in the plots and make claims about things other than just correlation. Be sure students are not equating correlation and slope.

13. a. For Woman B, the ratio of waist to hip is 32 to 39, or 0.82. For Woman A, the ratio is 26 to 36, or 0.72. The ratios indicate that the risk of death is greater for Woman B.

b. Risk of Death in Females



- Compare the percentage of football players who entered in 1985 and also graduated to the percentage of football players who entered in 1986 and also graduated.
- Compare the percentage of athletes who entered in 1985 and graduated to the percentage of all students who entered in 1986 and graduated.

- c. What conclusions can you draw about the associations between the percentages of graduating athletes? Use your work from b to support your claims.
13. An article in the *Milwaukee Journal* in January 1993 reported the following:

Battle of bulge: Waist-hip ratio is predictor of death, study says

In a study of 41,837 Iowa women ages 55 to 69, researchers at the University of Minnesota found that there was a strong correlation between the waist-hip ratio and the risk of death. The bigger the waist in comparison to the hips, the higher the risk of death regardless of weight. A 15% increase in waist-hip ratio increased the risk of death by 60%.

The article continued by stating that for women, the ratio should be less than 0.8 and for men, it should be less than 0.95.

- a. According to the article, who would be expected to have a greater risk of death: woman A, who has a waist measurement of 26 inches and a hip measurement of 36 inches; or woman B, who has a waist measurement of 32 inches and a hip measurement of 39 inches?
- b. Make a sketch of a scatter plot that might show the research data.
- c. How do you think the 15% increase in waist-hip ratio, that increased the risk of death by 60%, would be reflected in the scatter plot?
- d. Based on the information in the article, which of the following do you think would be the most likely correlation for the data: -0.9, -0.6, -0.2, 0, 0.2, 0.6, or 0.9? Tell why you selected the value you did.
- e. Comment on the cause-and-effect relationship implied in the newspaper article.

c. It would be shown by the slope of the data points. Here, the slope is 4.

d. 0.6 or 0.9. The researchers claim there is strong correlation indicating a number close to 1, so 0.2 can be eliminated. Because an increase in the ratio means an increase in the risk, the correlation will be positive.

e. The article implies there is a direct relationship. A typical question would be the factor of overall weight, but the article states that the relationship remains regardless of weight. There could still be other contributing factors, such as genetics, which could affect the waist-hip ratio and the risk of death.

LESSON 11

End-of-Module Project: The Domino Topple

Materials: graph paper, pencils or pens, rulers, a box of dominoes, meterstick, stopwatch for each group, *End-of-Module Test*

Technology: graphing calculators (optional)

Pacing: 1 class period

Overview

In this experiment, students set up a continuous string of dominoes and use a stopwatch to determine how long it will take for the dominoes to fall. Students recognize that the distance between the dominoes will have an impact on the length of time, as will a variety of other factors. Students will incorporate these factors into the design of their experiment. This experiment offers students the opportunity to investigate the rate of change in the length of time it takes for a given number of dominoes to fall: Will the time be constant as the number of dominoes increases or will the time it takes for the dominoes to fall increase or decrease as the number of dominoes increases?

Teaching Notes

This experiment has been adapted from work done by Jere Confrey at Cornell University. Students will find that a variety of factors has an impact on the experiment. Encourage them to find some way to control the experiment as much as possible (for instance, have the same person topple the dominoes). Initially, many students will use one set of dominoes, around 10 or 20, and on the basis of the time it takes them to fall, extrapolate to the time for 1,382,101 dominoes to fall. Be sure they recognize two things: Using one data point is not very conclusive; a different number of

dominoes may or may not fall the same way. Does the rate of change remain constant as more and more dominoes fall? Using more dominoes in multiples of 5 or 10 dominoes and investigating what happens will give students a better understanding of the relationship between the number of dominoes and the length of time it takes the dominoes to fall.

As suggested by the student lesson opener, it is often the case that not all of the dominoes in the string fall with one push. According to the 1993 *Guinness Book of Records*, Klaus Friedrich in Furth, Germany, toppled 281,581 out of 320,236 dominoes within 12 minutes 57.3 seconds. It took him 31 days to set up the dominoes, working 10 hours a day.

You might want half of the class to work on the domino experiment while the other half works on the gummy candy launch experiment. Different groups can share their results through group reports and presentations.

Follow-Up

Have students vary the distance between the dominoes and verify their answers to Question 4.

Solution Key**Data Collection and Analysis**

- Variables suggested by students might include the distance between the dominoes, the material from which the dominoes are made, the surface on which they are placed, and the force used to knock over the first domino.

LESSON 11

End-of-Module Project: The Domino Topple

On January 2, 1988, thirty university students from Europe set up a continuous string of 1,500,000 dominoes. How long do you think it would take to set up that many dominoes?

Of that number, the students were able to topple (knock over) 1,382,101 dominoes with one push, setting a new world record according to the 1994 *Guinness Book of Records*. How long would it take you to topple a continuous string of 1,382,101 dominoes?

OBJECTIVE

Explore the relationship between several variables.

Suppose you would like to be able to predict with some certainty how long it will take a string of dominoes to fall over. Think about the rate of change and whether it will remain constant as the number of dominoes increases. Will the dominoes start falling faster or slower as more and more dominoes fall? Use what you have learned in this unit to help you find a solution.

INVESTIGATE**The Domino Topple**

Devise a domino experiment of your own. Work with at least one other student. Be as complete as possible in your work.

Data Collection and Analysis

- Define the variables in your problem. The only rule is that when a domino falls, it can knock over only one other domino.

STUDENT PAGE 129

2. Students might control the variables by having one person knock over the dominoes each time, by using the same surface, and by fixing an arbitrary distance between the dominoes. Students will design a variety of different ways to collect data. Be sure they move beyond using only a fixed number of dominoes. Also have students consider whether the rate of change will be constant as the number of dominoes increases. They should eventually decide to set up a few dominoes and measure the length of time it takes them to fall. They can then repeat the process for a different number of dominoes.
3. Students should find a linear relationship that can be described with a straight line. They may plot points, find the correlation to see if a line is appropriate, draw a line of fit (possibly a median fit line), predict the length of time to topple 1,382,101 dominoes, and find the error in the prediction given by the line.
4. Comments will vary, based on students' original variables. If the distance between the dominoes is shortened, the dominoes will fall faster and the rate of change will increase causing the slope of the line to become steeper than the slope of the original line. If the distance is lengthened, the rate of change will decrease, and the slope will be less steep causing the line to lie below the original line. This provides an opportunity for students to think about the concepts of acceleration and deceleration in a meaningful context and to reflect on how these will affect the linear relationship between the number of dominoes and time.

2. Decide how you can best control these variables. Design an experiment using a box of dominoes, a meterstick, and a stopwatch.
3. Describe how you designed your experiment, what data you collected, and how you used the data to decide on your solution. You should have scatter plots and data tables showing how you reached your solution.
4. How will your solution change if
 - a. You change the distance between the dominoes?
 - b. You change any of your other variables?

LESSON 12 (OPTIONAL)

Catapults and Candy

Materials: at least one gummy candy, 9 tiles or small blocks, 2 ice cream sticks, 2 elastic bands, meterstick, metric tape measure, pencils or pens, graph paper, rulers for each group

Technology: graphing calculators (optional)

Pacing: 1 class period

Overview

The following activity has been modified from an activity by George Cobb at Mount Holyoke College in South Hadley, Massachusetts. Students explore what happens when an object is propelled from a launching pad as the launchpad height is changed. They look for a relationship between the height of the launchpad and flight distance and write a mathematical formula for the relationship they identify. In the activity, students use most of the ideas they studied in this module: making scatter plots, identifying slope, finding equations of lines, and graphing linear equations.

Teaching Notes

This experiment can be done at any time during the last part of the module but works well at the end of the module. Some students might do the domino toppling experiment in *Lesson 11* while others build the launchers for this experiment. Students should work in pairs or groups of three for this activity.

Students make a launchpad similar to the one shown. From this pad, students launch a piece of gummy candy forward. The question of interest is this: Is there a relationship between the height of the launch end of the pad and the distance the candy travels?

The experiment is an example of an experimental design problem and illustrates how important it is to

think about variables that might affect outcomes. It works best if students are given the freedom to explore by trial-and-error and later discuss with the entire class what happened in each instance. If the activity is presented according to a prescribed design, students will never realize why certain procedures are necessary. They should learn to recognize variability due to the design factors and think of some ways they might be able to control the situation.

Follow-Up

Other questions students might investigate include: Is taking the mean of the three trials the best way to get a value for a given height? What would happen to the model if the three values were plotted? Would the median give a better fit? How can you tell which one would be better: a line depending on the median or one depending on the mean? If you repeated the experiment would you get similar results? How do the results from others in class compare to those you obtained? What might account for any differences?

A suggestion for extension is to have each group investigate a variable and see how that affects the outcome. Variables include: the angle between the two ice cream sticks as a function of the thickness of the pencil; the length of the ice cream sticks; the amount of force on the launcher; the location of the candy on the launcher; the weight of the candy; and other suggested variables.

One way to assess what students learned from the experiment is to ask the following:

1. Summarize your experiment and the results.
2. For the data you collected, what is the rate of change in the distance for a given change in height? How can you find this from the graph? From the equation?
3. Is your model a good model to describe the relationship between height and distance? Explain why or why not.
4. What did you learn from this problem about designing an experiment?

Solution Key**Data Collection and Analysis**

Students should assemble the launchers according to the diagram.

- When thinking about how to design the experiment, students should consider such factors as the angle between ice cream sticks, how hard the candy is launched, how far down the stick is pushed, the way chosen to measure distance the candy flies, the length of the ice cream stick, the position of the launchpad, and the location of the pencil. Each of these might influence the outcome of the experiment. Students could actually design an experiment to see which factors matter. They should keep a set of variables constant and observe the outcome, then fix another set of variables constant and observe the outcome. Students should decide how many repetitions are necessary before any pattern emerges. They should also try launching the candy before they begin the actual experiment.

LESSON 12 (OPTIONAL)

Catapults and Candy

How far will a gummy candy travel when it is launched from a certain height?

Is there a relationship between the height of the launch end of the pad and the distance the candy travels?

OBJECTIVES

Collect and organize data. Investigate the relationship between two variables. Use slope and intercept in meaningful contexts. Write an equation that can be used to make predictions. Design an experiment, and understand how the variables can change the results. Prepare an argument based on data.

Modern catapults employ tension, hydraulic pressure, and other forces to launch airplanes from the decks of aircraft carriers. Follow the directions to make a catapult that uses tension, and experiment to answer the questions above.

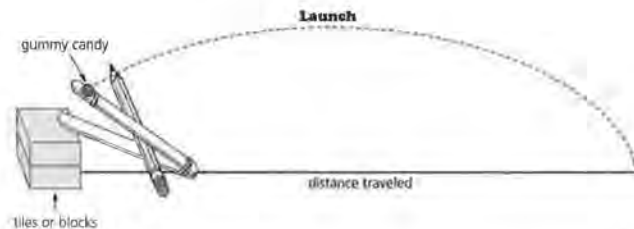
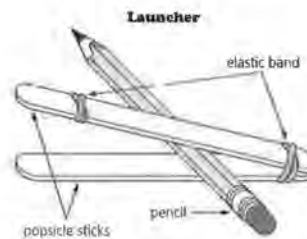
INVESTIGATE**The Gummy Candy Launch**

Each group will need at least one gummy candy (for example, a bear), about 10 tiles or small blocks, 2 ice-cream sticks, 2 elastic bands, a pencil, a meterstick, and a graphing calculator or graph paper. Each group should build a launchpad as shown here, place a gummy candy on the end of the launcher (an elastic band keeps the gummy candy from sliding down the ice-cream stick), and press down on the end of the launcher to release the candy. See the following diagrams of the launcher and the launch.

2. The sample data came from 25 trials with only one trial run. There was considerable variability; some of it was due to the way the candy skipped after it landed. Students can produce their own data for distance only and apply single-variable analysis techniques, using scatter plots and values to describe how far a candy would travel if it were launched from a launchpad at ground zero.

Distance (in centimeters): 26.75, 22.25, 30.75, 9.00, 6.50, 37.00, 22.00, 24.00, 12.25, 23.25, 10.25, 10.00, 24.25, 23.00, 11.25, 16.50, 15.75, 18.25, 13.25, 6.75, 11.25, 26.25, 25.50, 4.25, 12.50.

- a. The mean is 18.03 centimeters.
- b. The range is $37 - 4.25 = 32.75$ centimeters and the median is 16.5 centimeters. (The standard deviation is 8.65 and the interquartile range is from 10.75 to 24.5.)
3. Students should try a few launches and then do the actual experiment. To control the variability, the following data were collected from three trials at a given height. The scatter plot is (*height, average distance of the three trials from that height*). Those students who use only one trial per height will probably have very little pattern in their results unless they find some other way to control the situation. Allowing students to resolve the problem, however, will have more benefits than instructing them in any particular process.

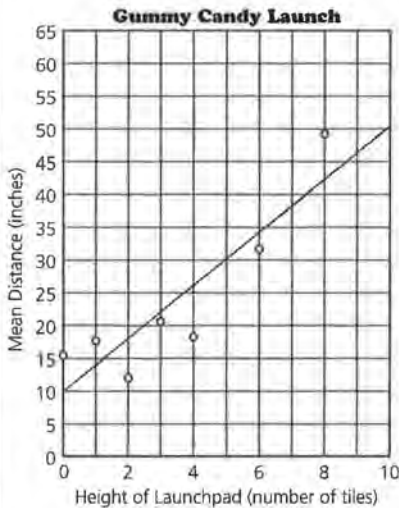


Data Collection and Analysis

1. Work with at least one partner: Define the variables in your experiment and decide how you can control them.
2. Conduct an experiment to answer these questions:
 - a. On average, how far will a gummy candy travel from a given height?
 - b. How much variability is there in a given launch?
3. What is the relationship between the height of the launchpad and the distance the candy travels? Write an equation to describe the relationship. Explain your equation in terms of the data.
4. Use your answers to Question 3.
 - a. If the height is 7 tiles, predict how far the candy will travel.
 - b. If the height is 10 tiles, what is the expected distance the candy will travel?
 - c. At what height should the launchpad be for the candy to travel 40 centimeters?

(3)

Height (number of tiles)	Distance (in cm)	Average Distance (in cm)
0 tiles	9.75	
	19.25	
	18.5	15.8
1 tile	16.5	
	19.25	
	16.75	17.5
2 tiles	18.5	
	6.25	
	11.75	12.2
3 tiles	27.5	
	22.25	
	10.5	20.1
4 tiles	19.75	
	24.5	
	11.25	18.5
6 tiles	33.75	
	40.5	
	20.5	31.6
8 tiles	65.5	
	24.25	
	59.25	49.7



5. Examine your predictions.

- a. For how many values did your equation predict a greater distance than the experimental average distance? For which height was the prediction from the equation the worst?
- b. How confident are you in your equation? Explain.

Some students may try to make predictions using only the scatter plot. Students can write the equation of the line using any two points that lie on the line. (5, 30) and (2.5, 20) are two points that seem to be approximately on the line shown. For an increase of 2.5 tiles there is a 10-centimeter increase in the distance the candy travels. The point slope form of the equation of a line is $d = 20 + 4(h - 2.5)$.

- 4. a. $d = 20 + 4(7 - 2.5)$
The candy may travel a distance of 38 centimeters according to the line for the sample data.
- b. $d = 4(10) + 10$
The expected distance of travel is 50 centimeters according to the line for the sample data.
Note that the equation seems to predict a shorter distance than you

(4b) might suspect from the line. This makes it seem unlikely that the relationship is really linear.

As students continue to investigate the relationship, they should recognize that their model is limited. What would this equation predict as the number of tiles continues to increase? If the height gets too high, the gummy candy will travel straight down and the distance will be very short or 0. When will that happen? Will the gummy candy ever travel backward? Over what x -values (h -values) will the equation for the data be accurate? An important point for students to recognize is that many models are good for only limited x -values.

c. $h = 7.5$, or 7.5 tiles

5. a. Four points are below the line. The prediction was the worst for 4 tiles and for 8 tiles, but off by 7.4 centimeters.

b. Students can determine how good the model is by using the data they have and finding the error in using their equation to predict for these values. For a height of 6 tiles, the linear equation predicts a distance of about 34 centimeters. The actual distance is 31.6 centimeters—an error of 2.4 centimeters. A linear equation that predicts values with a very small sum of errors should give relatively good predictions.

The linear model seems to underestimate the small values and the large values and overestimate those in between. This is a good indication that a linear model is probably not the best model.

Teacher Resources

Equations of Lines

NAME _____

In 1986, the number of CDs sold was 53 million, whereas in 1990, the number of CDs sold was 287 million.

- Graph the ordered pairs of data for CD sales.



- Find the rate of change in CD sales and explain what the rate of change means in the context of the data.
- Write an equation of the line determined by the data points (*year, sales*).
- What assumptions did you make when you wrote your equation? How valid do you think your assumptions are?
- Predict how many CDs were sold in 1993 and explain how you made your prediction.
- In what year would the predicted number of CD sales be 369 million? Explain how you determined your answer.
- Bonus** In 1986, 125 million LPs were sold, whereas in 1990, 12 million LPs were sold. In what year does the number of CDs sold exceed the number of LPs sold? Explain how you found your answer.

Equivalent Forms of Equations

NAME _____

1. A long-distance telephone company advertised the following rates: Five minutes for just \$.85 and ten minutes for just \$1.10. Write the ordered pairs (*minutes, cost*) for the data.
 - a. Assume that the rate of change for the cost of a long-distance call over time is constant. Write a linear equation to describe the cost of a long-distance call in terms of time.
 - b. Explain the rate of change in the cost of a long-distance call over time in the context of the data.
 - c. Use your equation to find the cost of a 20-minute long-distance call.

2. The number of calories burned while in-line skating depends on skating speed. The following table shows the number of calories burned by a 140-pound skater at various speeds. Graph the ordered pairs (*speed, calories*) and draw a line to represent the relationship.

Calories Burned By a 140-pound In-line Skater

Speed	8 mph	9 mph	10 mph	11 mph	12 mph	13 mph	14 mph	15 mph
Calories	5.1	6.7	8.3	9.9	11.4	13.0	14.6	16.1

Source: *Rollerblade*, P.O. Box 59224, Dept. P., Minneapolis, Minn., 55459

- a. Find a linear equation for your line.
- b. Explain the rate of change in the context of the data.
- c. Use your equation to determine the number of calories burned by a 140-pound skater who skates at 6 mph.

- 3. a.** Chan's equation for the number of calories burned by an in-line skater is $c = 13 + 1.6(s - 13)$. Is his equation equivalent to yours? Explain how you can tell.
- b.** Tarita's equation for the number of calories burned by an in-line skater is $c = 5.1 + 1.575(s - 8)$. Is her equation equivalent to Chan's equation? Explain why or why not.
- 4.** The graphs of the ordered pairs listed below in Set A and in Set B are straight lines. Are the equations for each of the lines equivalent? Justify your answer.

Set A		Set B	
x	y	x	y
15	94	48	31
18	11	54	35
21	13	60	39
24	15	66	43
27	17	78	51
30	19	84	55

- 5.** Which of the following equations are equivalent? Justify your answer.
- a.** $y = -3x + 90$
- b.** $y = 39 + 1.5(x - 29)$
- c.** $y = 12 + -3(x - 26)$

LESSON 7 QUIZ

Lines on Scatter Plots

NAME _____

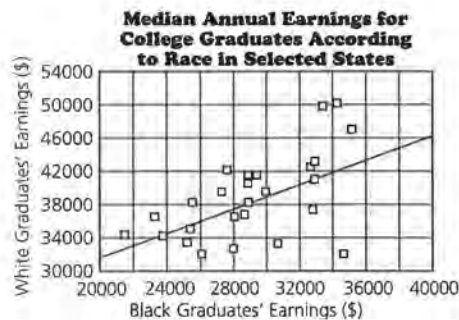
According to a report by *The Journal of Blacks in Higher Education*, the 1995 median earnings for college graduates in randomly selected states were as follows.

1995 Median Earnings of Black and White College Graduates in Selected States

State	Black Graduates	White Graduates	State	Black Graduates	White Graduates
California	\$35,033	\$47,096	Missouri	\$28,660	\$36,862
Colorado	32,684	37,438	New Jersey	33,299	49,298
Connecticut	34,214	50,222	Ohio	29,969	39,460
Delaware	29,290	41,546	Oklahoma	25,601	35,189
Georgia	27,682	42,498	Rhode Island	28,984	38,662
Florida	27,166	39,495	South Carolina	23,211	36,457
Idaho	23,762	34,128	Tennessee	25,729	38,568
Iowa	27,869	32,917	Texas	28,850	41,512
Kansas	27,796	36,290	Vermont	26,079	32,050
Maine	30,645	33,096	Virginia	28,860	40,441
Maryland	32,756	43,555	Washington, DC	32,654	42,300
Massachusetts	32,923	41,211	West Virginia	25,559	33,517
Mississippi	21,540	34,439	Wyoming	34,529	32,111

Source: USA TODAY, May 9, 1995.

This scatter plot shows a line representing the relationship of the data.



- 1. a.** There are three data points in the upper right corner of the scatter plot. Which states are represented by these points? Do these states appear to have anything in common? Explain.
 - b.** Which state does the data point farthest from the line represent? How will this data point affect the error in any prediction made from the line?
 - c.** Draw the line $y = x$ on the scatter plot. What does this line represent in the context of the data?
 - d.** According to the data, in which states do black graduates earn on average more than white graduates?
-
- 2. a.** What is the rate of change for the line on the scatter plot, and what does the rate of change represent?
 - b.** Write an equation of the line shown on the scatter plot.
 - c.** What is the y -intercept and what does it represent in terms of the data?
-
- 3. a.** Use your equation from Question 2b to predict the earnings of a white college graduate if a black college graduate earns \$31,000.
 - b.** Show on the scatter plot the difference between the actual and predicted earnings for a white college graduate in Colorado if you know the earnings of a black graduate in Colorado. What is the difference between the predicted and actual earnings of a white college graduate in Colorado?

LESSON 9 QUIZ**Lines, Lines, and More Lines**

NAME _____

According to *Consumer Reports*, 1991, the following data show the amount of fat and the number of calories in popular fast-food breakfasts.

Breakfast	Fat (in grams)	Calories
Hardee's Pancakes, Two Bacon Strips	9	470
McDonald's Pancakes with Sausage Patty	21	543
Burger King French Toast Sticks	32	622
Burger King Bagel with Egg and Cheese	18	407
McDonald's Egg McMuffin	13	390
McDonald's Sausage McMuffin with Egg	27	440
Burger King Croissan'wich with Egg and Cheese	20	315
Hardee's Sausage and Egg Biscuit	31	490
McDonald's Biscuit with Sausage and Egg	36	520
Burger King Croissan'wich with Sausage, Egg, and Cheese	40	534
Hardee's Bacon Biscuit	21	360
Hardee's Sausage Biscuit	28	440
McDonald's Biscuit with Sausage	29	440
McDonald's Sausage, Potatoes, and Biscuit	46	710
Hardee's Big Country Breakfast with Sausage, Potatoes, and Biscuit	57	850
Burger King Sausage, Potatoes, and Croissant	53	768
McDonald's Apple Bran Muffin	0	190
Burger King Apple Cinnamon Danish	13	390
McDonald's Apple Danish	18	390
Hardee's Cinnamon 'n' Raisin Biscuit	17	320

Source: *Consumer Reports*, September, 1991.

Exploring Linear Relations

NAME _____

Part I

- 1.** The average price of a new car in 1985 was \$11,450. In 1994, the average price of a new car was \$20,021. The rate of change in price per year was relatively constant.
 - a.** Find the rate of change in the price of a new car per year.
 - b.** Make a graph that shows the price of a new car over time.
 - c.** Write an equation that shows the relationship between new car price and time.
 - d.** Predict the average price of a new car in 1996. Describe how you made your prediction.

- 2.** Four students described the relationship between the price of the same item over time by writing the following equations:
 - 1)** $P = \$124 + ^{-}4(T - 1980)$
 - 2)** $P = \$84 + ^{-}4(T - 1990)$
 - 3)** $P = \$8,044 - 4(T - 0)$
 - 4)** $P = ^{-}4(-\$2011 + T)$
 - a.** Decide whether the equations represent the same line and indicate how you decided.
 - b.** Describe what you can tell about each line by looking at the values in each equation.

Part II

- 3.** According to *Anger Kills* by Dr. Redford Williams at Duke University Medical Center, hostile people have an increased risk of heart disease and death by heart attack. Recent research shows that the same is true for cities—cities with higher hostility levels have higher death rates. The following

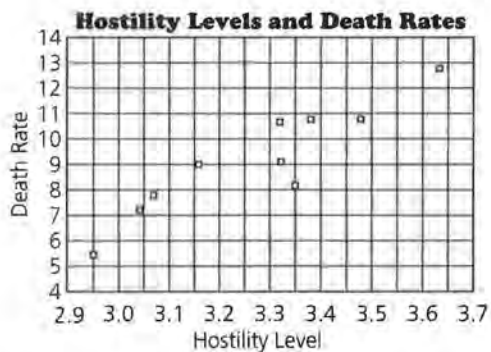
scatter plot shows research data for selected cities in the United States.



¹Adjusted for race, education, age, income, and gender.

Source: *USA TODAY*, May 31, 1994.

- a. In 1994, did Chicago or Des Moines have a higher death rate? How do you know?
 - b. Can you say that hostility level is correlated with death rates? Explain why or why not.
 - c. Do you think a high hostility level will cause an increase in death rates for a given city? Why or why not?
4. a. Draw a line on the following scatter plot that you think fits the data and write its equation.



- b. Find the y -intercept and the zero. What do they indicate about the data?
- c. Predict the death rate for a city with a hostility level of 3.0. Explain how you made your prediction.
- d. Suppose you know that there is a negative correlation between hostility levels and death rates. Describe the scatter plot and a line representing the relationship of the data.

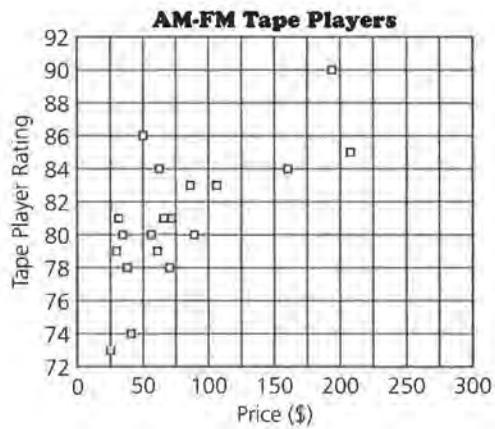
Part III

In 1991, *Consumer Reports* rated AM-FM tape players according to price, tape performance, features, convenience, and AM-FM radio performance. The following table shows these ratings.

AM-FM Tape Player	Rating	Price (\$)	AM-FM Tape Player	Rating	Price (\$)
Panasonic RQ-S55V	90	\$194	Aiwa Radical HS-RD7A	80	89
Aiwa HS-T90	85	210	Magnavox AW6508/17	80	56
Aiwa HS-T50, A Best Buy	84	64	GE 3-5474A	79	30
Sony WM-AF605	84	159	Sharp JC528	79	61
Sony WM F2085	83	86	Sanyo MGR200	78	39
Panasonic RQ-VI80	81	65	Sears LXI21193	80	35
Sanyo MGR600	81	73	Sony WM-AF54	78	69
Aiwa HSt220	86	49	GE 3-5477A	74	40
Realistic SCP39	83	105	Emerson AC2106	73	24
Sony WM-F2015	81	33			

Source: *Consumer Reports*, October, 1991.

The following scatter plot shows the relationship between the price of a tape player and its rating.



- 5.** Tom's linear equation describing the relationship between price (P) and tape player rating (T) is $T = 0.02P + 80$.
- Graph Tom's line on the scatter plot shown.
 - What is the slope of Tom's line and what does it tell you about the relationship between tape player rating and price?
 - Suppose Tom predicts the tape player rating for an Aiwa Best Buy. How close is his prediction to the actual rating?
 - For how many tape players would Tom predict a rating lower than the actual rating? How did you find your answer?
- 6.** Sabrina's equation for the relationship is $T = 82 + 0.05(P - 100)$.
- For a tape player with a rating of 90, what price does Sabrina's equation predict?
 - Is Sabrina's equation equivalent to Tom's equation? Why or why not?
 - Who has the better prediction for the rating of the Sony WM-AF605?
 - Sabrina's equation has a root mean square error of 2.8. Whose equation do you think is a better predictor, and why?

Equations of Lines

In this quiz, students apply what they have learned about finding the rate of change, writing an equation for a line, and making predictions based on the data.

1.



2. The rate of change is 58.5. This means each year, about 59 million more CDs are sold.
3. One possible equation is $n = 287 + 58.5(y - 1990)$.
4. The assumption is that the sales of CDs have been constant since 1986. This probably is not entirely valid, since sales usually vary from year to year. However, the equation does give a general idea about the nature of the increase in CD sales.
5. About 462.5 million CDs were sold in 1993 according to the equation. Students may estimate from the graph or let $y = 1993$ in the equation and solve for n .

6. The predicted sales were about 369 million in early 1991. Students may estimate by using the graph or let $n = 369$ in the equation and solve for y .

7. **Bonus** The number of CDs sold exceeded the number of LPs sold in late 1986. Students may draw both lines on the graph and estimate where the lines intersect, or they may use the equations and solve for the year:

CDs

$$n = 287 + 58.5(y - 1990)$$

LPs

$$n = 12 - 28.25(y - 1990)$$

The value of y that satisfies both equations is 1986.83 (where the graphs of the two lines intersect). The year is late 1986 or just before 1987.

Equivalent Form of Equations

1. The points are (5, \$.85) and (10, \$1.10).

a. $y = 1.10 + \frac{(1.10 - 0.85)}{(10 - 5)}(x - 10)$

$$y = 1.1 + \frac{(0.25)}{(5)}(x - 10)$$

$$y = 1.1 + 0.05(x - 10)$$

- b. For each additional one minute in the length of a long-distance call, the cost increases \$0.05.

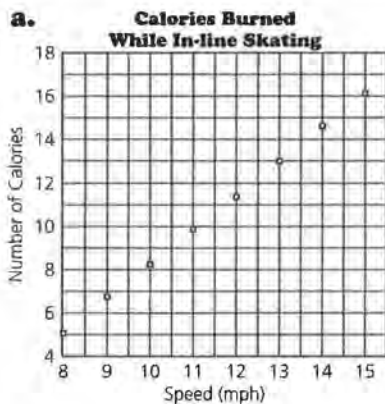
c. $y = 1.1 + 0.05(20 - 10)$

$$y = 1.1 + 0.5$$

$$y = 1.60$$

The cost of a 20-minute long-distance call is \$1.60.

2. a.



The points chosen are (8, 5) and (13, 13).

$$c = 5 + \frac{(13 - 5)}{(13 - 8)}(s - 8)$$

$$c = 5 + 1.6(s - 8)$$

- b. For every 1 mph increase in speed, there is a corresponding 1.6 increase in the number of calories burned.

- c. 1.8 calories

3. a. The equations are equivalent. $c = 13 + 1.6(s - 13)$ can be rewritten as $c = -7.8 + 1.6s$. The other equation $c = 5 + 1.6(s - 8)$ can be rewritten as $c = 1.6s - 7.8$.

- b. Tarita's equation is not equivalent to Chan's equation because when rewritten, her equation is $c = -7.5 + 1.575s$.

4. The graphs of the two sets of points are the same line with the equation $y = -1 + \frac{2}{3}x$.

Students may discuss the rate of change and note that it is the same for the two sets, but this could mean the lines are parallel. Students may graph the ordered pairs or they may write the equation for each set and discover that the equations are equivalent.

5. Equations a and c are equivalent; equation b has a different rate of change. Students might rewrite the equations to show equivalent equations or graph each. Be sure students discuss why the graphs are the same if that is the method they use.

Lines on Scatter Plots

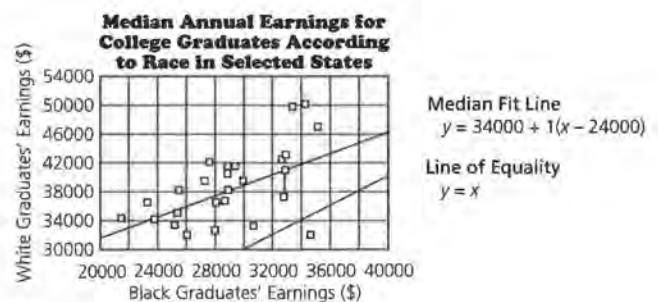
This quiz will enable you to determine whether students can read and interpret a scatter plot, write the equation of a line drawn through a set of points that appears to be linear, interpret the equation of a line drawn through a scatter plot by thinking about a measure of error, find and interpret the x - and y -intercepts of an equation, and apply concepts of slope and linearity.

The data set used in this quiz illustrates important concepts about fitting a line to data. Here students can use the line $y = x$, or the median fit line which is not sensitive to outliers. It is important to stress that the line students chose should not be overly affected by the data for Wyoming. Although the least squares regression line is not addressed in this module, some students may choose this line which is a function of the mean of the x and y data points, and thus is also affected by outliers.

1. a. According to the data, the states are California, Connecticut, and New Jersey. In all three states, the median earnings of white college graduates are between \$47,000 and \$51,000, whereas the median earnings of black college graduates are between \$33,000 and \$36,000. While two of the three states are in the northeast, there does not appear to be any common factor. An investigation into the kinds of businesses, the standard of living, job opportunities, and college enrollments of whites and blacks in the three states might reveal some common factors.
- b. The data point for Wyoming is farthest from the line. Black college graduates in Wyoming earn significantly more than black college graduates in any other state as compared with the earnings for white college graduates for that state.
- c. The line $y = x$ represents equal earnings for black and white college graduates.
- d. According to the data, Wyoming is the only state in which the median income for black graduates is more than the median income for white college graduates. (The data point for Wyoming is below the line $y = x$.) The incomes for black and white graduates in the other states are not very

close; white graduates consistently earn more than black graduates.

2. a. The rate of change for the line drawn is about 1.00. For each dollar increase in income for black college graduates, the income for white college graduates increases by a dollar also. While this may seem reasonable to students, they should recognize that in most cases, the income for black graduates will never equal the income for white graduates because the incomes were not the same to begin with. According to the model for this data, although the rate of change is the same, the income for blacks will never catch up with the income for whites. For this to happen, the rate of change must be greater than 1. You might ask students why this is so.
- b. A possible equation is $W = 34,000 + 1(B - 24,000)$. Students might use different points, but the difference should always be about \$10,000. This means that according to the data, the difference between the earnings of black and white graduates is about \$10,000. Thus, as long as the rate of change remains constant, the difference in income will remain constant also.
- c. The y -intercept is about \$10,000. This means that if black graduates earn \$0, white graduates earn \$10,000.
3. a. A white graduate would earn about \$41,000.
- b. The actual earnings for white college graduates in Colorado are \$37,438, while the predicted earnings are \$27,438. The difference is \$10,000, and it is shown by a vertical line segment from the line to the data point representing Colorado.

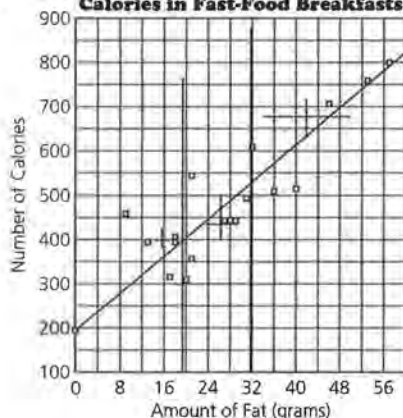


Lines, Lines, and More Lines

The quiz will assess whether students are able to draw and interpret a median fit line and solve an equation.

- Students may notice the cluster of data points representing three breakfasts with the same number of calories and almost the same amount of fat: the McDonald's Sausage McMuffin with Egg, the McDonald's Biscuit with Sausage, and the Hardee's Sausage Biscuit. All of the breakfasts with 26 to 42 grams of fat, except the Burger King French Toast Sticks, include sausage; only one breakfast which includes sausage, McDonald's pancakes with sausage, has fewer than 26 grams of fat. For breakfasts with 26 to 42 grams of fat, the number of calories is from 440 to 620.

2. Calories in Fast-Food Breakfasts



- A possible equation for the median fit line is $C = 250 + 10(F - 4)$, or $C = 210 + 10F$.
- The slope is about 10. This means that for each 1 gram increase in fat, the number of calories increases by 10.

The y -intercept is about 210. This means that if a breakfast contains 0 grams of fat, the number of calories it contains is about 210. This is reasonable because there are other contributors to calories besides fat.

The zero is about -21 . This means that if a breakfast has 0 calories, the breakfast has -21 grams of fat. This has no meaning in the context of the data.

- Because the median fit line is not affected by outliers, it would not change at all.
- Using the median fit line in Question 2, there would be 650 calories in the breakfast. Students could use the graph of the line or its equation to make their predictions.
 - The line predicts 420 calories. The actual number of calories is 543, so the line predicts 123 too few calories.
 - According to the line, a breakfast with 550 calories would have 34 grams of fat.
 - To use a table to make a prediction, look for the two closest entries and estimate the middle in some way; this is interpolation. An advantage is that it is easy to find the average of two values; a disadvantage is that using just two values to define the entire relationship is not very reliable. This is because one of the two values might be an extreme or have a large variability compared with the rest of the data.

To use a line to make a prediction, look for the point on the line that has the given coordinate. An advantage is that the line gives a good summary of all the points, and it is easy to see the relationship between the value you are looking for and the rest of the data. A disadvantage is that it is difficult to find an exact answer without estimating (unless you have a graphing utility that lets you zoom in on the point).

To use an equation to make a prediction, substitute the value you are given into the equation and solve for the other variable. An advantage is that equation solving can easily be done using a calculator; the equation uses all of the data and it will give you the exact solution. A disadvantage is that it might take more time to solve an equation, and you do not see the spread or variability of data so you have no sense about how much "error" there might be in your prediction.

Exploring Linear Relations

Part I

The test assesses the objectives for each lesson in the module. Students will show what they know about the aspects of linearity—from rate of change to lines as models for the relationship between two variables. Students can use a variety of strategies to answer many of the questions. If students use the same strategy for each problem, they may be missing the insights of looking at problems graphically, numerically, and algebraically.

1. a. The rate of change is $\frac{(\$20,021 - \$11,450)}{9} = \$952.33$ per year.



- c. $P = 11,450 + 952(T - 1985)$,
or $P = -1,878,270 + 952T$
- d. The average price in 1996 for a new car is \$21,922.
2. a. The equations are all equivalent. Students can justify their responses with graphs, finding equivalent forms of the equations, or by using some reasoning about the points. Students must use more than one point in their argument, however.
- b. 1) The rate of change is a decrease of \$4 per year, and the item cost \$124 in 1980.
- 2) The rate of change is a decrease of \$4 per year, and the item cost \$84 in 1990.

3) The rate of change is $^{-}$4$, and the item cost \$8,044 in the year 0 which has no meaning in this context.

4) The rate of change is $^{-}$4$, and in the year 2011, the item will cost \$0. This too has no meaning in this context.

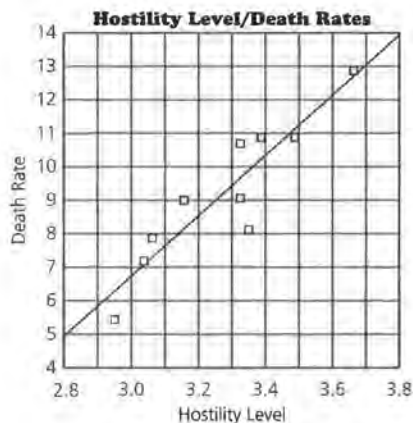
Part II

3. a. Chicago with a death rate more than 9 is higher on the scatter plot, whereas Des Moines has a death rate a little higher than 8.

b. Students may take different approaches to this problem. Those who base their answers on the graph, describing it as linear with “good” correlation, should not be given as much credit as students who find a numerical approximation for the correlation. Students should realize that after working through this module, numerical and graphical arguments together make the strongest case. The data do look linear, and the estimated correlation coefficient is 0.75. This is a fairly high correlation.

c. Students may take either side of the issue as long as they justify their arguments. It is not likely that having a high level of hostility causes a higher death rate. There are probably underlying causes for both. For example, poor education and lack of jobs along with inadequate housing and health care could cause hostility among people and also increase the risk of illness. Students might reason that anger and stress raise blood pressure so there is a greater chance of a stroke. Therefore, hostility does cause a higher death rate. Students may also mention that the way the hostility level was calculated might have been very subjective, and thus is not as objective as the way death rate is calculated.

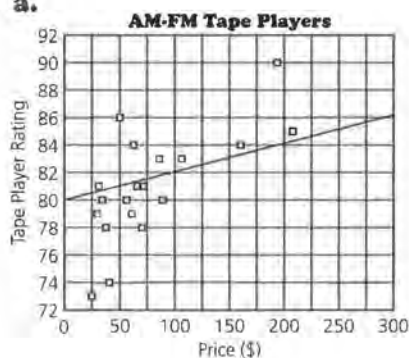
4. A possible line is $D = -20.5 + 9.1H$.



- b. Using the equation given, the y -intercept is about -20.5 , and the zero is about 2.25 . The y -intercept indicates that if a city has a 0 level of hostility, the death rate is -20.5 , which does not make sense in this context. The zero indicates that if the death rate is 0, the hostility level is 2.26 , which again does not make much sense in this context.
- c. A predicted death rate is 6.8 .
- d. If the correlation is negative, the line would go from the top left to the bottom right of the grid. The slope of the equation would be negative, and the y -intercept would be positive.

Part III

5. a.



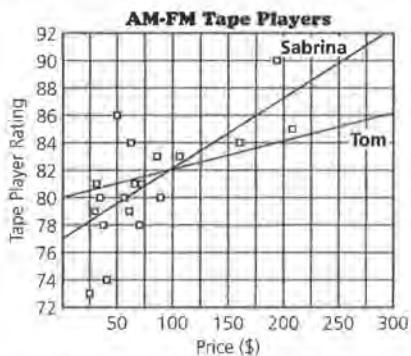
- b. The slope is 0.02 . This means that for every \$100 increase in price, the tape player rating increases by 2.

- c. The predicted rating is 81.28 and the actual rating is 84 . Tom would be off by 2.72 .

- d. Tom's equation would predict lower ratings for eight of the tape players. One way to find the number of tape players is to see how many data points are above the line. Students might also find the predicted values using the equation and compare them with the actual values.

6. a. Solve $90 = 82 + 0.05(P - 100)$ for $P = \$260$.

- b. The two equations are not equivalent. Sabrina's equation has a slope of 0.05 , whereas Tom's equation has a slope of 0.02 . These equations could not represent the same line. Students might also graph the two equations and show that the lines are different, or generate tables of values and show that the lines contain different points.



Tom's equation: $T = 80 + 0.02P$
 Sabrina's equation: $T = 82 + 0.05(P - 100)$

- c. They are both close. Tom's equation predicts 83.18 , off by -0.82 . Sabrina's equation predicts 84.95 . The actual tape player rating is 84 , so Tom is closer.

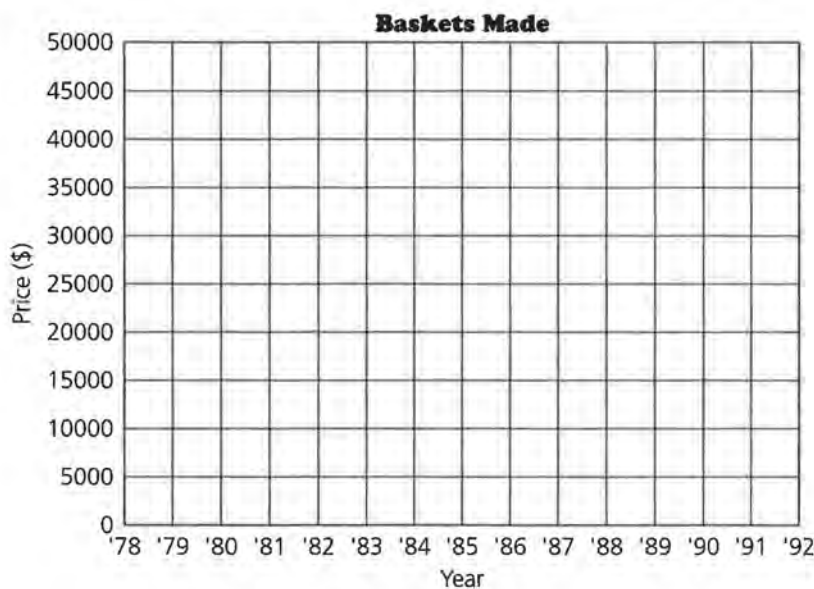
- d. In general Sabrina is closer. Students may estimate the error or they may calculate it for both. For Sabrina, the mean absolute error is 2.16 and the root mean squared error is 2.8 . For Tom, the mean absolute error is 2.45 and the root mean squared error is 3.30 .

Lesson 1: Rates of Change

NAME _____

- 2. a.** Using the change in price each year that you found in Question 1, complete the chart, and plot the points on the following grid.

Year	Cost of Mercedes	Year	Cost of Mercedes	Year	Cost of Mercedes
1980	\$23,000	1986	_____	1991	_____
1981	24,668	1987	_____	1992	_____
1982	26,336	1988	_____	1993	_____
1983	_____	1989	_____	1994	_____
1984	_____	1990	_____	1995	_____
1985	_____				



Lesson 1: Rates of Change

NAME _____

18. c. Estimate the percentages for the growth in revenue of the fast-food industry, and complete the table.

Year	Revenue (\$)	% Growth in Revenue	Growth in Revenue (\$)
1980	\$200,000		
1981		12.2%	
1982		10.0%	
1983		11.5%	
1984			
1985		8.0%	
1986		11.0%	
1987		9.8%	
1988			
1989		7.2%	
1990			

Lesson 2: Equations of Lines

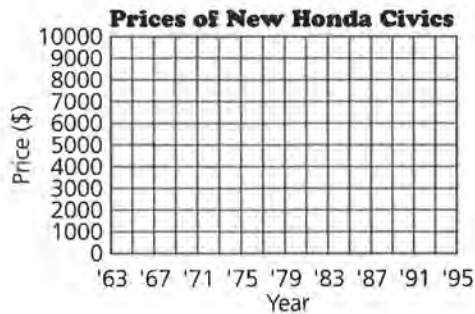
NAME _____

4. **b.** Complete the following table to find a general rule for the cost of a new Honda Civic.

Cost	Rule	Dollar Amount
Cost in 1980 =	$4500 + 389 (\quad)$	=
Cost in 1983 =	$4500 + 389 (\quad)$	=
Cost in 1979 =	$4500 + 389 (\quad)$	=
Cost in 1988 =	$4500 + 389 (\quad)$	=
Cost in General =	$4500 + 389 (\quad)$	=

6. **d.** Using the equation $C = \$4500 + \$389(T - 1980)$, estimate the cost of a Honda Civic in the even-numbered years. Complete the table, and plot the points on the following grid.

Year	Cost (\$)	Year	Cost (\$)
1970		1984	
1972		1986	
1974		1988	
1976		1990	
1978		1992	
1980		1994	
1982			



Lesson 4 (Optional): Buying Power

NAME _____

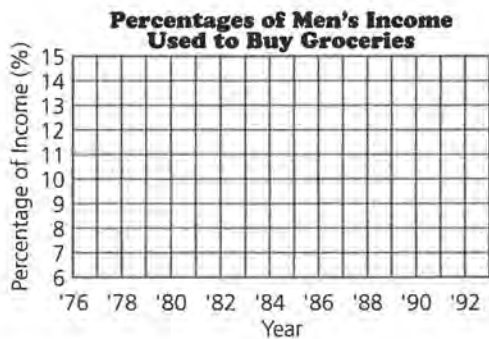
2. a. The table shows the average weekly cost of groceries for a family of four in Wisconsin. Use the data for men's median income and complete the table to calculate men's buying power for a year's worth of groceries.

Weekly Grocery Cost

Year	Weekly Cost of Groceries	% Income for Year	Year	Weekly Cost of Groceries	% Income for Year
1981	\$59.00		1988	\$47.00	
1982	61.00		1989	51.50	
1983	56.00		1990	49.50	
1984	45.00		1991	51.00	
1985	45.00		1992	55.00	
1986	44.50		1993	50.00	
1987	47.00				

Source: *The Milwaukee Journal Consumer Analysis*, 1981–1993.

2. b. On the following grid, plot the year and the percentage of income used to buy groceries.



Exploratory Lesson: How Can Two Variables Be Related?

NAME _____

2. Record the data from your balloon experiment in the following table.

Lesson 5: Scatter Plots

NAME _____

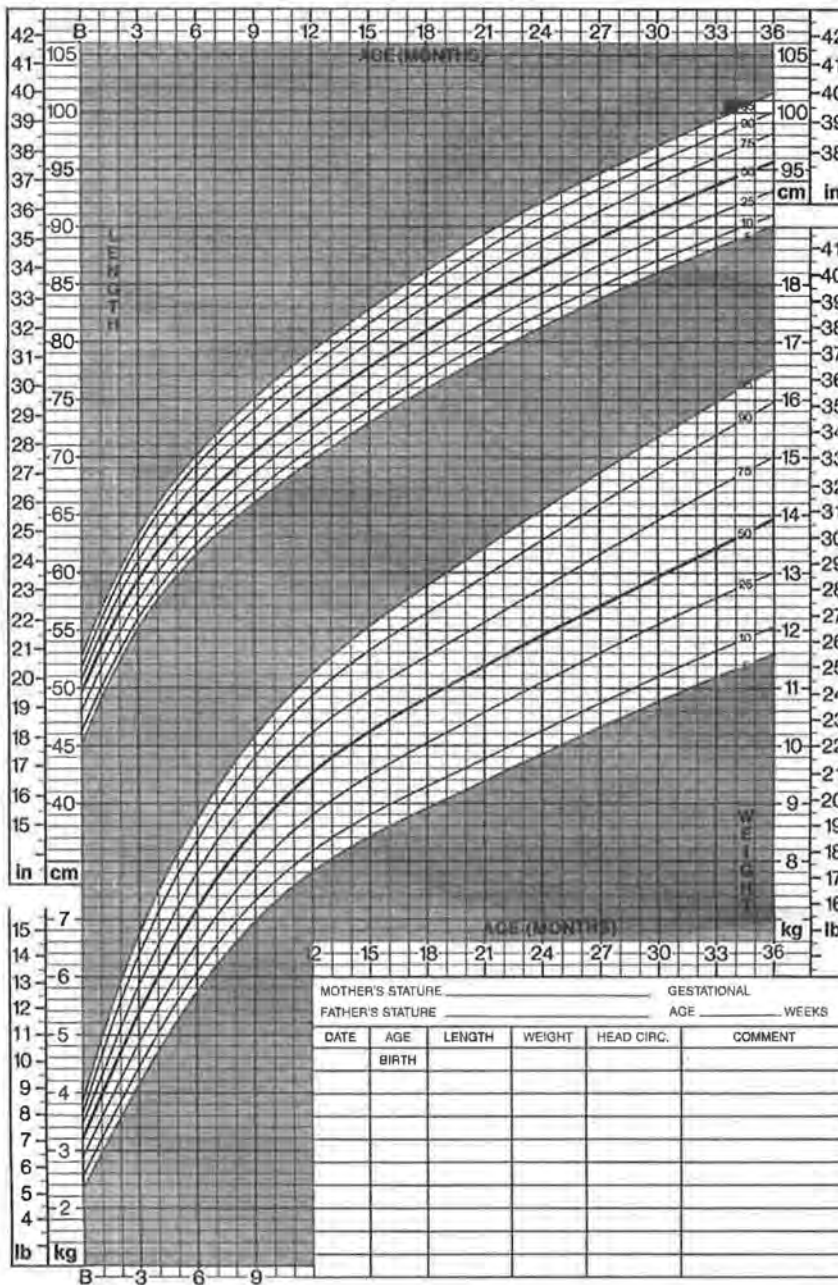
3. **b.** Plot the growth data for either Sarah or Sophia on the following growth chart, and describe the growth of the girl you chose.



**GIRLS: BIRTH TO 36 MONTHS
PHYSICAL GROWTH
NCHS PERCENTILES***

Name _____

Record # _____



Adapted from Hamill PW, Drizd TA, Johnson CL, Reed RB, Roche AF, Moore WM: Physical Growth: National Center for Health Statistics percentile. AMJ CLIN NUTR 32:607-629, 1979. Data from the Fehls Longitudinal Study, Wright State University School of Medicine, Yellow Springs, Ohio. © 1982 Ross Products Division, Abbott Laboratories.

ACTIVITY SHEET 6

Lesson 5: Scatter Plots

NAME _____

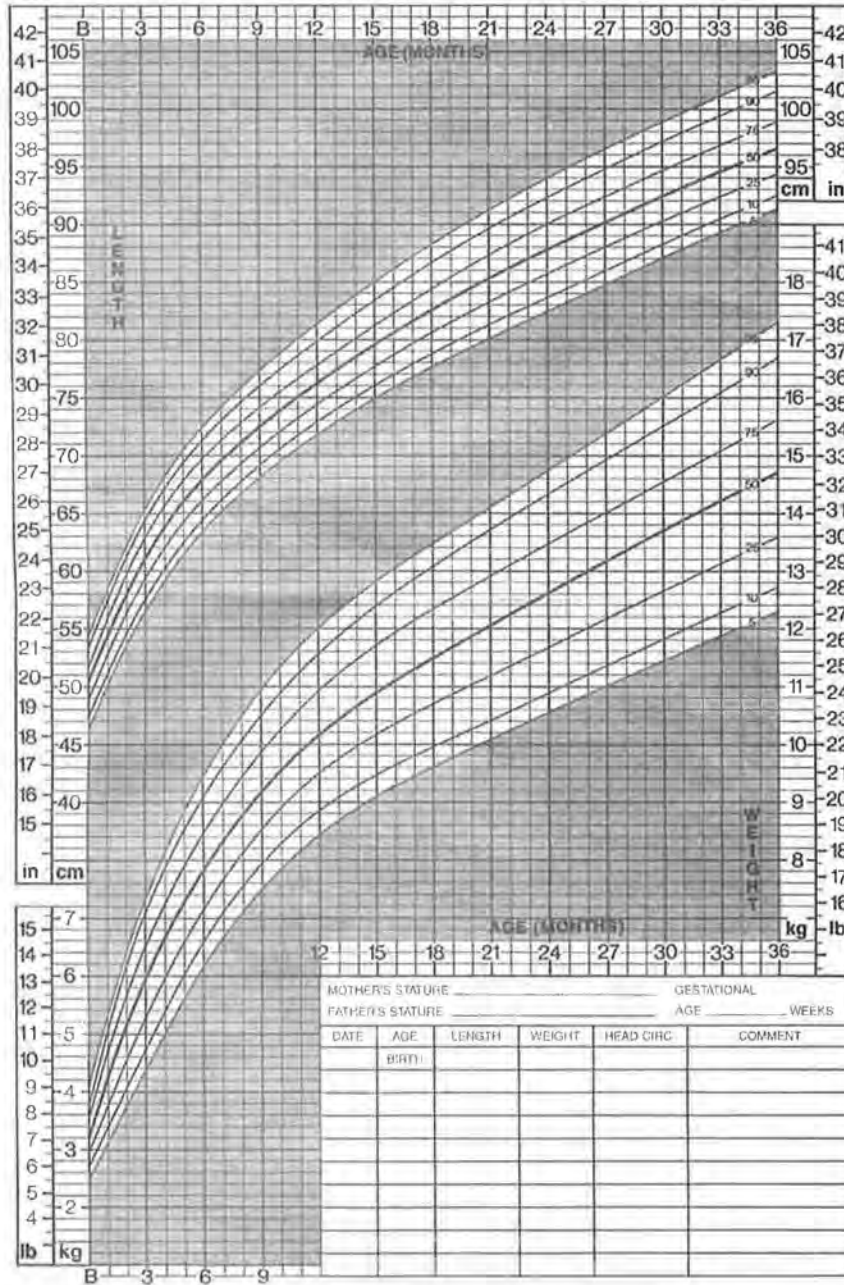
3. **b.** Plot the growth data for Tim on the following growth chart, and describe Tim's growth.



BOYS: BIRTH TO 36 MONTHS
PHYSICAL GROWTH
NCHS PERCENTILES*

Name _____

Record # _____



Adapted from Hamill PW, Drizd TA, Johnson CL, Reed RB, Roche AF, Moore WM: Physical Growth: National Center for Health Statistics percentile. AMJ CLIN NUTR 32:607-629, 1979. Data from the Fehls Longitudinal Study, Wright State University School of Medicine, Yellow Springs, Ohio. © 1982 Ross Products Division, Abbott Laboratories.

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Lesson 5: Scatter Plots

NAME _____

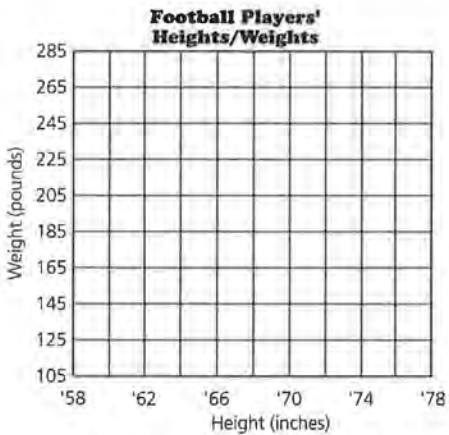
5. **b.** Plot (*height, weight*) of the football players on the grid following the table.

High School Football Players

Height (in inches)	Weight (in pounds)	Position
70	160	QB
68	145	K
70	185	LB
74	190	FS
70	169	LB
71	155	K
68	140	FS
68	160	DB
62	125	SS
70	160	SS
67	154	RB

Height (in inches)	Weight (in pounds)	Position
70	155	FS
71	150	LB
73	178	FS
72	190	LB
71	160	LB
72	205	LB
73	170	C
75	190	LB
76	230	DT
76	265	DT

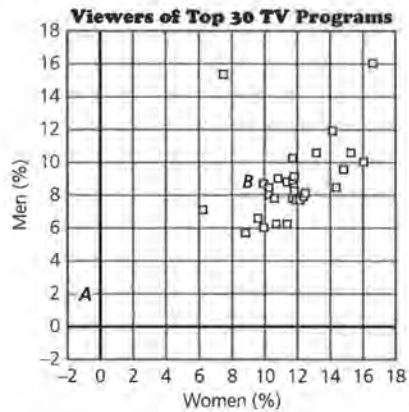
(FS = Free Safety, RB = Running Back, DT = Defensive Tackle, SS = Strong Safety, K = Kicker, C = Center, LB = Line Backer, QB = Quarterback, DB = Defensive Back)



Lesson 6: Graphs and Their Special Properties

NAME _____

11. Draw the line $y = x$ on the graph below.



Television Viewing Habits

Rank	Program	% Women	% Men
1	<i>60 Minutes</i>	16.5	16.1
2	<i>Roseanne</i>	15.3	10.6
3	<i>Home Improvement</i>	14.1	12.0
4	<i>Murphy Brown</i>	14.7	9.6
5	<i>Murder She Wrote</i>	16.0	10.1
6	<i>Coach</i>	13.1	10.7
7	<i>NFL Monday Night Football</i>	7.6	15.3
8	<i>CBS Sunday Night Movie</i>	14.3	8.4
9	<i>Cheers</i>	11.6	10.4
10	<i>Full House</i>	10.7	6.4
11	<i>Northern Exposure</i>	11.8	9.0
12	<i>Rescue 911</i>	11.7	9.2
12	<i>20/20</i>	11.6	9.0
14	<i>CBS Tuesday Night Movie</i>	11.8	8.3
15	<i>Love and War</i>	11.9	7.7

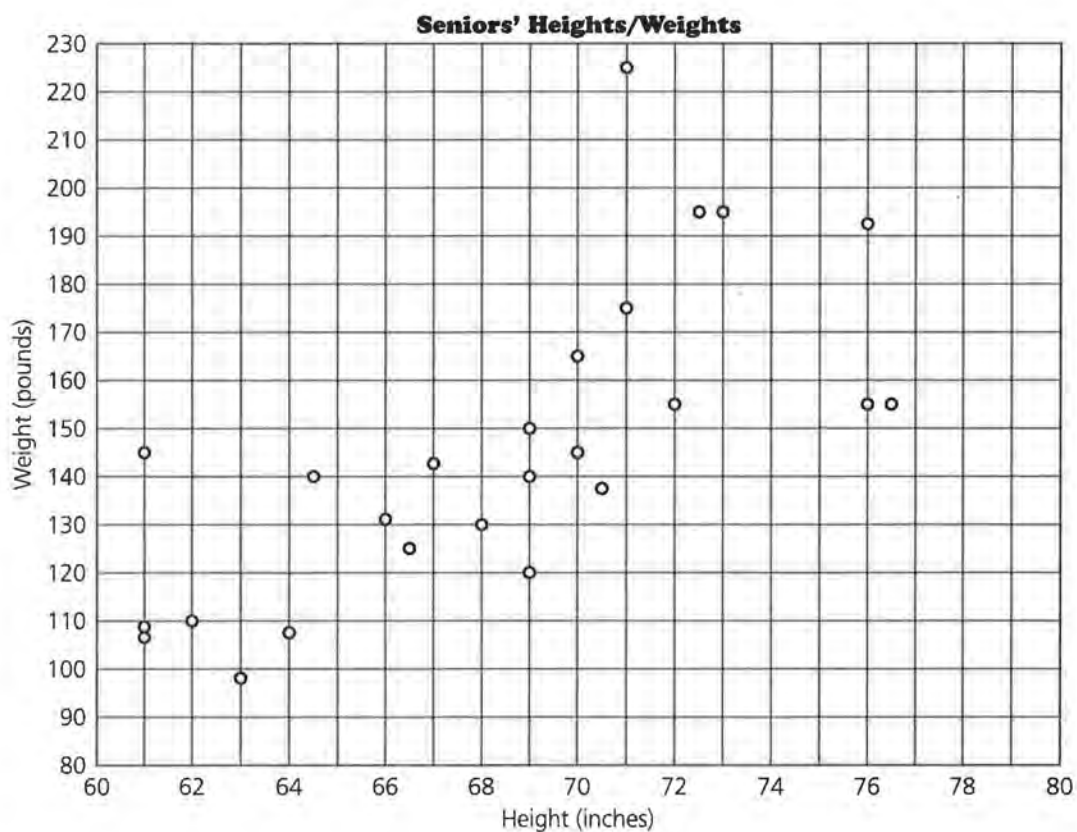
Rank	Program	% Women	% Men
16	<i>Prince of Bel Air</i>	9.5	6.6
16	<i>Hangin' With Mr. Cooper</i>	9.9	6.1
16	<i>Jackie Thomas Show</i>	10.5	7.8
19	<i>Evening Shade</i>	12.4	8.2
20	<i>Hearts Afire</i>	12.1	7.7
20	<i>Unsolved Mysteries</i>	11.2	8.8
22	<i>Primetime Live</i>	10.7	9.1
23	<i>NBC Monday Night Movie</i>	11.2	6.4
24	<i>Dr. Quinn Medicine Woman</i>	12.3	8.0
25	<i>Seinfeld</i>	9.9	8.7
26	<i>Blossom</i>	8.7	5.6
26	<i>48 Hours</i>	10.2	8.4
28	<i>ABC Sunday Night Movie</i>	10.2	8.2
29	<i>Matlock</i>	11.6	7.8
30	<i>Simpsons</i>	6.3	7.2
30	<i>Wings</i>	9.5	8.1

Source: *The World Almanac and Book of Facts*, 1994.

Lesson 7: Lines on Scatter Plots

NAME _____

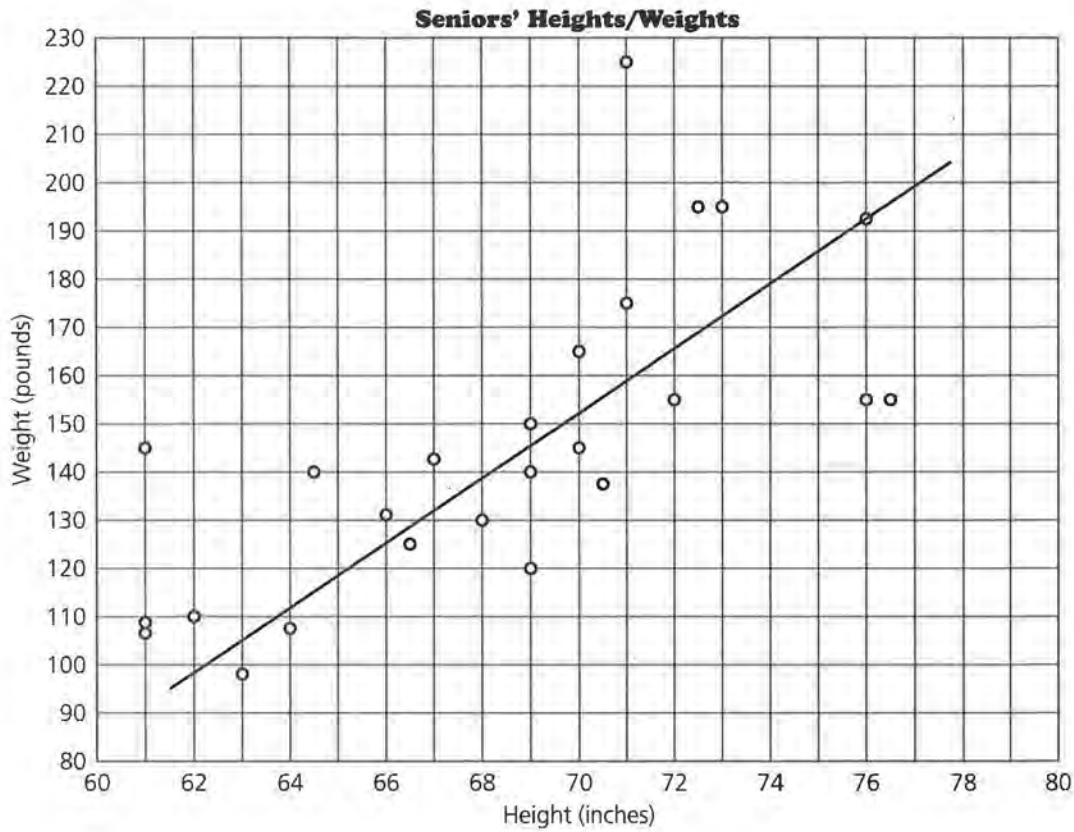
7. **b-d.** On the following scatter plot, put a star on each point representing female heights/weights. Draw a line on the scatter plot that you think will summarize or “fit” the data for all students, male and female. Find the equation of your line.



Lesson 7: Lines on Scatter Plots

NAME _____

9. a-c. Graph the point (68, 140) on the following scatter plot. Look at the table in the student book to find the weight of the senior who is 68 inches tall. Graph this point on the scatter plot also. What is the difference between the weight predicted by the line and the actual weight?



Lesson 7: Lines on Scatter Plots

NAME _____

13. a-b. Use the equation for the line you drew in Question 7 to predict the weight for each height. Complete the following table.

High School Seniors' Heights/Weights

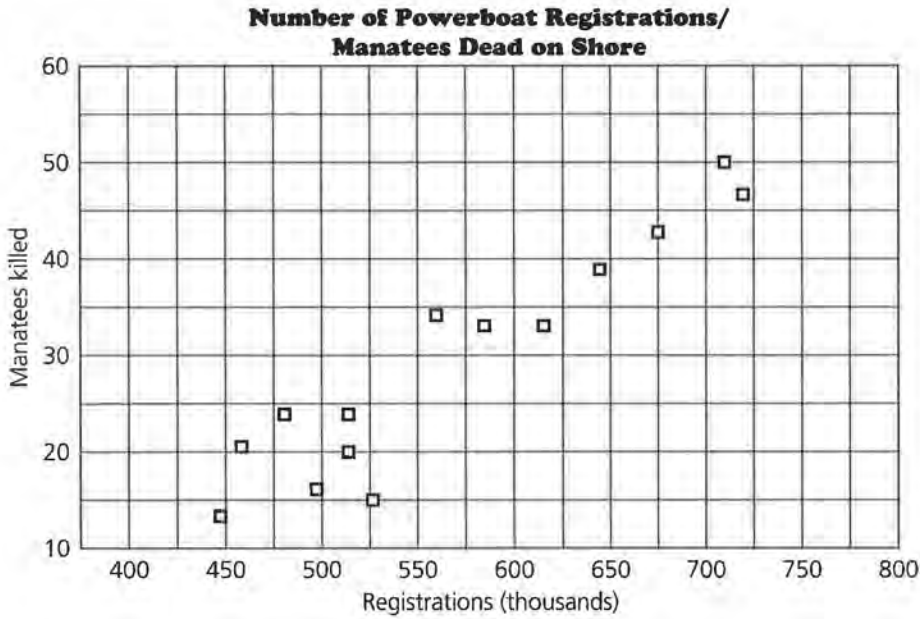
Males Height (in inches)	Actual Weight (in pounds)	Predicted Weight	Difference
72.5	195		
70.5	137		
72	156		
70	145		
71	175		
70	165		
73	195		
76	155		
67	143		
76.5	155		
76	192		
69	149		
71	225		

Females Height (in inches)	Actual Weight (in pounds)	Predicted Weight	Difference
66	132		
63	97		
61	145		
61	108		
64	106		
66.5	125		
64.5	140		
69	120		
68	130		
61	105		
69	140		
62	110		

Lesson 7: Lines on Scatter Plots

NAME _____

- 19.** On the following scatter plot, draw a line that you think summarizes the relationship between the number of manatee deaths and the number of powerboat registrations.



Lesson 7: Lines on Scatter Plots

NAME _____

- 21.** Predict the number of manatees found dead on shore for the given number of powerboat registrations. Record your predictions in the following table.

Powerboat Registrations (in thousands)	Predicted Number of Manatees Dead on Shore
447	_____
460	_____
481	_____
498	_____
513	_____
512	_____
526	_____
559	_____
585	_____
614	_____
645	_____
675	_____
711	_____
719	_____

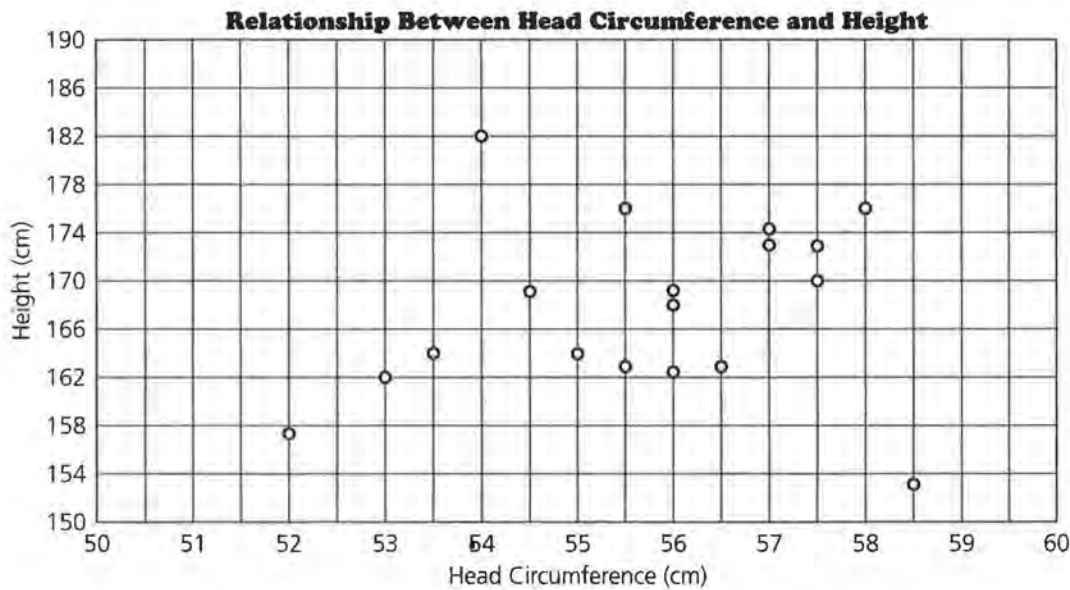
Lesson 9: Lines, Lines, and More Lines

NAME _____

4. **b-d.** Correct the following scatter plot by using the points (58.5, 172) and (54, 164). Plot the remaining data shown in the table. Draw a median fit line, and write an equation for your line.

Freshmen's Head/Height Measurements

Head Circum. (in centimeters)	Height (in centimeters)	Head Circum. (in centimeters)	Height (in centimeters)
54	160	54.5	164
55	166	53	156
59	178	53.5	158.5



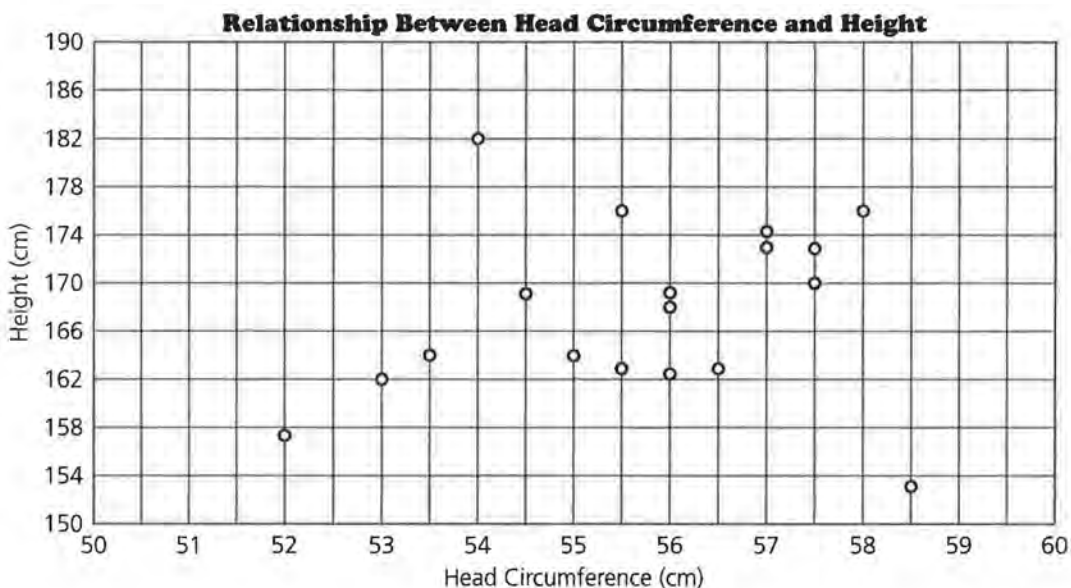
Lesson 9: Lines, Lines, and More Lines

NAME _____

5. a. The following scatter plot does not show the corrected data for the head circumference and heights of two students. Plot on this scatter plot the data in the table, draw a median fit line, and find its equation. Compare the equation of your line with the equation of the line on *Activity Sheet 12*.

Freshmen's Head/Height Measurements

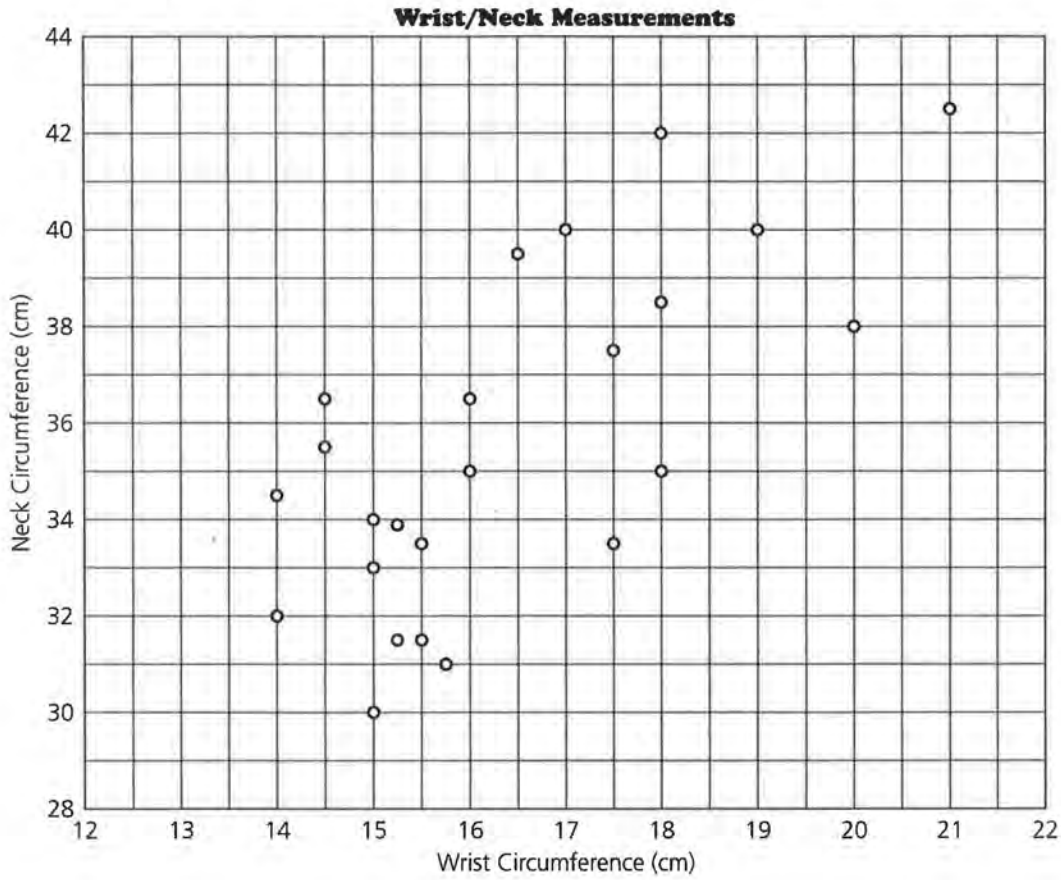
Head Circum. (in centimeters)	Height (in centimeters)	Head Circum. (in centimeters)	Height (in centimeters)
54	160	54.5	164
55	166	53	156
59	178	53.5	158.5



Lesson 9: Lines, Lines, and More Lines

NAME _____

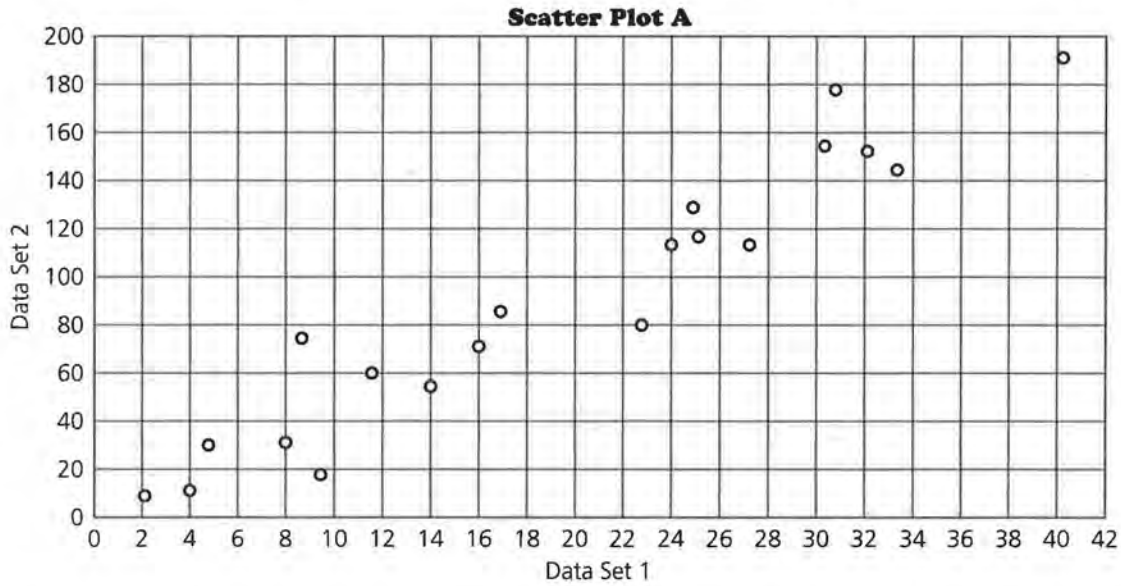
6. **b.** Draw a median fit line on the following scatter plot, and write the equation for the line.



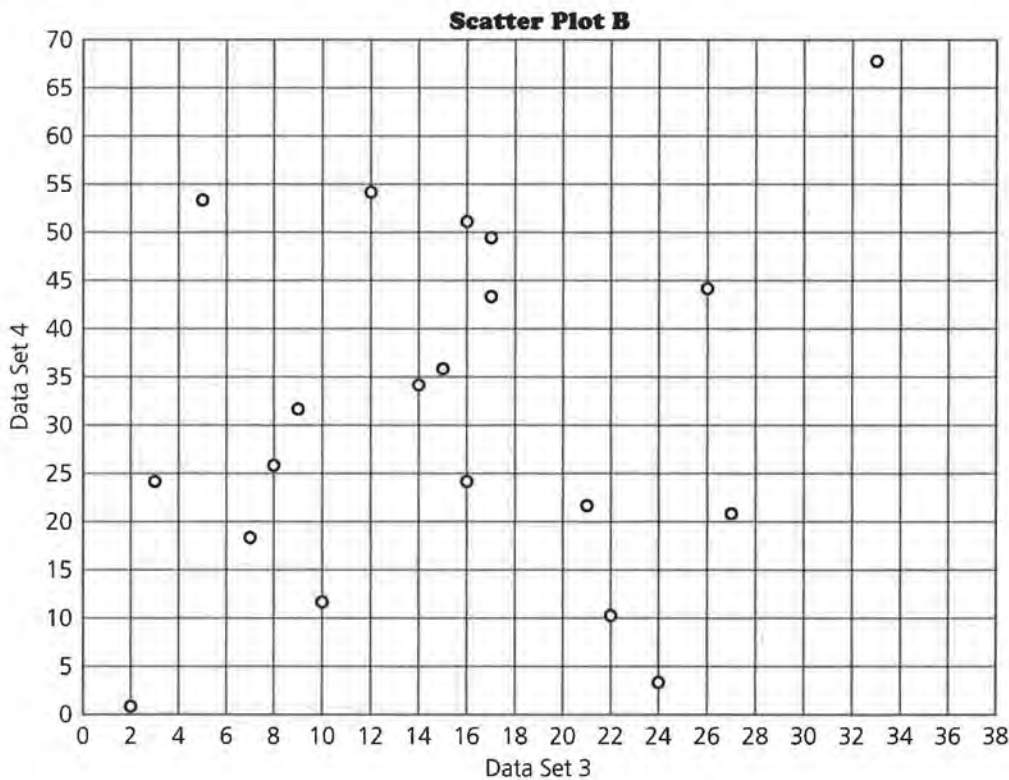
Lesson 10: A Measure of Association

NAME _____

3. a. Estimate the correlation for each of the following scatter plots.



b.



Lesson 10: A Measure of Association

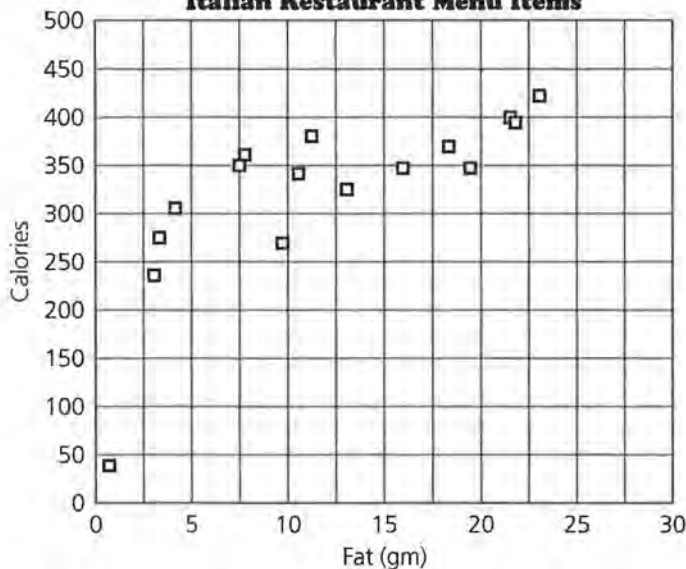
NAME _____

7. Estimate the correlation, find a median fit line, and write the equation of the median fit line for the following scatter plot.

That's Amore Restaurant Menu Items

Menu Item	Fat (in grams)	Calories	Menu Item	Fat (in grams)	Calories
Linguini Primavera	2.9	235	Chicken Piccata	16.1	348
Linguini with Scallops	3.1	276	Italian Frittata	23.0	424
Linguini with Shrimp	4.1	304	Sicilian Pork	11.2	379
Classic B.L.T.	19.6	347	Florentine Chicken	7.9	362
T.L.T. (Turkey)	13.1	328	Veal Piccata	21.9	394
Chicken Primavera	7.5	350	Sweet and Sour Chicken	10.4	341
Eggplant Parmigiana	9.7	269	Veal Parmigiana	21.0	450
Poached Roughy	18.4	370	Breadsticks	0.6	40

Italian Restaurant Menu Items



Data-Driven Mathematics Procedures for Using the TI-83

I. Clear menus

ENTER will execute any command or selection. Before beginning a new problem, previous instructions or data should be cleared. Press ENTER after each step below.

1. To clear the function menu, $Y=$, place the cursor any place in each expression, CLEAR
2. To clear the list menu, 2nd MEM
ClrAllLists
3. To clear the draw menu, 2nd Draw ClrDraw
4. To turn off any statistics plots, 2nd STATPLOT
PlotsOff
5. To remove user created lists from the Editor, STAT SetUpEditor

II. Basic information

1. A rule is active if there is a dark rectangle over the option. See Figure 1.

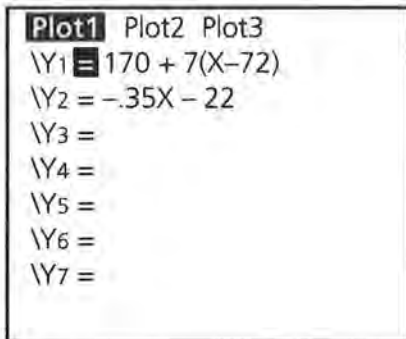


FIGURE 1

On the screen above, Y1 and Plot1 are active; Y2 is not. You may toggle Y1 or Y2 from active to inactive by putting the cursor over the = and pressing ENTER. Arrow up to Plot1 and press ENTER to turn it off; arrow right to Plot2 and press ENTER to turn it on, etc.

2. The Home Screen (Figure 2) is available when the blinking cursor is on the left as in the diagram below. There may be other writing on the screen. To get to the Home Screen type 2nd QUIT. You may also clear the screen completely by typing CLEAR.

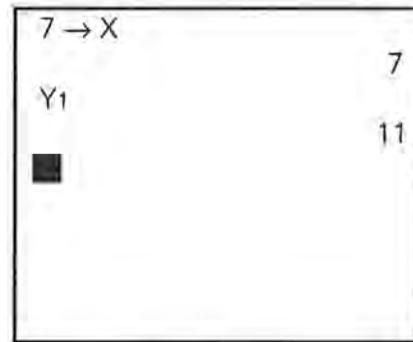


FIGURE 2

3. The variable x is accessed by the X, T, Θ , n key.
4. Replay option: 2nd ENTER allows you to back up to an earlier command. Repeated use of 2nd ENTER continues to replay earlier commands.
5. Under MATH, the MATH menu has options for fractions to decimals and decimals to fractions, for taking n th roots and for other mathematical operations. NUM contains the absolute value function as well as other numerical operations (Figure 3).

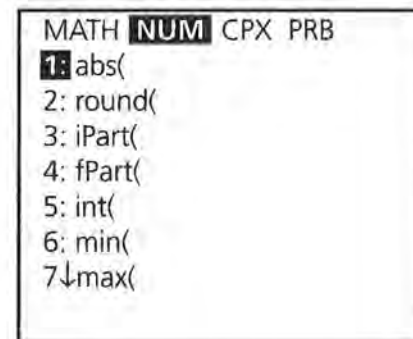


FIGURE 3

III. The STAT Menu

1. There are three basic menus under the STAT key: EDIT, CALC and TESTS. Data are entered and modified in the EDIT mode; all numerical calculations are made in the CALC mode; statistical tests are run in the TEST mode.
2. **Lists and Data Entry**
Data is entered and stored in Lists (Figure 4). Data will remain in a list until the list is cleared. Data can be cleared using CLEAR L_1 (List name), or by placing the cursor over the List heading and selecting CLEAR ENTER. To enter data, select STAT EDIT and with the arrow keys move the cursor to the list you want to use.

Type in a numerical value and press **ENTER**. Note that the bottom of the screen indicates the List you are in and the list element you have highlighted. 275 is the first entry in L1. (It is sometimes easier to enter a complete list before beginning another.)

L1	L2	L3
275	67	190
5311	144	120
114	64	238
2838	111	153
15	90	179
332	68	207
3828	94	153
L1 (1) = 275		

FIGURE 4

For data with varying frequencies, one list can be used for the data, and a second for the frequency of the data. In Figure 5 below, the L5(7) can be used to indicate that the seventh element in list 5 is 4, and that 25 is a value that occurs 4 times.

L4	L5	L6
55	1	-----
50	3	
45	6	
40	14	
35	12	
30	9	
25	4	
L5 (7) = 4		

FIGURE 5

3. Naming Lists

Six lists are supplied to begin with. L₁, L₂, L₃, L₄, L₅, and L₆ can be accessed also as 2nd L_i. Other lists can be named using words as follows. Put the cursor at the top on one of the lists. Press 2nd **INS** and the screen will look like that in Figure 6.

	L1	L2	i
	-----	-----	
Name =			

FIGURE 6

The alpha key is on so type in the name (up to five characters) and press **ENTER** (Figure 7).

PRICE	L1	L2	2
	-----	-----	
PRICE(1) =			

FIGURE 7

Then enter the data as before. (If you do not press **ENTER** the cursor will remain at the top and the screen will say error: data type.) The newly named list and the data will remain until you go to Memory and delete the list from the memory. To access the list for later use, press 2nd **LIST** and use the arrow key to locate the list you want under the **NAMES** menu. You can accelerate the process by typing **ALPHA P** (for price). (Figure 8) Remember, to delete all but the standard set of lists from the editor, use SetUp Editor from the **STAT** menu.

NAMES	OPS	MATH
↑ PRICE		
: RATIO		
: RECT		
: RED		
: RESID		
: SATM		
↓ SATV		

FIGURE 8

4. Graphing Statistical Data

General Comments

- Any graphing uses the **GRAPH** key.
- Any function entered in Y1 will be graphed if it is active. The graph will be visible only if a suitable viewing window is selected.
- The appropriate x and y scale can be selected in **WINDOW**. Be sure to select a scale that is suitable to the range of the variables.

Statistical Graphs

To make a statistical plot, select **2nd Y=** for the **STAT PLOT** option. It is possible to make three plots concurrently if the viewing windows are identical. In Figure 9, Plots 2 and 3 are off, Plot 1 is a scatterplot of the data (Costs, Seats), Plot 2 of (L3,L4), and Plot 3 is a boxplot of the data in L3.

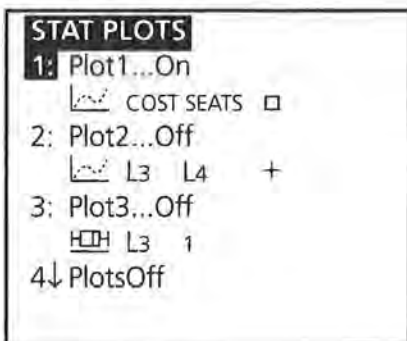


FIGURE 9

Activate one of the plots by selecting that plot and pressing **ENTER**.

Choose **ON**, then use the arrow keys to select the type of plot (scatter, line, histogram, box plot with outliers, box plot, or Normal probability plot). (In a line plot, the points are connected by segments in the order in which they are entered. It is best used with data over time.) Choose the lists you wish to use for the plot. In the window below, a scatter plot has been selected with the x -coordinate data from **COSTS**, and the y -coordinate data from **SEATS**. (Figure 10) (When pasting in list names, **2nd LIST**, press **ENTER** to activate the name and **ENTER** again to locate the name in that position.)

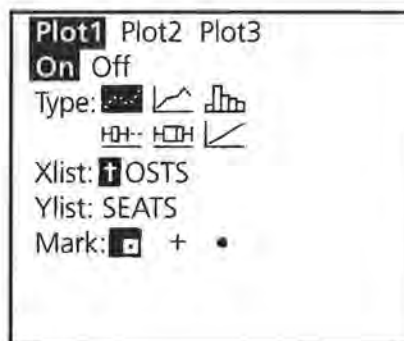


FIGURE 10

For a histogram or box plot you will need to select the list containing the data and indicate whether you used another list for the frequency or are using 1 for the frequency of each value. The x scale selected under **WINDOW** determines the width of the bars in the histogram. It is important to specify a scale that makes sense with the data being plotted.

5. Statistical Calculations

One variable calculations such as mean, median, maximum value of the List, standard deviation, and quartiles can be found by selecting **STAT CALC 1-Var Stats** followed by the list in which you are interested. Use the arrow to continue reading the statistics. (Figures 11, 12, 13)

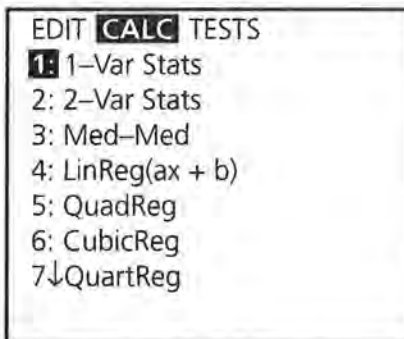


FIGURE 11

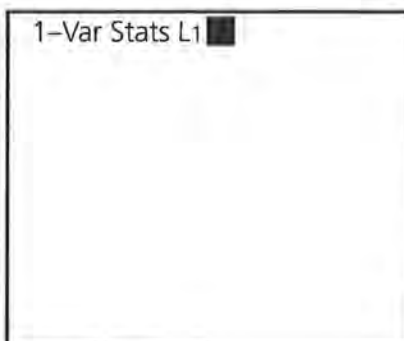


FIGURE 12

```

1-Var Stats
 $\bar{x}$  = 1556.20833
 $\Sigma x$  = 37349
 $\Sigma x^2$  = 135261515
 $S_x$  = 1831.353621
 $\sigma_x$  = 1792.79449
 $\downarrow n$  = 24

```

FIGURE 13

Calculations of numerical statistics for bivariate data can be made by selecting two variable statistics. Specific lists must be selected after choosing the 2-Var Stats option. (Figure 14)

```

2-Var Stats L1, L
2

```

FIGURE 14

Individual statistics for one or two data sets can be obtained by selecting VARS Statistics, but you must first have calculated either 1-Var or 2-Var Statistics. (Figure 15)

```

X/Y  $\Sigma$  EQ TEST PTS
1: n
2:  $\bar{x}$ 
3:  $S_x$ 
4:  $\sigma_x$ 
5:  $\bar{y}$ 
6:  $S_y$ 
7:  $\downarrow \sigma_y$ 

```

FIGURE 15

6. Fitting Lines and Drawing their graphs

Calculations for fitting lines can be made by selecting the appropriate model under STAT CALC: Med-Med gives the median fit regression; LinReg the least squares linear regression

and so on. (Note the only difference between LinReg ($ax+b$) and LinReg ($a+bx$) is the assignment of the letters a and b.) Be sure to specify the appropriate lists for x and y . (Figure 16)

```

Med-Med LCal, LFA
CAL

```

FIGURE 16

To graph a regression line on a scatter plot, follow the steps below:

- Enter your data into the Lists.
- Select an appropriate viewing window and set up the plot of the data as above.
- Select a regression line followed by the lists for x and y , VARS Y-VARS Function (Figure 17, 18) and the Y_i you want to use for the equation, followed by ENTER.

```

VARS Y-VARS
1: Function...
2: Parametric...
3: Polar...
4: On/Off...

```

FIGURE 17

```

Med-Med _CAL, LFA
CAL, Y1

```

FIGURE 18

The result will be the regression equation pasted into the function Y1. Press **GRAPH** and both the scatter plot and the regression line will appear in the viewing window. (Figure 19, 20).

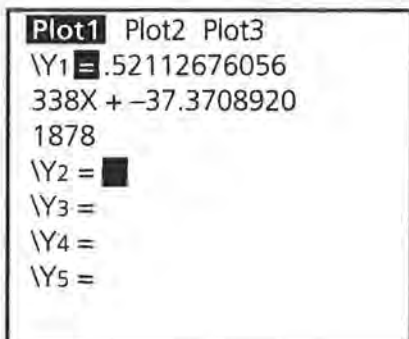


FIGURE 19

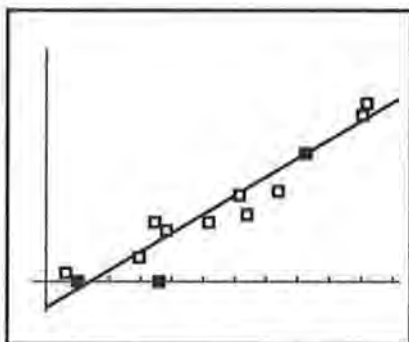


FIGURE 20

- There are two cursors that can be used in the graphing screen.

TRACE activates a cursor that moves along either the data (Figure 21) or the function entered in the Y variable menu (Figure 22). The coordinates of the point located by the cursor are given at the bottom of the screen.

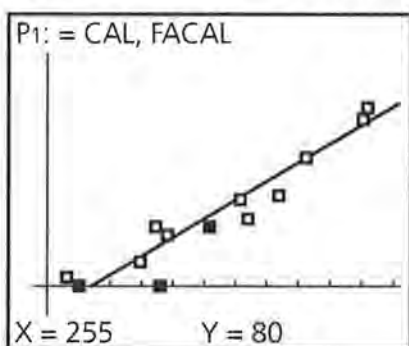


FIGURE 21

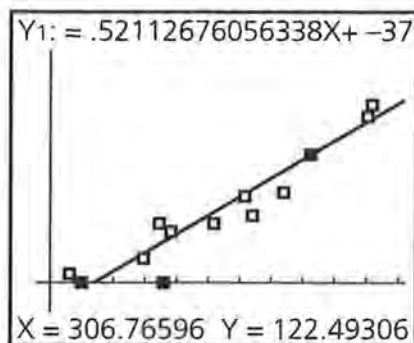


FIGURE 22

Pressing **GRAPH** returns the screen to the original plot. The up arrow key activates a cross cursor that can be moved freely about the screen using the arrow keys. See Figure 23.

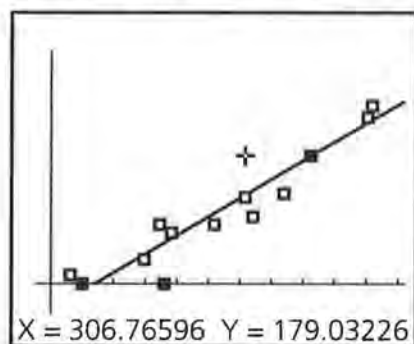


FIGURE 23

Exact values can be obtained from the plot by selecting **2nd CALC Value**. Select **2nd CALC Value ENTER**. Type in the value of x you would like to use, and the exact ordered pair will appear on the screen with the cursor located at that point on the line. (Figure 24)

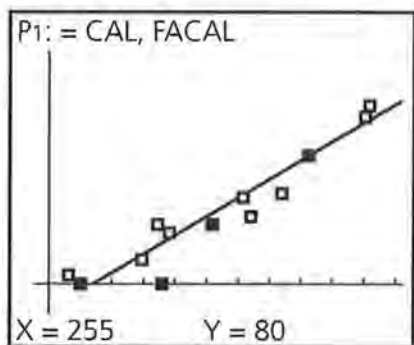


FIGURE 24

IV. Evaluating an expression:

To evaluate $y = .225x - 15.6$ for $x = 17, 20$ and 24 you can:

1. Type the expression in Y_1 , return to the home screen, $17 \text{ STO } X, T, \theta, n \text{ ENTER, VARS } Y_1 = 1 \text{ VARS Function } Y_1 \text{ ENTER ENTER.}$ (Figure 25)

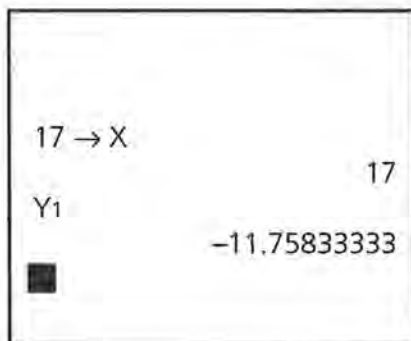


FIGURE 25

Repeat the process for $x = 20$ and 24 .

2. Type $17^2 - 4$ for $x = 17$, **ENTER** (Figure 26) Then use **2nd ENTRY** to return to the arithmetic line. Use the arrows to return to the value 17 and type over to enter 20 .

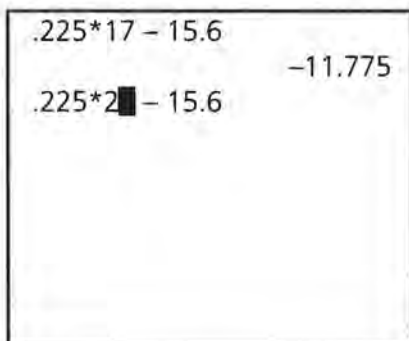


FIGURE 26

You can also find the value of x by using the table command. Select **2nd TblSet** (Figure 27). (Y_1 must be turned on.) Let $TblMin = 17$, and the increment $\Delta Tbl = 1$.

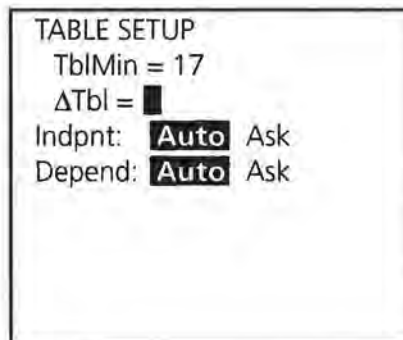


FIGURE 27

Select **2nd TABLE** and the x and y -values generated by the equation in Y_1 will be displayed. (Figure 28)

X	Y1
17	-11.76
18	-11.53
19	-11.31
20	-11.08
21	-10.86
22	-10.63
23	-10.41

X = 17

FIGURE 28

V. Operating with Lists

1. A list can be treated as a function and defined by placing the cursor on the label above the list entries. List 2 can be defined as $L1 + 5$. (Figure 29)

L1	L2	L3
275	-----	190
5311		120
114		238
2838		153
15		179
332		207
3828		153

L2 = L1 + 5

FIGURE 29

Pressing **ENTER** will fill List 2 with the values defined by $L1 + 5$. (Figure 30)

L1	L2	L3
275	280	190
5311	5316	120
114	119	238
2838	2843	153
15	20	179
332	337	207
3828	3833	153
L2(1) = 280		

FIGURE 30

- List entries can be cleared by putting the cursor on the heading above the list, and selecting **CLEAR** and **ENTER**.
- A list can be generated by an equation from $Y=$ over a domain specified by the values in L_i by putting the cursor on the heading above the list entries. Select **VARS Y-VARS Function Y1** **ENTER** (L_1) **ENTER**. (Figure 31)

L1	L2	L3
120	12	-----
110	14	
110	12	
110	11	
100	?	
100	6	
120	9	
L3 = Y1(L1)		

FIGURE 31

- The rule for generating a list can be attached to the list and retrieved by using quotation marks (**ALPHA +**) around the rule (Figure 32). Any change in the rule (Y_1 in the illustration) will result in a change in the values for L_1 . To delete the rule, put the cursor on the heading at the top of the list, press **ENTER**, and then use the delete key. (Because L_1 is defined in terms of CAL , if you delete CAL without deleting the rule for L_1 you will cause an error.)

CAL	FACAL	L1	5
255	80	-----	
305	120		
410	180		
510	250		
320	90		
370	125		
500	235		
L1 = "Y1(LCAL)"			

FIGURE 32

VI. Using the DRAW Command

To draw line segments, start from the graph of a plot, press **2ND DRAW** and select **Line(**. (Figure 33)

DRAW	POINTS STO
1:	ClrDraw
2:	Line(
3:	Horizontal
4:	Vertical
5:	Tangent(
6:	DrawF
7:	↓Shade(

FIGURE 33

This will activate a cursor that can be used to mark the beginning and ending of a line segment. Move the cursor to the beginning point and press **ENTER**; use the cursor to mark the end of the segment, and press **ENTER** again. To draw a second segment, repeat the process. (Figure 34)

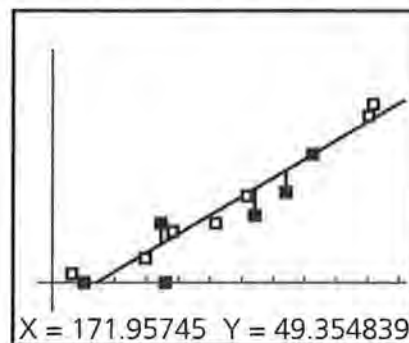


FIGURE 34

VII. Random Numbers

To generate random numbers, press **MATH** and **PRB**. This will give you access to a random number function, **rand**, that will generate random numbers between 0 and 1 or **randInt(** that will generate random numbers from a beginning integer to an ending integer for a specified set of numbers. (Figure 35) In Figure 36, five random numbers from 1 to 6 were generated.

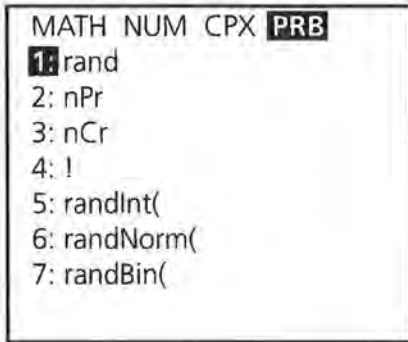


FIGURE 35

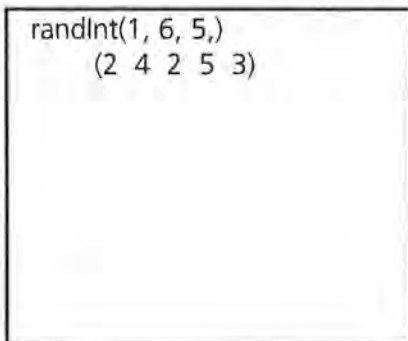
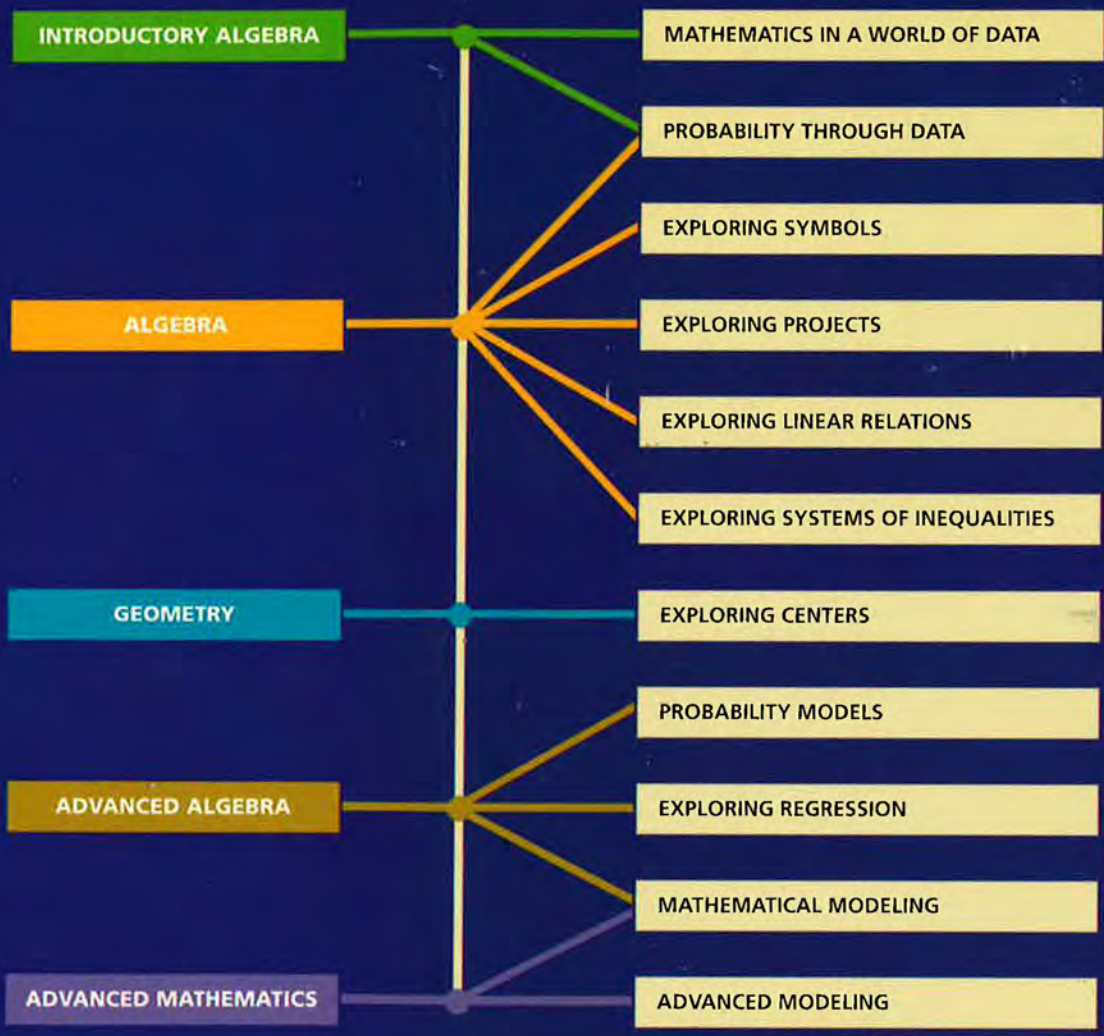


FIGURE 36

Pressing **ENTER** will generate a second set of random numbers.

Data-Driven Mathematics is a series of modules written by teachers and statisticians that focuses on the use of real data and statistics to motivate traditional mathematics topics. This chart suggests which modules could be used to supplement specific middle-school and high-school mathematics courses.



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