

# Connecting Representations of Functions

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In this lesson, the study of functions focuses on relationships in meaningful contexts and is presented through multiple methods of representations examining these relationships. An emphasis is placed on connecting representations of functions (tables, patterns and sequences, student-drawn scatter plots and line graphs, technology-assisted graphs, functions as equations) so that each can provide a different picture of the relationship.

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## Background

Seven periods of instruction; each period is based on 45 minutes.

### **Rationale**

The concept of function is one of the big ideas in all of mathematics. In the past, a study of functions was relegated to Algebra I courses. Algebra I is typically offered in Grade 8 or 9, and not all students take it. In today's world, it is important that all students develop algebraic reasoning, especially with regard to functions. *Principles and Standards for School Mathematics* (NCTM) suggests that function concepts should be integrated throughout the middle school program rather than relegated to an algebra course.

The study of functions should focus on relationships in meaningful contexts and be presented through multiple methods of representing and examining these relationships. An emphasis should be placed on connecting representations of functions (tables, patterns and sequences, student-drawn scatter plots and line graphs, technology-assisted graphs, functions as equations) so that each can provide a different picture of the relationship. Technology can aid in this.

### **Reference**

Van de Walle, John A. (2001). *Elementary and Middle School Mathematics: Teaching Developmentally*(4th ed.). Addison Wesley.

### **Standards (Grades 6-8)**

Patterns, Functions and Algebra Standard

- Represent, analyze and generalize a variety of patterns and functions with tables, graphs, words and symbolic rules.
- Relate and compare different forms of representation for a relationship.
- Identify functions as linear or nonlinear and contrast their properties from tables, graphs, or equations.
- Use mathematical models to represent and understand quantitative relationships.
- Model and solve contextualized problems using various representations, such as graphs, tables, and equations.

### **Tools/Resources**

- Calculator Based Ranger (CBR)
- TI-83 Graphing Calculator (<http://mason.gmu.edu/~mmankus/ti83/inform.htm>)
- Projection device
- Presentation computer connected to projection device
- Spreadsheet software, presentation software, word processing software
- Internet connectivity for a minimum of four student workstations, one instructor station

## Day One — The Bike Route

The strategy for the introduction of functions is whole-group instruction using the following scenario for graphing data. Students will also work in pairs to develop a written narrative of events discussed in The Bike Route.

### **Objectives**

Given 40-minutes of instruction, students will be able to:

- describe patterns of change and describe how to predict the value of one variable from the value of the other variable.
- use a graphing calculator to make graphs and tables from equations.

### **Resources**

- Calculator Based Ranger (CBR)
- TI-83 Graphing Calculator (<http://mason.gmu.edu/~mmankus/ti83/inform.htm>)
- Graph paper
- Van de Walle, John A. (2001). *Elementary and Middle School Mathematics: Teaching Developmentally* (4th ed.). Addison Wesley.

### **Fictional Scenario**

Bill woke up early one bright Saturday morning and decided to ride his bicycle to the minor league baseball park where he helps his uncle run a concession stand. Bill lives in a hilly area so his regular route provides great exercise. An alternate route takes much longer but is much flatter so his ride is more relaxing.

### **Teacher Notes**

- Discuss with students the factors that affect the speed of Bill's trip to the ballpark. Ask students, "What factors might interrupt his journey to the ball park?"
- Encourage factors that affect speed, such as stop signs, hills, flat tires, weather, and potholes. Ask students the following question to further develop their thoughts, "What would a graph of Bill's speed look like if he had to stop to fix a flat tire half way to the ballpark?"

### **Student Activity**

- In pairs, write a story that represents the eventful trip Bill makes to the ballpark.
- Have students draw a graph representing the story they have created about the route to the ballpark. Ask students to imagine what Bill's route would look like in the form of a graph.

***Whole Class Instructional Activity***

Students share their stories about Bill's trip to the ballpark.

Teacher says, "To help you draw these graphs, let's study some graphs that are already created so you can see how change affects the look of the graph." For set-up and practice activity go to <http://www.math.mtu.edu/gk-12/cbr.html>. Use Calculator Based Ranger (CBR) to play "Distance Match."

## Day 2 — Graphs and Distance

### Teacher demonstrates set-up of CBR; does a sample distance match

Teacher says, "The graphs you recreated in the distance match activity plotted your distance and speed toward and away from the motion sensor."

### Objectives

Given a 40-minute period, students will be able to:

- describe patterns of change and describe how to predict the value of one variable from the value of another variable.
- use a graphing calculator to make graphs and tables from equations.

### Resources

- Calculator Based Ranger (CBR)
- TI-83 Graphing Calculator (<http://mason.gmu.edu/~mmankus/ti83/inform.htm>)
- Download student activity sheet "Sketch-a-Graph"
- Download student Homework Assignment

### Teacher Notes

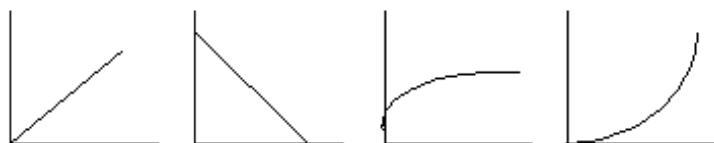
For additional student activities see *Elementary and Middle School Mathematics*, Chapter 20, pp. 415-416.

### Student Activity

Students work in pairs or groups to use CBR to recreate distance match graphs. Follow student activity sheet "Sketch-a-Graph".

### Homework Assignment

Graphing speed over time is just one way to create a graph. You can show many relationships using a graph. Suppose you were asked to show the relationship between a person's age and height. Which of the following graphs would you choose to best represent a person's height compared to his age? Explain your choice. If you feel that none of the graphs shows this relationship, draw and explain your own graph.



## Day 3 — At the Ballpark

### Objectives

Given a 40-minute period, students will be able to:

- learn some useful mathematical methods for studying patterns of change.
- make tables and graphs to show how different variables are related.

### Resources:

- Projection device
- Presentation computer connected to projection device
- Spreadsheet software, presentation software, word processing software
- Internet connectivity for a minimum of four student workstations, one instructor station

### Teacher Notes

- Teacher continues discussion of Bill going to the ballpark. Bill reached the ballpark around 10 a.m. to help get things ready for sale at the afternoon's ballgame. Before opening for the day, Uncle Vic, who owns the concession stand, asked Bill to go over the popcorn sales for the previous 12-weeks and look for any patterns that may help them predict how much popcorn to pop.
- Teacher projects the following table showing the popcorn sales for the last 12 Saturdays.

Week #	1	2	3	4	5	6	7	8	9	10	11	12
# bags popcorn sold	72	89	92	85	100	105	110	65	101	111	118	130

- Teacher prompts student responses:
  - What patterns do you notice?
  - What might account for the drop in sales on the eighth week?
  - How much popcorn should Bill suggest be popped for today's sales?
  - Explain your reasoning.
- The following activity can be facilitated as a whole-group effort, small groups in collaborative learning, or individuals in a lab environment.

### Student Activity

Get some experience of your own at being in charge of a concession stand. Go to <http://www.coolmath-games.com/lemonade/> to try your luck at turning a profit on the "Lemonade Stand" game.



## Day 5 — Graphing Calculators and Equations

### Objectives

Given a 40-minute period, students will be able to:

- learn some useful mathematical methods for studying patterns of change.
- analyze data given in tables, graphs, and written reports.
- use a graphing calculator to make graphs and tables from equations.

### Resources

- Projection device
- Presentation computer connected to projection device
- Spreadsheet software, presentation software, word processing software
- Internet connectivity for a minimum of four student workstations, one instructor station
- TI-82 or TI-83 Graphing Calculator
- Texas Instruments provides a calculator loan service a [http://education.ti.com/educationportal/sites/US/nonProductMulti/support\\_borrowtechnology.html?bid=2](http://education.ti.com/educationportal/sites/US/nonProductMulti/support_borrowtechnology.html?bid=2)

### Teacher Notes

- Have students use a graphing calculator to make a scatter plot of the weekly profits.
- Give step-by-step instructions on the use of the graphing calculator. Follow these steps for a TI-82.
  1. Turn the calculator on, press **STAT** and then **ENTER**. Type each week's number in **L<sub>1</sub>** (list one) by typing each number and then pressing **ENTER**. Use the right arrow button to move to **L<sub>2</sub>** (list two) and type in each week's profit.
  2. After you have entered your information, tell the calculator what kind of graph you want. Press **2<sup>nd</sup>** and **Y=**, then press **ENTER** for Plot 1. Select **ON** in the first row, the **scatter plot picture** (first picture in second row), **L<sub>1</sub>** in the third row and select any **mark** you would like.
  3. Next set up your window screen so that your data fits the screen. Press **WINDOW** and set your screen to the following settings:

**Xmin 0**  
**Xmax 13**  
**Xscl 1**  
**Ymin 0**  
**Ymax 50**  
**Yscl 1**

4. These settings represent the x and y axis of your graph. The x-axis will represent the weeks and the y-axis plots the amount of profit. You are now ready to press **GRAPH** to display your scatter plot. Press **TRACE** and **arrow left and right** to see the coordinates of your graph.
- For instruction on using a TI-83 graphing calculator go to <http://mason.gmu.edu/~mmankus/ti83/inform.htm>.

### ***Student Activity***

Engage students in discussion of these questions:

- Does your scatter plot on the calculator resemble the scatter plot you created by hand?
- What differences, if any, do you notice?
- What could account for these differences?

Have students display their scatter plots and discuss and explain their results.

## Day 6 — Tables and Graphs

### Objectives

Given a 40-minute period, students will be able to:

- learn some useful mathematical methods for studying patterns of change.
- analyze data given in tables, graphs, and written reports.
- use a graphing calculator to make graphs and tables from equations.
- learn how to use symbols to write equations for rules relating variables.

### Resources

- Projection device
- Presentation computer connected to projection device
- Spreadsheet software, presentation software, word processing software
- Internet connectivity for a minimum of four student workstations, one instructor station
- TI-82 or TI-83 Graphing Calculator
- Texas Instruments provides a calculator loan service at [http://education.ti.com/educationportal/sites/US/nonProductMulti/support\\_borrowit\\_echnology.html?bid=2](http://education.ti.com/educationportal/sites/US/nonProductMulti/support_borrowit_echnology.html?bid=2)

### Teacher Notes

With the whole-group, discuss:

- Tables and graphs provide many opportunities to study patterns. The relationship between the way change in one variable affects change in another is called a function.
- The function is the rule that defines how the first variable affects the second. Try to find the relationship or function of the following tables and write a rule for the relationship using a variable. The first example has been done for you.

<b>X</b>	1	2	3	4	5	6
<b>5x + 1</b>	6	11	16	21	26	31
<b>4x - 5</b>						
<b>2x + 3</b>						
<b>3x - 6</b>						

- Graphing calculators can also take a pattern and graph the pattern's equation.

### ***Student Activity***

How could you write an equation to represent the amount of profit for any number of bags of popcorn sold provided that 150 bags were always prepared ahead of time?

Answer:  $0.50n - (150 \times 0.12)$

Using your graphing calculator again, let's see what the graph of your equation looks like. Press  $Y=$  and type in your equation. Use the same settings as before and press GRAPH. You should now see both graphs at the same time.

What do you notice about your graphs?

What is the fewest number of bags you can sell and still make a profit?

What is the greatest number of bags you would recommend that Bill make? Justify your answers.

The graph of profits created a straight line showing a constant relationship between amount sold and amount popped. This straight-line graph is an example of a linear function because the rate of change is constant.

## Day 7 — Analyzing the Best Proposal

### **Objectives**

Given a 40-minute period, students will be able to:

- learn some useful mathematical methods for studying patterns of change.
- analyze data given in tables, graphs, and written reports.
- use a graphing calculator to make graphs and tables from equations.

### **Resources**

- Projection device
- Presentation computer connected to projection device
- Spreadsheet software, presentation software, word processing software
- Internet connectivity for a minimum of four student workstations, one instructor station
- TI-82 or TI-83 Graphing Calculator

### **Teacher Notes**

Using whole group instruction, discuss the following,

- Functions represented in graph form can take on many different appearances. Explore another type of function.
- At the end of each baseball game, Uncle Vic is responsible for picking up litter. Uncle Vic would rather not have to do this so he offered to pay Bill \$1 for clean-up this Saturday and promised to double Bill's pay every Saturday for the next 12 weeks.
- Bill felt he deserved to be paid \$40 each game for the next 12 weeks.
- If you were Bill's financial advisor, which plan would you recommend?

### **Student Activity**

- Investigate each plan using any method you prefer (table, paper-pencil graph, graphing calculator graph).
- Develop a way to present your findings to Bill (PowerPoint presentation, poster, Excel spreadsheet). Include a written explanation of your findings in a summary report.
- When you have completed your graphs for the two plans, answer these questions:
  1. What differences did you see in the appearance of the graphs?
  2. Did you notice that one plan created a straight line and the other plan formed a curve? The straight-line graph was another example of a linear function.
  3. The curved graph represented a different kind of function. It was nonlinear in appearance. We call a curved graph of this sort an exponential function. Why do you think it is called an exponential function?

Try to discover an equation for the curved graph. How is the curved-graph equation different from the straight-line equation?

## Integrated Lesson Rubric

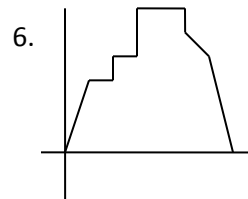
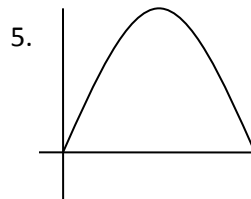
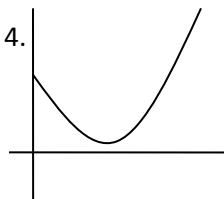
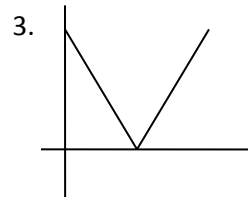
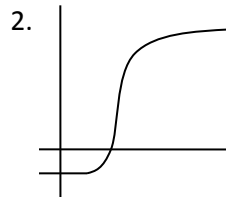
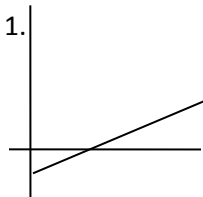
	<b>4 Points</b>	<b>3 Points</b>	<b>2 Points</b>	<b>0 Points</b>
<p>Learn how to use symbols to write equations for rules relating variables.</p> <p>Homework Assignment</p>	Equation is accurate and concisely written.	Equation will produce accurate results but may not be written as concisely as possible.	Equation is workable but mathematically unorganized.	Not a workable equation.
<p>Analyze data given in tables, graphs, and written reports.</p> <p>Graphing Calculator Activity Age and Height</p>	Analysis shows a thorough and complete interpretation of data.	Analysis provides essential aspects of interpretation but is partially thorough.	Analysis provides partial interpretation. Missing some key components.	Failed to analyze any data correctly.
<p>Make tables and graphs to show how different variables are related.</p> <p>Popcorn Scatter Plot</p>	Tables and graphs contain correct data, properly titled and labeled.	Tables and graphs contain correct data, but label or title is missing.	Tables and graphs contain data that is mostly correct but have minor flaws.	Tables and graphs are incomplete and inaccurate.
<p>Graph motions using a digital device (CBR).</p> <p>Distance Match Sketch-a-Graph</p>	Works cooperatively with partner/group and successfully completes all matches.	Works cooperatively with partner/group but does not participate fully.	Is able to reproduce some of the matches but does not work effectively with group/partner.	Refuses to work in partner/group setting and does not reproduce distance matches.
<p>Learn some useful mathematical methods for studying patterns of change.</p> <p>Sketch-a-Graph</p>	Accurately sketches all 6 scenarios.	Accurately sketches 4 to 5 of the 6 scenarios.	Accurately sketches 2 to 3 of the scenarios.	Inaccurately sketches the scenarios or makes no sketches.
<p>Use a graphing calculator to make graphs and tables from equations.</p> <p>Distance Match</p>	Successfully creates desired table or graph.	Creates a table or graph with minor imperfections such as wrong data or slight error in equation.	Creates a table or graph that contains several mistakes, such as wrong equation.	Unable to create table or graph.

## Student Resource—Sketch-a-Graph

Sketch a graph for each of these situations. No numbers or formulas are to be used.

1. The temperature of a frozen dinner from 30 minutes before it is removed from the freezer until it is removed from the microwave and placed on the table. (Consider time 0 to be the moment the dinner is removed from the freezer.)
2. The value of a 1970 Volkswagen Beetle from the time it was purchased to the present. (It is in top condition.)
3. The level of water in the bathtub from the time you begin to fill it to the time it is completely empty after your bath.
4. Profit in terms of number of items sold.
5. The height of a baseball in terms of time from when it is thrown straight up to the time it hits the ground.
6. The speed of the baseball in the situation in number 5.

Have students sketch their graphs on transparencies without identifying which situation is being graphed (no labels on the graphs). Let students examine the graphs to see if they can determine which situation goes with each graph. Examine the graphs for one situation drawn by several students to decide which graph represents a situation best and why. Ask students to match the graphs below with the six situations? Discuss how these graphs compare to the students sketched?

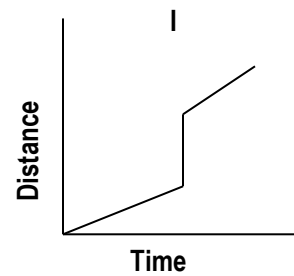
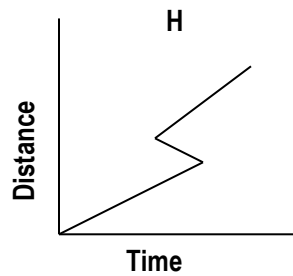
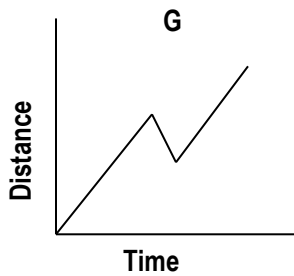
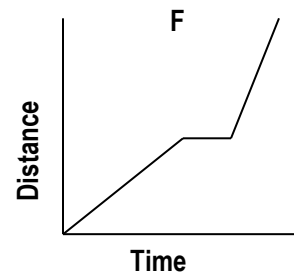
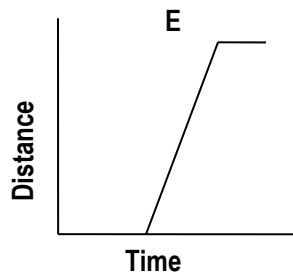
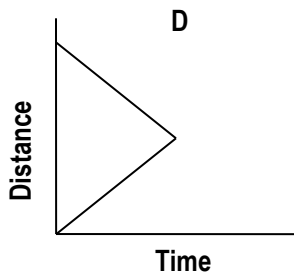
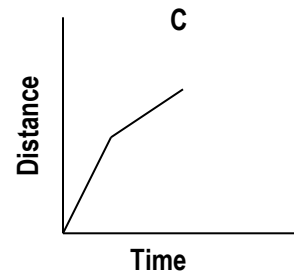
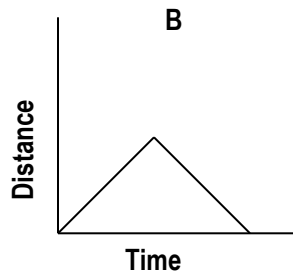
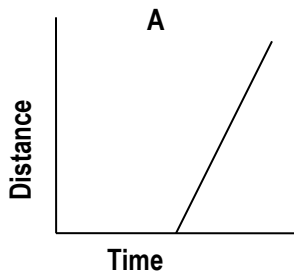


## Student Resource—Time and Distance

A car traveling at about 45 mph approaches a stop sign. It stops for the sign and then accelerates to the same 45-mph speed. Sketch a graph of the *distance* the car has traveled from the beginning of the story to the end. The horizontal axis should be *time*. In other words, the graph should show distance as a function of time. How would a graph of the speed of the car look over the same interval?

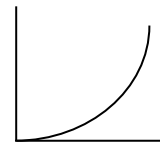
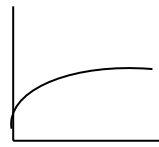
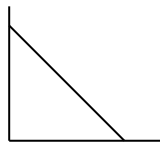
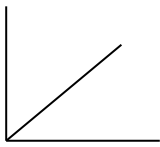
### Create a Journey Story

Suppose that a student has created the time-distance graphs shown below. Each is supposed to represent the journey of a single vehicle or person. Some of them are impossible and could not represent any journey. First identify the impossible graphs. Then make up a plausible story for each of the remaining graphs.



## Student Resource—Homework Assignment

Graphing speed over time is just one way to create a graph. You can show many relationships using a graph. Suppose you were asked to show the relationship between a person's age and height. Which of the following graphs would you choose to best represent a person's height compared to his age? Explain your choice. If you feel that none of the graphs shows this relationship, draw and explain your own graph.







## Student Resource—Graphing Profits Worksheet

How could you write an equation to represent the amount of profit for any number of bags of popcorn sold provided that 150 bags were always prepared ahead of time?

<b>X</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
$5x + 1$	6	11	16	21	26	31
$4x - 5$						
$2x + 3$						
$3x - 6$						

Using your graphing calculator again, let's see what the graph of our equation looks like. Press **Y=** and type in your equation. Use the same settings as before and press **GRAPH**. You should now see both graphs at the same time.

What do you notice about your graphs?

What is the fewest number of bags you can sell and still make a profit?

What is the greatest number of bags you would recommend that Bill make? Justify your answers.

## Student Resource—Final Presentation Project

Find the best solution based on the following story:

At the end of each baseball game, it is Uncle Vic's responsibility to pick up litter. This is a job that Uncle Vic would rather not have to do so he offered to pay Bill \$1 for clean-up this Saturday and promised to double Bill's pay every Saturday for the next 12 weeks. Bill felt he deserved to be paid \$40 each game for the next 12 weeks.

If you were Bill's financial advisor, which plan would you recommend?

Be sure to:

1. Investigate each plan using any method you prefer (table, paper-pencil graph, graphing calculator graph).
2. Develop a way to present your findings to Bill (PowerPoint presentation, poster, Excel spreadsheet). Be sure to include a written explanation of your findings in a summary report.
3. When you have completed creating your graphs for the two plans, answer these questions:
  - What differences did you see in the appearance of the graphs?
  - Did you notice that one plan created a straight line and the other plan formed a curve? The straight-line graph was another example of a linear function.
  - The curved graph represented a different kind of function. It was nonlinear in appearance. We call a curved graph of this sort an exponential function. Why do you think it is called an exponential function?
  - Try to discover an equation for the curved graph. How is the curved-graph equation different from the straight-line equation?

# Additional Teaching Resources

## **Assessment & Evaluation**

Teaching Methods Resources

<http://www.mhhe.com/socscience/education/methods/resources.html#evaluation>

Alternative Instruction and Alternative, Performance-Based Assessment

<http://mathforum.org/~sarah/Discussion.Sessions/biblio.assessment.html>

Methods of Assessment

<http://jeffcoweb.jeffco.k12.co.us/isu/math/mathsd/assess/assessmeth.html>

## **Teaching Resources**

The Math Forum Internet Mathematics Library

<http://mathforum.org/library/>

eTech Ohio's eCommunity

<http://www.etech.ohio.gov/>

Instructional Strategies

<http://www.sabine.k12.la.us/vrschool/instructstrat.htm>

## **Extension Activities for Connecting Representations of Functions**

*Use the following URLs to locate additional learning experiences for teachers and their students.*

Modeling Motion: High School Math Activities with the CBR

[http://education.ti.com/educationportal/sites/US/nonProductSingle/activitybook\\_cbr\\_modeling.html](http://education.ti.com/educationportal/sites/US/nonProductSingle/activitybook_cbr_modeling.html)

maths online

<http://www.univie.ac.at/future.media/moe/>

## **Assistive Technology Resources**

National Institute on Disability and Rehabilitation Research (NIDRR)

<http://www.ed.gov/about/offices/list/osers/nidrr/about.html>

Information Technology Technical Assistance and Training Center

<http://www.ittatc.org>

Assistive Technology Act of 1998 - RESNA

<http://www.resna.org/taproject/library/laws/ata98sum.html>

## Sample Lesson Review and Analysis

1. The lesson meets the Ohio Academic Content Standards and learning outcomes.
  - This lesson includes patterns, relations, functions, algebra, number sense, data analysis, and representations and problem solving.
  - Content is integrated, contextualized, and intriguing. The authors included real-world applications and connected them to an interesting grade-level-appropriate story line. This story line provides for natural links to other subject areas.
2. The lesson incorporates technology appropriate for supporting learning goals, including Ohio academic goals, and individualized student needs.
  - The authors made use of graphing calculators, spreadsheets, the Internet, CBRs (Calculator-Based Ranger), and web pages.
  - The technology supports learning goals and academic standards. For each lesson, the equipment needed is listed and links to support materials are provided. Most of this lesson could not be done without technology. Technology is a real value added here.
  - Because this lesson addresses the content from many representations and perspectives, students with different learning styles and abilities will benefit.
3. The lesson incorporates technology appropriate for the professional development requirements of the National Council for Accreditation of Teacher Education (NCATE) or other professional development licensure needs.
  - This lesson provides a matrix in three parts and one is for the professional development person. Many resources are included.
4. Technology is integral to learning in the lesson.
  - In this lesson, many activities require technology. For example, one activity uses the Calculator-Based Ranger (CBR), a motion detector that is used to determine the relationship between variables such as time and distance.
  - This type of technology increases student participation and enthusiasm for learning.
5. Technology use in the lesson empowers learners.
  - Because the authors included many resources, directions, links, and extensions, this lesson is as "stand-alone" as one can get. The learner is empowered because the authors did a good job of anticipating questions and needs.
  - For novice users of graphing calculators and spreadsheets, there are tutorial links. For schools without graphing calculators, there is information about a calculator loan program.
  - The special needs addressed by this lesson include the varied learning styles of students.

6. The lesson promotes a variety of research-based instructional strategies and takes into account various learning and teaching styles.
  - Instructional strategies included in this lesson range from direct step-by-step instruction to inquiry-based explorations. This lesson allows for many styles of teaching and learning.
  - The questions in this lesson are multileveled. Most of the assignments require higher-level thinking and reflection.
7. The lesson engages students in learning that is anchored in the diverse needs of individuals.
  - There are group activities, paired activities, and individual activities.
8. The lesson requires students to be active participants, explorers and researchers.
  - The content includes many important mathematical concepts embedded in an interesting story line. The real-world context will engage the learners, the multiple representations will clarify the concepts, and the questions and assignments will assist the learners in solidifying their learning.
  - Many of the activities are explorations.
9. The lesson requires students to demonstrate conceptual understanding, not just recall.
  - The final presentation provides for numerous opportunities for students to demonstrate conceptual understanding.
10. The lesson encourages students to develop understanding and create personal meaning through reflection.
  - This lesson provides numerous opportunities for students to develop understanding mathematical understanding through reflection.
11. The lesson requires students to relate knowledge to real-world contexts.
  - Every major component of this lesson relates knowledge to real world contexts.
  - There are many resources available to support the students' understanding of the concepts.
  - The lesson is rich with ideas to engage or support real world applications.
12. The lesson promotes a variety of assessments that align with Ohio standards, learning outcomes, instructional strategies, and technology use.
  - This lesson provides numerous opportunities for both formal and informal assessment and both formative and summative evaluation.
  - The use of technology is an integral part of many performance assessments.

13. Lesson assessments promote teacher understanding of a variety of assessment tools and how to implement them.

- A list of the worksheets and assignments are presented below a well-developed rubric.
- The depth of assessment and the types of assessments provided make this a great resource for teachers.
- In the teacher resource section, the lesson plans and teacher notes are complete with reasonable directions for assessment. Assessment tasks, questions, and rubric are provided.

14. Lesson assessments support and expand upon students' learning and inform stakeholders.

- In several of the assignments, students are asked to study a pattern and predict outcomes. They are also asked to find the best buy and the best rate.
- The type of data produced here will be that from performance assessment and from rubric scores. There are also writing samples that would have to be studied qualitatively.

15. Lesson assessments are performance-based and advance higher-order thinking and knowledge construction.

- This lesson does a great job of using performance-based assessment and advances and knowledge construction.
- There are a number of assignments for which the students have to transfer their newly learned knowledge to a new situation.