



Tom Snyder Productions®
A Scholastic Company

The Research Basis for Graphing and Data Analysis Software Tools to Support Instruction in Grades K–8

Grades K–4



Grades 4–8



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The Research Basis for Graphing and Data Analysis Software Tools to Support Instruction in Grades K–8

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Introduction

This paper describes research in areas of graphing and data analysis where K–8 students struggle and shows how *The Graph Club 2.0* and *Graph Master*, software tools published by Tom Snyder Productions, support teaching and learning in these critical areas.

Graphing and Data Analysis – An Instructional Challenge

In our information-driven world, the ability to graph and interpret data is a critical skill. Every day, we are confronted with graphs and tables conveying important information—from election results to social trends to fluctuations in the stock market. In school, students evaluate data not only in math class but across a range of subject areas—whether analyzing graphs of historical trends or charting results from a science experiment.

Not surprisingly, statistical literacy has become "a major goal of the school curriculum" (Ben-Zvi, 2000). Once the province of college curricula, statistics and data analysis are now considered important topics in all grades, beginning in the primary years. The National Council of Teachers of Mathematics has recommended greater emphasis on data analysis within the mathematics curriculum at every grade level, and national standardized tests, such as the National Assessment of Educational Progress, have increased the proportion of test items in this area (Shaughnessy & Zawojewski, 1999).

However, data analysis remains a challenge for students (Lajoie & Romberg, 1998). At the primary level, students typically have trouble making the transition from concrete "object graphs" to abstract representations of data. In later elementary and middle school, they often fail to develop the deep conceptual understanding necessary to perform higher-level data analysis skills. Many students have difficulty drawing inferences or making predictions, identifying appropriate ways to display data, or recognizing when a graph's scale has been manipulated to mislead. In short, they struggle with "exactly the [skills] that people need in their everyday lives" (Shaughnessy & Zawojewski, 1999).

The Graph Club 2.0 and *Graph Master* – Tools to Support Instruction

Developing data analysis skills takes time. These skills must be learned early and reinforced often. *The Graph Club 2.0* and *Graph Master*, two software tools published by Tom Snyder Productions, provide an effective and engaging way to teach graphing and data analysis skills throughout the elementary and middle school years. *The Graph Club 2.0*, designed for grades K–4, features a flexible, manipulative environment that introduces students to fundamental graphing concepts and helps them make the transition from concrete to abstract representations of data. *Graph Master*, designed for grades 4–8, allows students to explore more complex sets of data and master higher-level data analysis skills. These two programs give K–8 teachers powerful resources for teaching graphing and data analysis, and they help students build the solid conceptual foundation they need for success in school and in life.

Graphing and Data Analysis in Grades K–4:

The Graph Club 2.0

Research reveals five important areas of the graphing and data analysis curriculum where elementary students struggle:

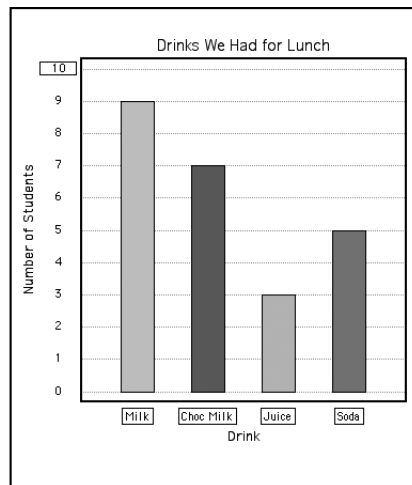
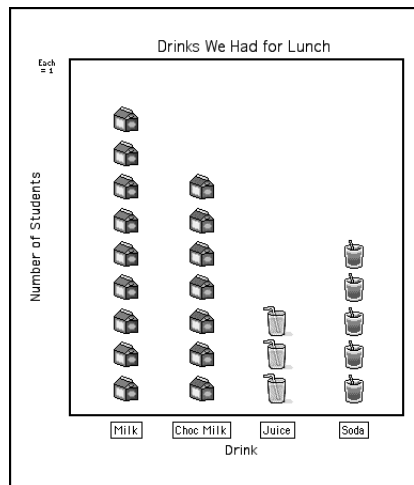
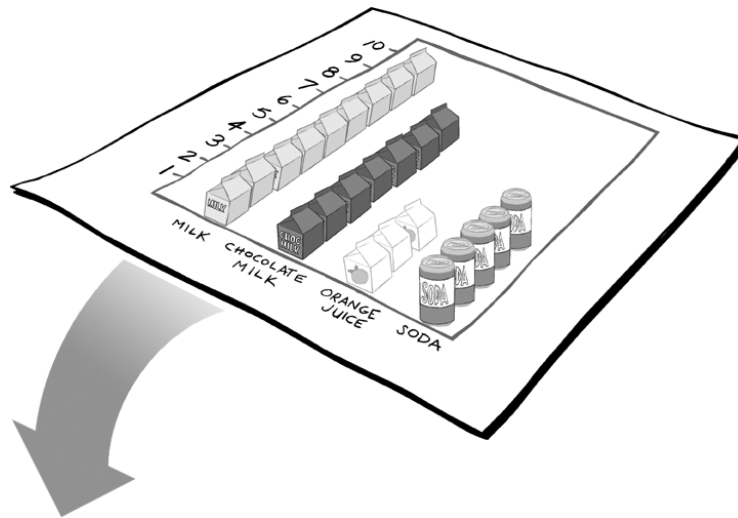
- 1 The transition from concrete to abstract
- 2 Data representations
- 3 Classification
- 4 Scale
- 5 Graph interpretation

The Graph Club 2.0, a graphing software program for grades K–4, was designed by Peggy Healy Stearns, Ph.D., to address these key areas of need.

I The Transition from Concrete to Abstract

The Research

When primary students are introduced to graphing, they typically begin by creating “object graphs” in which physical objects (e.g., shoes, milk cartons, attribute blocks) are sorted and lined up to form a real-life picture graph. However, students often have trouble connecting these real objects to abstract representations (Friel, Curcio, & Bright, 2001).



Students have difficulty making the transition from concrete “object graphs” to abstract representations of data.

The Graph Club 2.0

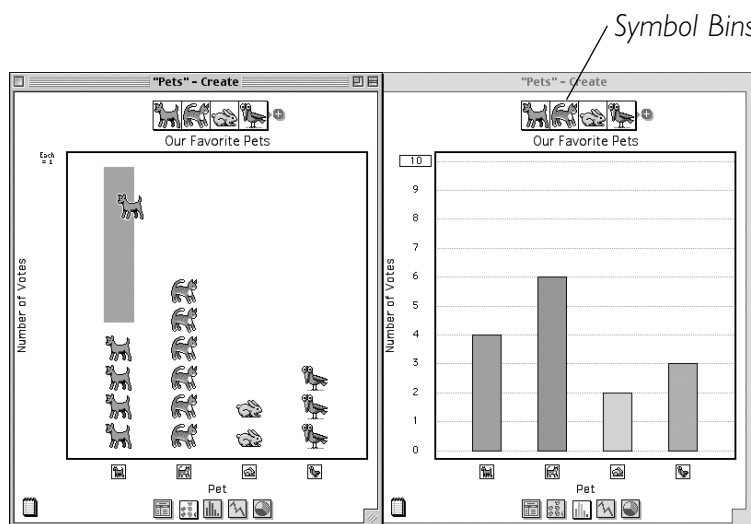
The Graph Club 2.0 helps students make the transition from concrete to abstract representations of data.

A Manipulative Software Environment

Research shows that computer software plays an important role in bridging the gap between concrete and abstract representations. In contrast to physical manipulatives, software can provide immediate visual or auditory feedback—linking students' physical experiences with corresponding symbolic representations (Clements & McMillen, 1996).

In *The Graph Club 2.0*, each category of data is represented by a graphic symbol that functions much like the physical objects in an object graph. Students drag these symbols one at a time from the “symbol bins” to the appropriate location on the graph. The program reinforces the addition of each new symbol by counting aloud.

This concrete approach to manipulating data in a graph helps students connect the real objects in an object graph to abstract representations (pictures of objects in a picture graph, or the height of a bar in a bar graph). As students begin to understand these representations, *The Graph Club 2.0* lets them progress to more abstract and efficient methods of adding data, such as dragging the top of a bar to the desired height, or simply typing a numerical value in a table.



Students drag symbols from the symbol bins into the appropriate columns.



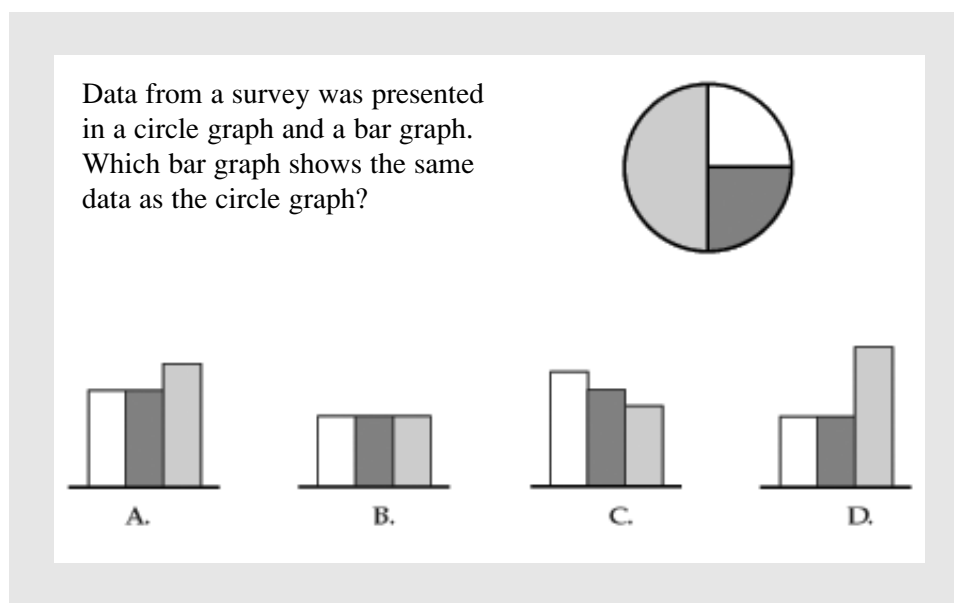
Pictorial Symbols

Whenever students create a graph with *The Graph Club 2.0*, they begin by choosing appropriate symbols for each category in the graph. These detailed, pictorial symbols help students visualize the connection between symbols and the concrete objects they represent. Students and teachers can choose from a library of more than 450 colorful symbols. They can also create and import their own symbols, custom designed to match classroom manipulatives or other objects.

2 Data Representations

The Research

The NCTM Principles and Standards for School Mathematics (2000) identifies “compar[ing] different representations of the same data” as an important skill. Specifically, students need the ability to translate among various representations of the same data and recognize when one representation is more useful than another (Bright & Friel, 1998). Questions asking students to translate from one representation to another are common on state and national tests. A typical example appears below.



SOURCE: Florida Department of Education, Florida Comprehensive Assessment Test, 2001, Mathematics assessment, Grade 5.

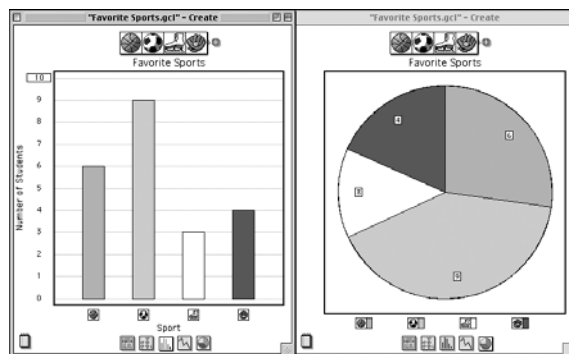
Studies show that students have difficulty recognizing the same data when it is presented in different ways (Kerslake, 1981; Bright & Friel, 1998). To address this problem, teachers should provide students with numerous opportunities “to compare multiple representations of the same data set” and engage students in “rich discourse on what each of the representations shows” (Bright & Friel, 1998).

The Graph Club 2.0

The *Graph Club* 2.0 makes it easy for students to view and compare different representations of the same data.

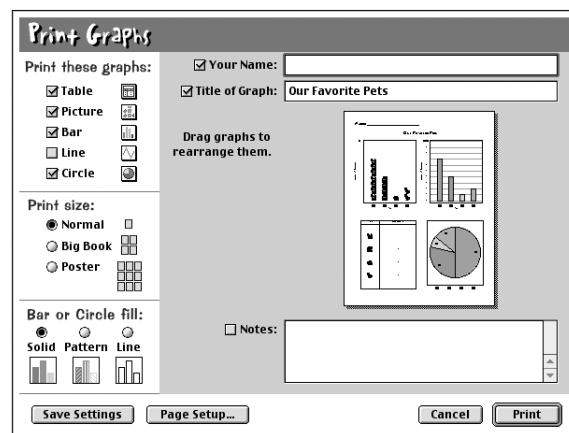
Dynamic Side-by-Side Graphs

Whenever students open a new file using *The Graph Club* 2.0, they are presented with two side-by-side representations of the same data. As students make a change to one graph (for example, by dragging additional symbols into a picture graph), the other graph changes dynamically, helping students see the relationship between the two representations. This feature also supports students as they make the transition from more concrete to more abstract types of graphs (e.g., picture to bar).



Multiple Graph Types

The *Graph Club* 2.0 allows students to display up to five different representations of the same data on-screen at one time: table, picture graph, bar graph, line graph, and circle graph. Using the program's Graph Type buttons, students can easily switch from one representation to another. Students can also print up to five graph types on one page using the program's versatile Print Graphs dialog. (Since line graphs should only be used to show change over time, teachers can turn off the line graph option when it is not appropriate.)

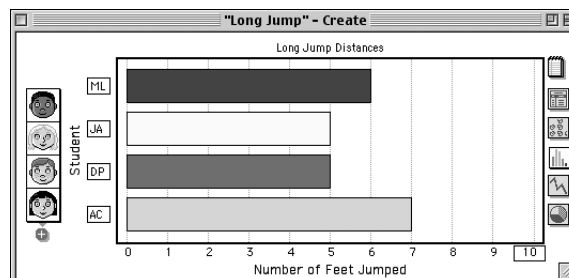


Matching Practice

The program's Match mode gives students practice translating from one representation of data to another. In this fun activity, students are provided one graph type (e.g., bar) and must change another graph type (e.g., circle) to match. The program provides feedback on correct answers and gives students the opportunity to correct their mistakes.

Horizontal and Vertical Views

The *Graph Club* 2.0 allows students to view and print graphs that are displayed either vertically or horizontally. Students can explore and discuss which view is most appropriate for a given set of data. For example, a horizontal graph might be preferable when comparing the distances students can jump.



3 Classification

The Research

Sorting and classification are critical skills. Students who develop these skills during kindergarten (along with related skills such as sequencing) are significantly more likely than their peers to succeed academically throughout elementary school (Dudek, Strobel, & Thomas, 1987; Silliphant, 1983). Often, young children classify items inappropriately, even on “simple properties such as form, size, orientation, function, or type” (Pasnak, Holt, Campbell, & McCutcheon, 1991). Teachers can help students develop classification skills by giving them many practice opportunities with a wide variety of objects.

The Graph Club 2.0

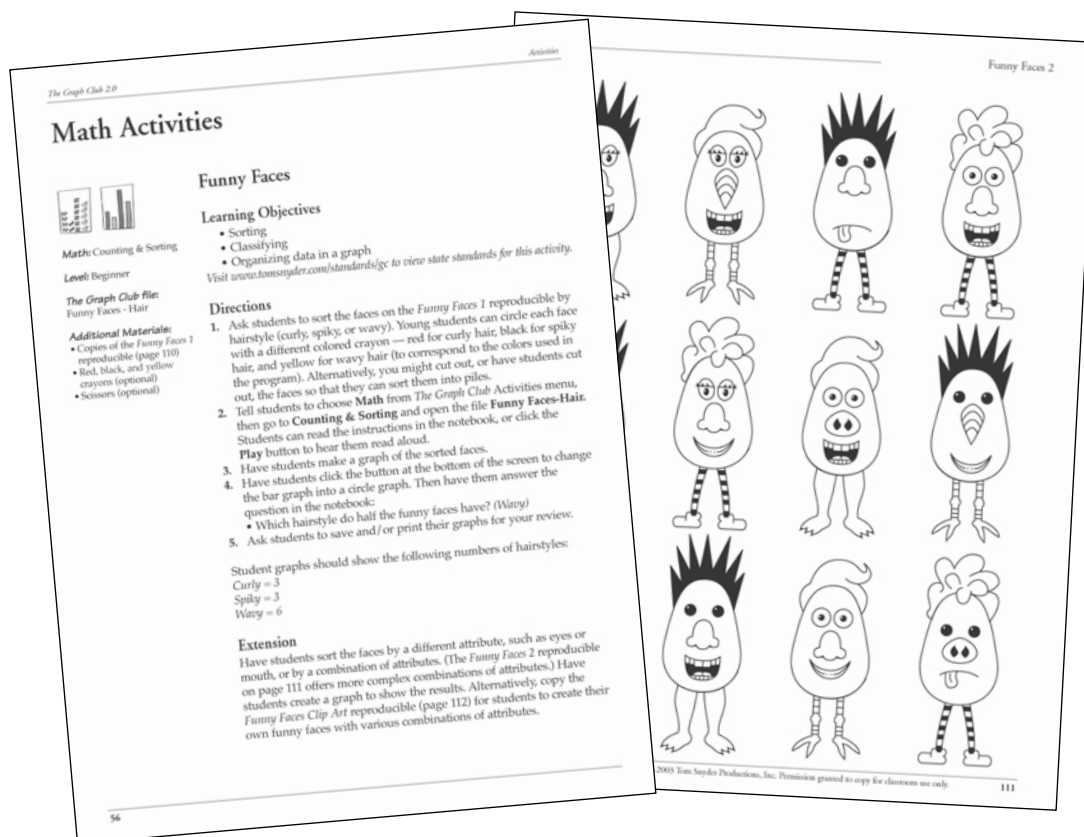
The Graph Club 2.0 reinforces sorting and classification skills.

Sorting Symbols

Unlike some other elementary graphing programs, which sort data automatically, *The Graph Club 2.0* provides students with a hands-on sorting experience each time they make a graph. When students create a graph using the program, they add data to a category by dragging symbols into the corresponding column (for example, the cat symbol must be dragged to the cat column). A reinforcing sound (“bing”) confirms that students have dragged a symbol to the correct location. The program’s extensive library of symbols allows students to sort and graph everything from animals or food to hair color or weather—reinforcing classification skills in a wide variety of contexts.

Classification Activities

The Graph Club 2.0 and the accompanying Ready-Made Activities contain a variety of activities focusing on sorting and classification skills. Some activities (e.g., Attribute Block Shapes) require students to sort classroom manipulatives, then graph the results. Others (e.g., Funny Faces) include reproducible masters featuring graphic symbols that students can cut out and sort by hand.



Funny Faces Activity and Reproducible

The Research

Understanding a graph's scale is essential to making sense of the data it displays, yet students typically pay little attention to scale when interpreting graphs. Many students assume that every "tick mark" on a scale represents a single unit and misread graphs in which the scale uses a different increment (Dunham & Osborne, 1991). Increments of more than one unit can be particularly challenging for young students, who often have a limited ability to count by 2s, 5s, 10s, etc. (Friel, Curcio, & Bright, 2001).

Students also frequently fail to understand how the proportions of a graph are affected by scale (Goldenberg et al., 1988; Kerslake, 1981). When a graph's proportions change, students assume that the data has changed. They don't realize that the same data can look radically different when displayed with a different scale.

The Graph Club 2.0

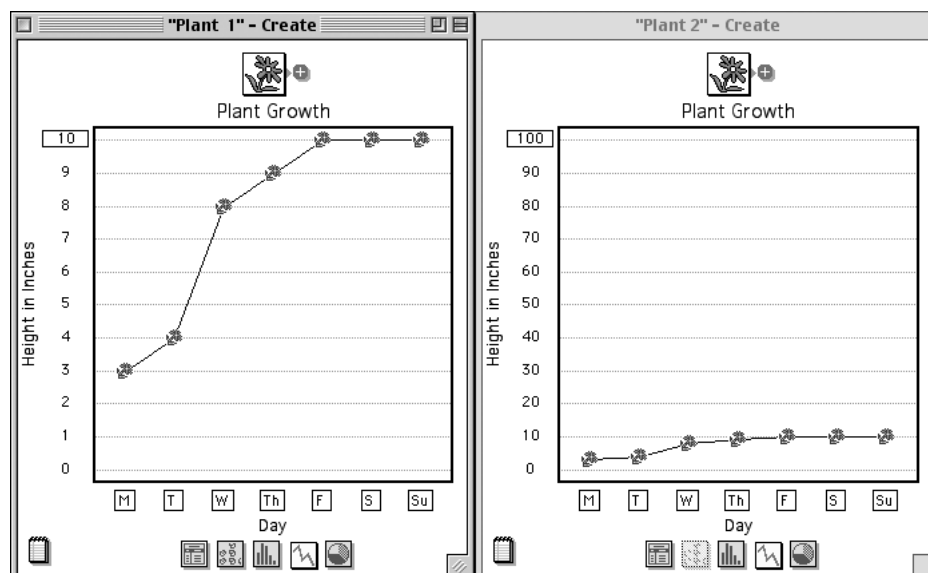
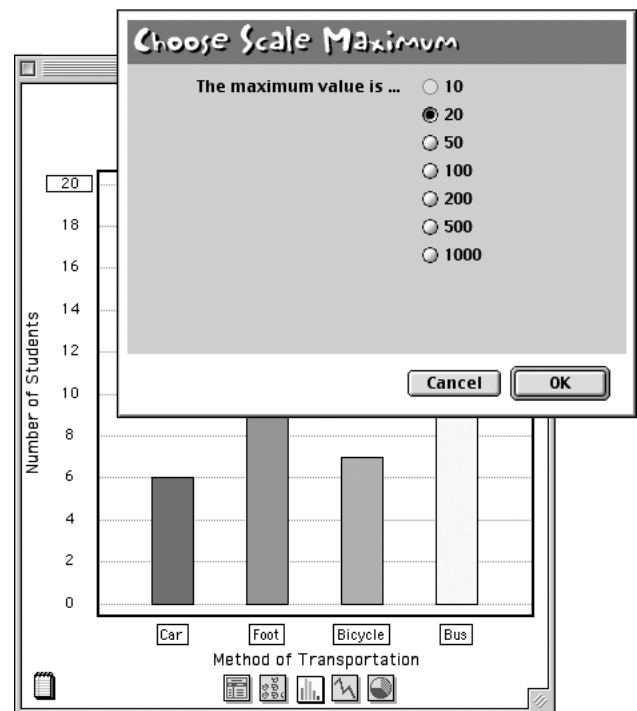
The Graph Club 2.0 helps students explore and understand scale.

Simplified Scale Options

When students create a graph using *The Graph Club 2.0*, the scale initially appears with a maximum of 10 and an increment of 1—the simplest scale for young students to understand. As they begin working with larger data values, students can easily change the scale. The Choose Scale Maximum dialog is easy for even primary students to use and allows them to work with data values as high as 1000, building experience with scale increments of 2, 5, 10, 20, 50, and 100.

Comparing Scales

Research shows that extensive practice exploring and describing the effects of scale helps students develop “scale sensitivity” and become more critical of misleading graphs (Ben-Zvi, 2000). *The Graph Club 2.0* allows students to change a graph’s scale easily, making it simple for students to explore how scale changes can affect a graph’s appearance and can distort trends.

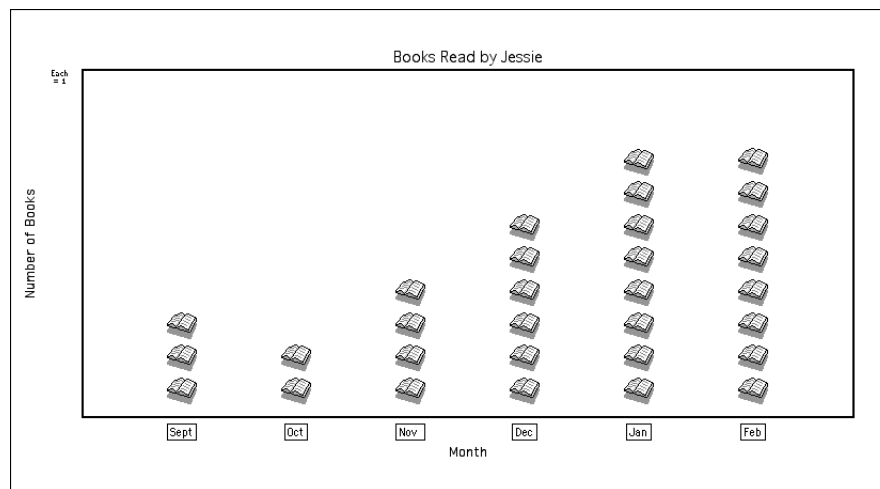


Students can explore how the same data looks when displayed with different scales.

The Research

A critical goal of the data analysis curriculum is to teach students to interpret data in order to make decisions and solve problems. However, studies show that students struggle with all but the most basic interpretive tasks.

Researchers have identified three levels of graph-interpretation skill that students should master (Curcio, 1987; Wainer, 1992). The first level involves extracting specific values from a graph: *How many books did Jessie read in November?* The second level requires integrating information from different parts of the graph: *How many more books did Jessie read in February than in September?* The third level involves understanding the data set as a whole, making predictions or noticing trends: *How many books do you think Jessie might read in March, and why?* While students generally can extract data values from a graph (a lower-level task), they perform poorly on higher-level tasks that involve additional computation or inference (Shaughnessy & Zawojewski, 1999).



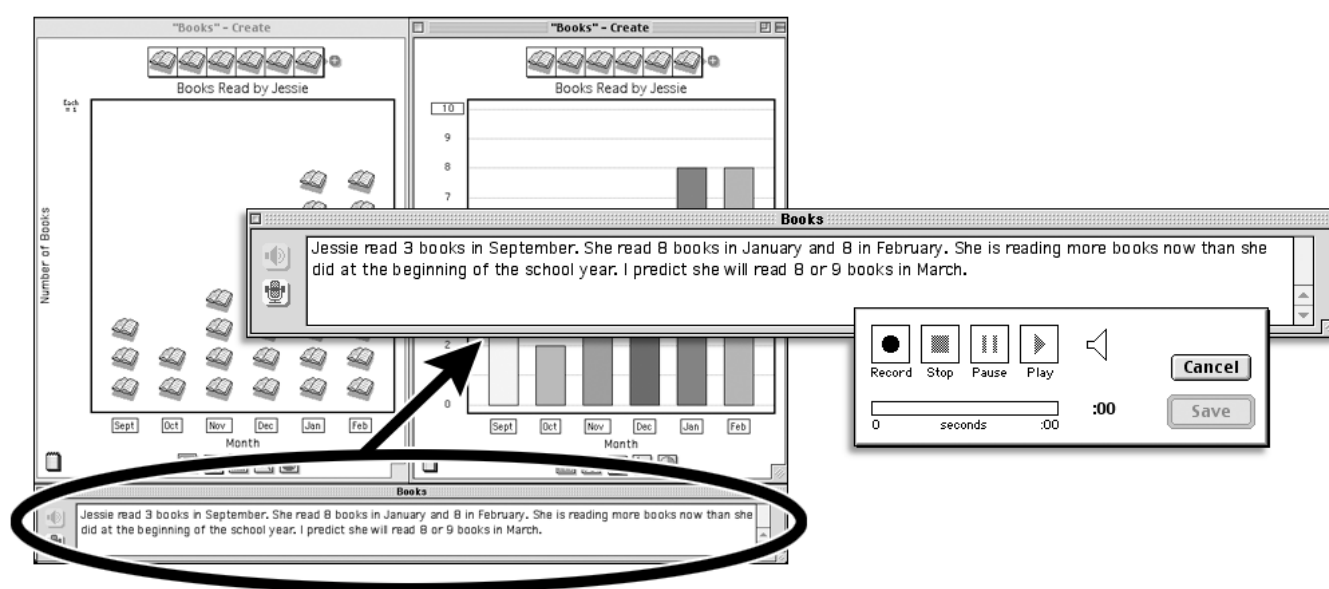
Students also have difficulty expressing their mathematical ideas in writing. This is particularly true for younger students. One study, for example, found that “the quality of students’ written work [was] inferior to their verbal reasoning” on statistics questions (Jacobs, 1993). Providing opportunities to speak as well as write about their statistical ideas helps all students demonstrate their understanding.

The Graph Club 2.0

The *Graph Club 2.0* was designed to support students as they build skills in data analysis and interpretation.

Built-in Notebook

The program includes a built-in notebook feature, encouraging students to interpret and write about their graphs. Notebook text can be printed with graphs and assessed.



The notebook also includes an audio feature that lets students record their ideas orally. This provides a scaffold for students to express more complex ideas, as well as an alternative for younger students or those whose writing skills are less developed. As students write and talk about their graphs, they develop a better understanding of their data.

Real-World Questions

The *Graph Club* includes more than 30 standards-aligned activities built around real-world questions, providing extensive practice with graph interpretation. (An additional 75 standards-aligned activities are available on the Ready-Made Activities CD.) In some activities, students collect data about themselves and their world, answering questions such as *How do you spend your time on a typical day?* or *How high does a ball bounce when dropped from different heights?* In other activities, students analyze and interpret existing graphs of historical, scientific, or economic data (e.g., dairy production, immigration trends). The emphasis on real-world questions encourages students to view data analysis as a tool for inquiry (McGatha, Cobb, & McClain, 1998), and motivates more thoughtful interpretation.

Graphing and Data Analysis in Grades 4–8:

Graph Master

Research reveals five important areas of the graphing and data analysis curriculum where upper elementary and middle school students struggle:

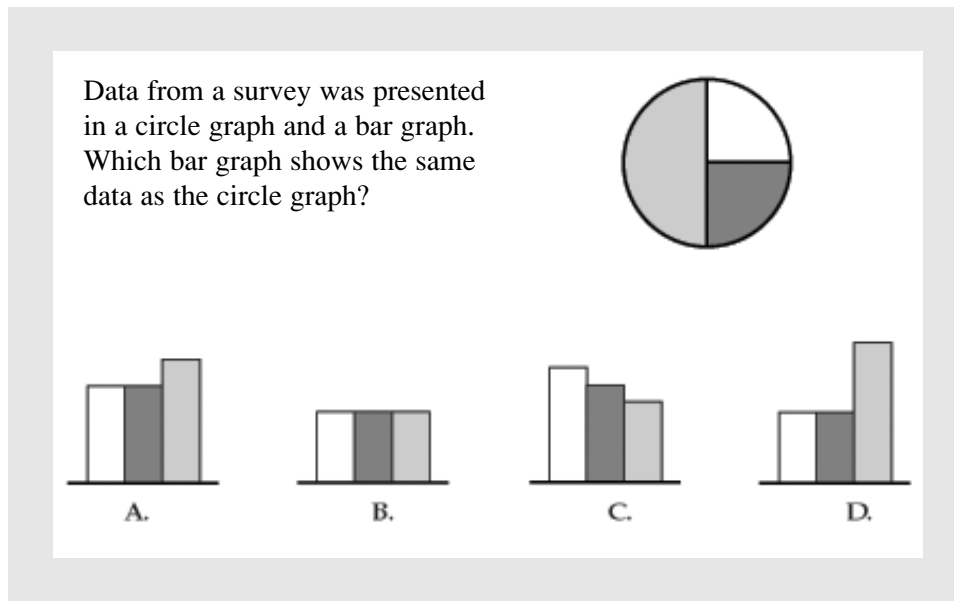
- 1 Data representations
- 2 Graph interpretation
- 3 Variables
- 4 Scale
- 5 Center: mean, median, mode

Graph Master, a data analysis software program for grades 4–8, was designed to address these key areas of need.

I Data Representations

The Research

The NCTM Principles and Standards for School Mathematics (2000) identifies “compar[ing] different representations of the same data” as an important skill. Specifically, students need the ability to translate among various representations of the same data and recognize when one representation is more useful than another (Bright & Friel, 1998). Questions asking students to translate from one representation to another are common on state and national tests. A typical example appears below.



SOURCE: Florida Department of Education, Florida Comprehensive Assessment Test, 2001, Mathematics Assessment, Grade 5.

Studies show that students have difficulty recognizing the same data when it is presented in different ways (Kerslake, 1981; Bright & Friel, 1998). To address this problem, teachers should provide students with numerous opportunities “to compare multiple representations of the same data set” and engage students in “rich discourse... on what each of the representations shows” (Bright & Friel, 1998).

Graph Master

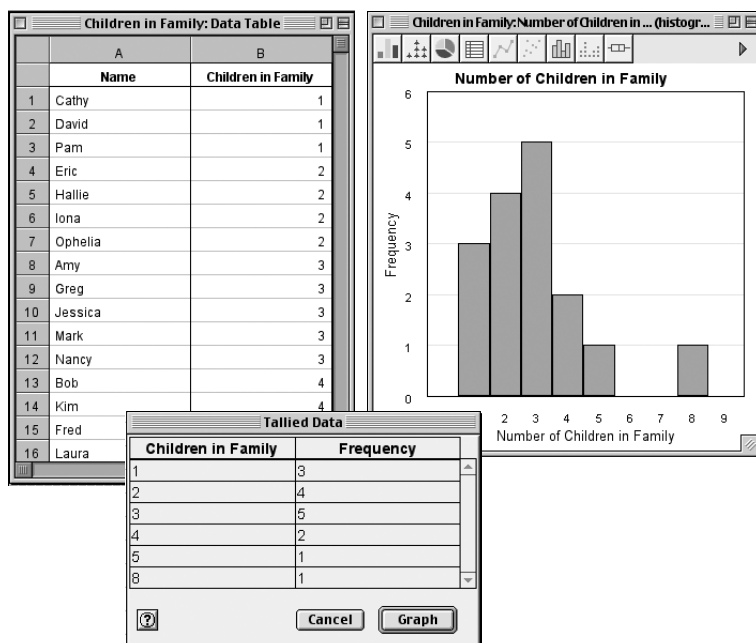
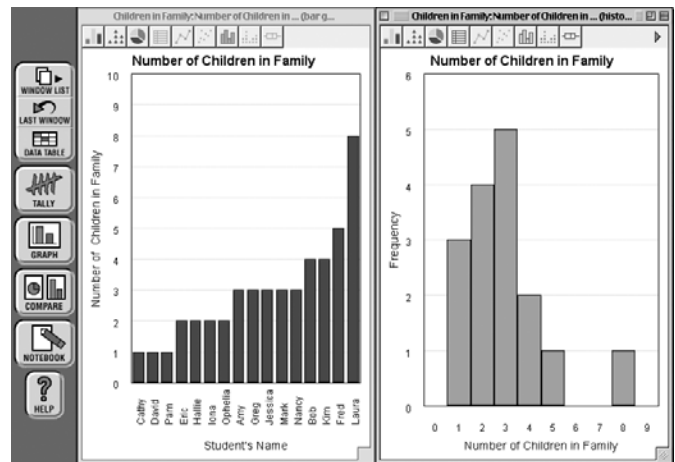
Graph Master facilitates comparisons between different representations of data.

Different Graphical Representations of the Same Data

The program's Compare feature makes it easy for students to view two graphical representations of the same data side by side (e.g., a bar graph and a circle graph). Using the Graph Type buttons, students can change from one graph type to another with the click of a button, exploring what each representation communicates (or fails to communicate) about the data.

Raw versus Grouped Representations of Data

Students have particular difficulty understanding the relationship between raw and grouped representations of data (Bright & Friel, 1998). The graph on the left represents data in raw form. In the graph on the right, this same data has been grouped or consolidated. *Graph Master* gives students an easy way to view these two representations side by side and discuss similarities and differences.

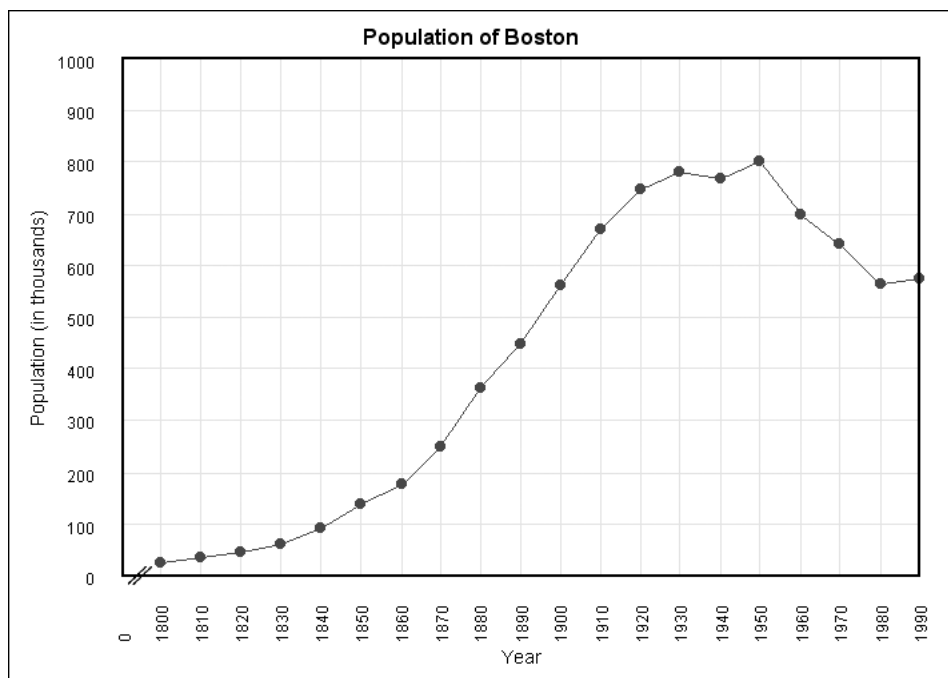


Tallying raw data helps students better understand the transition between raw and grouped data (Bright & Friel, 1998). The program's Tally feature allows students to tally columns of raw data. The resulting Tallied Data display provides a conceptual link between the data table and the final graph.

The Research

A central goal of the data analysis curriculum is to teach students how to interpret graphs in order to make decisions and solve problems. However, studies show that students struggle with all but the most basic interpretive tasks.

Researchers have identified three levels of graph-interpretation skill that students should master (Curcio, 1987; Wainer, 1992). The first level involves extracting specific values from a graph: *What was the population of Boston in 1960?* The second level requires integrating information from different parts of the graph: *How much did the population change between 1960 and 1970?* The third level involves understanding the data set as a whole, making predictions or noticing trends: *How did the population of Boston change during the 20th century?* While students generally can extract data values from a graph (a lower-level task), they perform poorly on higher-level tasks that involve additional computation or inference (Shaughnessy & Zawojewski, 1999).



Graph Master

Graph Master was designed to support students as they build skills in data analysis and interpretation.

Built-in Notebook

The program includes a built-in notebook feature, encouraging students to interpret and write about their graphs. This process makes student thinking explicit and external, helping to build conceptual understanding. Notebook text can be printed with graphs and assessed.

Real-World Data

Graph Master includes 10 activities built around real-world data sets. (An additional 50 are available on the Ready-Made Data Sets CD.) An emphasis on real-world data encourages students to view data analysis as a tool for inquiry, rather than a rote procedure (McGatha, Cobb, & McClain, 1998), and encourages thoughtful interpretation.

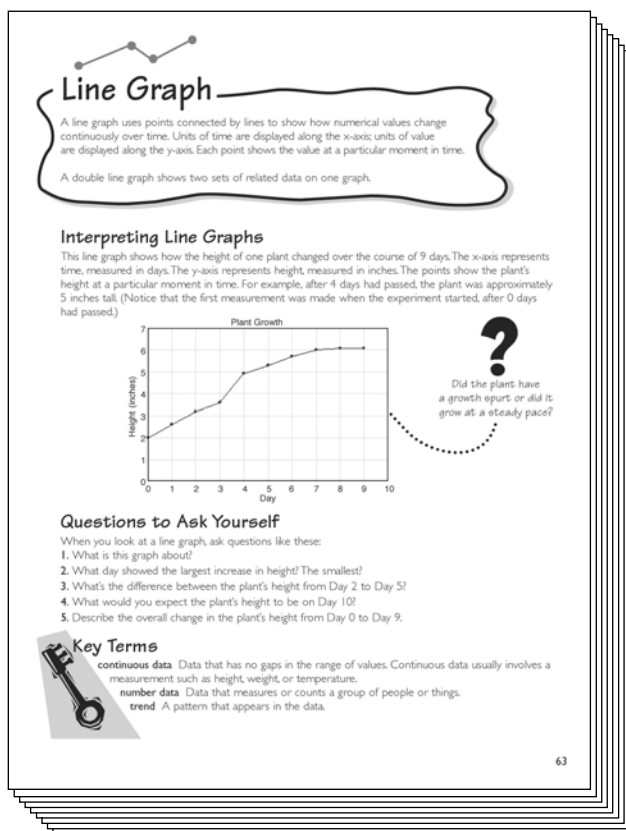
Meaningful Questions

Each of the activities included with the program focuses students on engaging and meaningful questions, for example, *How tall is the typical 4th grader?* or *What is the relationship between a roller coaster's height and speed?* Data analysis techniques (describing the “shape of the data,” identifying outliers, computing the mean or range) are introduced in context as students answer these questions.

A Supported Environment

The program's built-in glossary provides definitions and examples of key data analysis concepts and terms. The Teacher's Guide includes reproducibles that introduce each graph type and provide tips on graph interpretation.

Line Graph reproducible
from Teacher's Guide



The Research

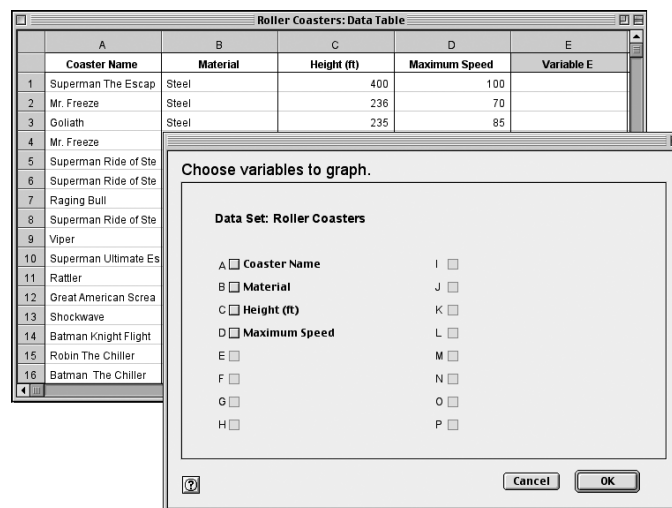
The concept of a variable is critical in data analysis. Variables help students organize data and construct appropriate graphs (Scheaffer, Watkins, & Landwehr, 1998). Some graphs (e.g., line plot) display the distribution of values within a single variable, while others (e.g., scatterplot) illuminate the relationship between two variables. To choose the appropriate graph type for a given data set, students must also distinguish between categorical variables (e.g., eye color, favorite food) and numerical variables (e.g., number of siblings, height). For example, categorical data could be presented in a bar graph or circle graph, whereas numerical data might be displayed as a line plot or histogram.

Graph Master

Graph Master develops students' understanding of variables in several ways.

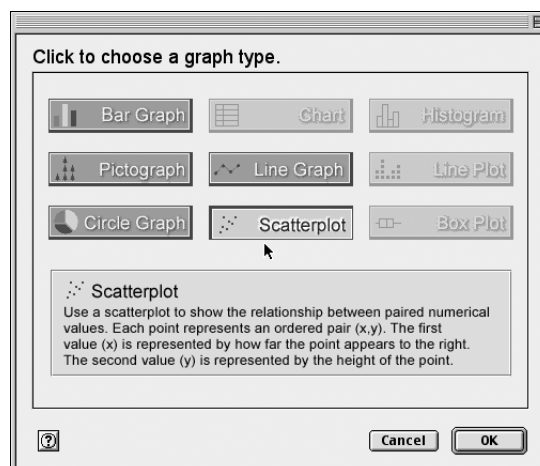
Data Organized by Variable

The program's data table, where students first enter data, is organized into 16 columns, each containing a distinct variable. When students create a graph from data in the data table, *Graph Master* prompts them to select variables to graph (instead of simply a group of cells). This helps focus students' attention on the number and types of variables that will be displayed in their graph.



Types of Variables

Once students have selected the variables they plan to graph, they must choose which kind of graph to display. *Graph Master* helps students determine the appropriate graph type for their data by providing a description of the graph they've selected, including which types of variables (categorical, numerical) it is used to display. The program also provides roll-over messages explaining why some graph types are unavailable. For example, if the student chooses to graph a categorical variable, the line plot will be unavailable, since it is used to show the distribution of values for a single numerical variable. This feedback helps students gain a better understanding of the appropriate graph type for a given set of variables.



4 Scale

The Research

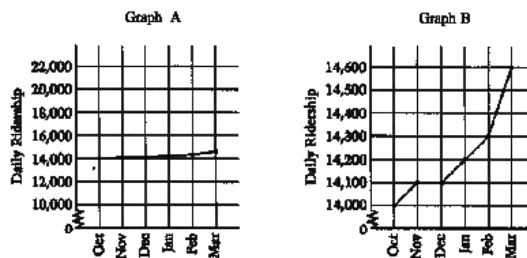
Understanding a graph's scale is essential to making sense of the data it displays, yet students typically pay little attention to scale when interpreting graphs. Many students assume that every "tick mark" on a scale represents a single unit and misread graphs in which the scale uses a different increment (Dunham & Osborne, 1991).

Students also frequently fail to understand how the proportions of a graph are affected by scale (Goldenberg et al., 1988; Kerslake, 1981). When a graph's proportions change, students assume that the data has changed. They don't realize that the same data can look radically different when displayed with a different scale. The following question on the 1996 NAEP exam assessed 8th graders' skill at interpreting scale to identify misleading graphs. Only 55% of the students chose the correct graph, and only 21% included a complete or partially complete explanation.

This question requires you to show your work and explain your reasoning. You may use drawings, words, and numbers in your explanation. Your answer should be clear enough so that another person could read it and understand your thinking. It is important that you show all of your work.

METRO RAIL COMPANY	
Month	Daily Ridership
October	14,000
November	14,100
December	14,100
January	14,200
February	14,300
March	14,600

The data in the table above has been correctly represented by both graphs shown below.



9. Which graph would be best to help convince others that the Metro Rail Company made a lot more money from ticket sales in March than in October?

Explain your reason for making this selection.

Why might people who thought that there was little difference between October and March ticket sales consider the graph you chose to be misleading?

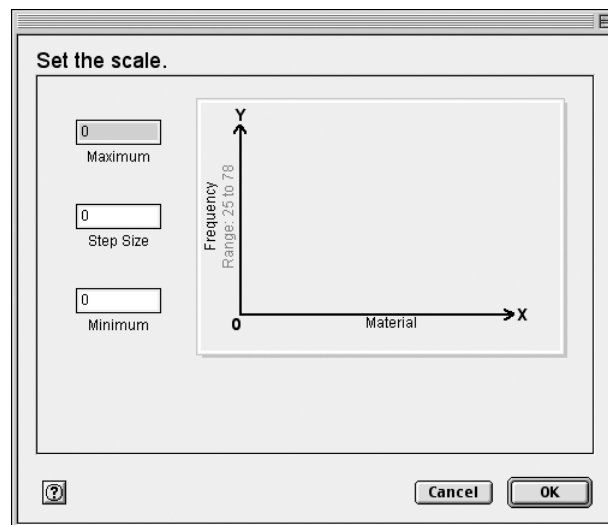
SOURCE: National Center for Education Statistics, National Assessment of Educational Progress, 1996, Mathematics Assessment, Grade 8.

Graph Master

Graph Master addresses students' difficulties with scale in several ways.

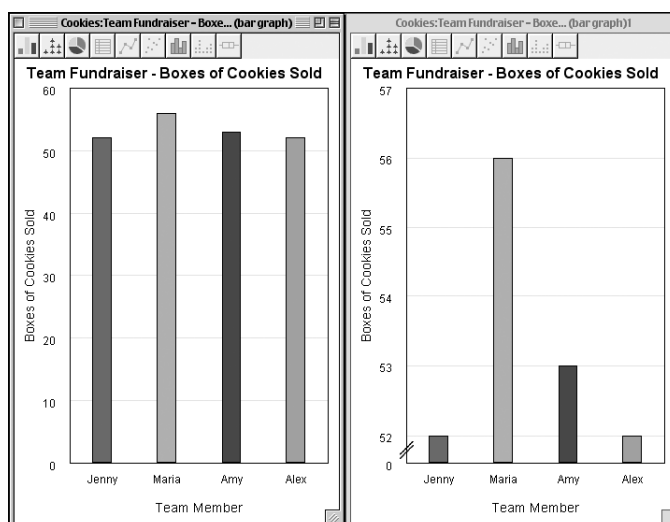
Setting the Scale

Graph Master requires students to make a decision about scale whenever they create a graph. In contrast to *Excel* and other standard spreadsheet programs, *Graph Master* can be set so that default values for scale minimum, maximum, and step size are not provided; students must identify appropriate values on their own. This focuses students' attention on scale and reinforces the idea that a graph's step size can be greater than one.



Comparing Scales

Research shows that extensive practice exploring and describing the effects of scale helps students develop "scale sensitivity" and become more critical of misleading graphs (Ben-Zvi, 2000). The program's Compare feature provides an easy way for students to compare side-by-side graphs of the same data with different scales. Students can use this feature to explore how graphs of the same data could support different points of view.



5 Center: Mean, Median, Mode

The Research

An important statistical skill identified by the NCTM Principles and Standards (2000) is the ability to interpret and summarize what is “typical” in a set of data using measures of center—mean, median, and mode. Many students display poor conceptual understanding of these measures (Mokros & Russell, 1995). Although they may have memorized algorithms for calculating the mean or median, students fail to understand what these values communicate about the data, and view them as arbitrary procedures rather than useful analytical tools.

Results from the 1996 8th-grade NAEP exam illustrate this poor understanding. For students with a well-developed concept of the mean, the question below should be easy to answer at a glance, yet only 38% of students answered all four parts correctly.

12. Akira read from a book on Monday, Tuesday, and Wednesday. He read an average of 10 pages per day. Indicate in the ovals below whether each of the following is possible or not possible.

Possible	Not Possible		Pages Read		
			Monday	Tuesday	Wednesday
☐	☐	(a)	4 pages	4 pages	2 pages
☐	☐	(b)	9 pages	10 pages	11 pages
☐	☐	(c)	5 pages	10 pages	15 pages
☐	☐	(d)	10 pages	15 pages	20 pages

SOURCE: National Center for Education Statistics, National Assessment of Educational Progress, 1996, Mathematics Assessment, Grade 8.

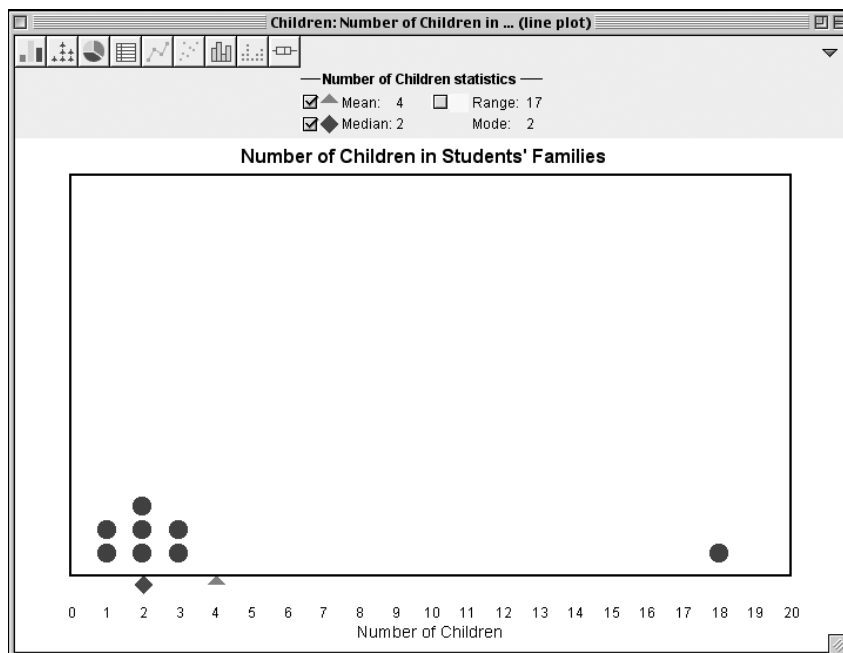
Graph Master

Graph Master includes several features designed to enhance students' understanding of measures of center:

Graphical Statistics Display

Graph Master allows students to display statistics (including mean, median, and mode) for graphs containing numerical data. The program displays these values in both numerical and graphical form. This display helps students make a visual connection between the values of the data and the mean or median. For example, students may note that the mean is never greater than the highest data value (an easy mistake to make when applying the algorithm without understanding).

Children: Data Table		
	A	B
	Name	Children in Family
1	Cathy	1
2	David	1
3	Hallie	2
4	Amy	2
5	Greg	2
6	Jessica	3
7	Mark	3
8	Laura	18
9		



Interactive Exploration

Students can view a data table and graph side by side and explore how changing the data will affect the mean, median, and mode. As they do so, students build a conceptual, rather than formulaic, understanding of these measures. For example, through dynamic explorations, students can observe how outliers affect the mean, while having little effect on the median. The *Mean & Median* activity (in the *Graph Master* Teacher's Guide) features this exploratory approach.

Investigating the Typical

Accompanying activities encourage students to examine what is "typical" in real sets of data. For example, students explore questions such as *How tall is the typical student in this class?* or *Which measure—mean, median, or mode—best describes how many medals a typical country won in the 2000 Olympics?* These questions encourage students to view mean, median, and mode as useful tools for describing and summarizing a data set, rather than as arbitrary procedures.

Summary

To succeed, both in school and in life, students must be able to interpret graphs and think critically about data. It is not sufficient for students to wait until high school or college to learn these skills; they must begin building a solid foundation in the elementary and middle school grades. Students must be able to collect, classify, and describe data; interpret and translate among a variety of graph types; identify patterns and trends; and recognize how graphs can both illuminate and mislead. Yet research reveals that these are precisely the areas of the data analysis curriculum where students struggle. To master these difficult skills, students need extensive practice in a supported environment. Tom Snyder Productions fills this instructional need through two graphing and data analysis software tools designed for K–8 classrooms.

The Graph Club 2.0, a dynamic, interactive graphing tool, helps students in grades K–4 make the transition from concrete manipulatives to abstract graphs. Using the software, students can compare different representations of the same data side by side, experiment dynamically with graph views and scale, and interpret graphs both orally and in writing. The extensive collection of standards-aligned activities helps teachers introduce data analysis concepts throughout the curriculum.

Graph Master, for grades 4–8, is a powerful yet easy-to-use data analysis tool. Unlike traditional spreadsheet programs, which are designed to support business needs, *Graph Master* was custom-designed for the classroom. Using the software, students can compare different graphs of the same data or graphs of related data. They can explore the effects of scale; experiment dynamically with mean, median, and mode; and interpret graphs in writing. The accompanying data sets and standards-aligned activities help teachers introduce data analysis concepts in the context of meaningful, real-world questions.

Both *The Graph Club 2.0* and *Graph Master* are powerful and flexible additions to the classroom, building the essential graphing and data analysis skills that students need to be successful.

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Tom Snyder Productions

Tom Snyder Productions, a Scholastic company, is a leading developer and publisher of educational software for K–12 classrooms. The company was founded over 20 years ago by Tom Snyder, a former science and music teacher, who pioneered the use of technology in the classroom to enhance teaching and learning. Today we are proud to carry over 140 award-winning software titles covering each curriculum area, developed with strict adherence to our high standards for quality and innovation. Our products help teachers meet curriculum goals in over 400,000 classrooms, improving student performance and understanding.

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