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SPOTLIGHT ON THE PRINCIPLES

Technology Enhances Student Learning across the Curriculum

ALTHOUGH THE USE OF TECHNOLOGY IS NOT new to the classroom, it is still a hotly debated issue in some schools. An important point to understand is that technology does not replace basic understandings and skills. Instead, it is an additional learning tool that fosters deeper understanding and better intuition about mathematical concepts. The word *technology* encompasses many platforms including calculators, programmable hand-held devices, tutorial software, interactive software, and Internet resources. Hand-held programmable devices provide affordable access to electronic tools that allow students to use multiple representations to explore mathematical situations. Interactive software also provides environments that allow students to explore and discover relationships on the computer. Technology is not static; it is a constantly growing and changing field. It challenges educators to continue to create innovative ways to implement new technologies in the classroom as teaching and learning tools.

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"Spotlight on the Principles" focuses on the six overarching principles for grades 6–8 found in NCTM's Principles and Standards for School Mathematics *(2000). The articles discuss how these principles relate to middle grades mathematics and suggest ways that teachers might incorporate them into their instruction.*

The Technology Principle in NCTM's *Principles and Standards for School Mathematics* (2000) states that "Electronic technologies—calculators and computers—are essential tools for teaching, learning, and doing mathematics" (NCTM 2000, p. 24). This Principle emphasizes the need for equal access to technology for all students. The Technology Principle makes three major points: technology enhances mathematics learning, it supports effective mathematics teaching, and it influences what mathematics is taught (NCTM 2000, pp. 25–26). In the following sections, we offer examples and a classroom vignette of how technology can be used across five Content Standards to enhance mathematics learning and support effective teaching.

Technology across the Content Strands

Algebra: A classroom vignette

A major task of the middle school mathematics teacher is to help students make generalizations from arithmetic and develop algebraic thinking. Students are just beginning to master their organization of the representations of relationships among numbers in graphs, tables, and algebraic equations. As students work to recognize patterns and make generalizations, such items as graphing calculators or graphing software enable students to efficiently move among tabular, graphical, and symbolic representations to analyze patterns. For the algebra strand, we share what happened in a sixth-grade classroom as Jean McGehee and Mrs. H., the classroom teacher, teamed to help students analyze graphs that represent walking motion.

Using the Calculator-Based Ranger (CBR), the TI-73 calculator, and an application called Distance Match, McGehee and Mrs. H. showed the class graphs of motion data on the overhead projector (see **fig. 1**).

The teachers explained to the students that the CBR is a motion detector that records the distance

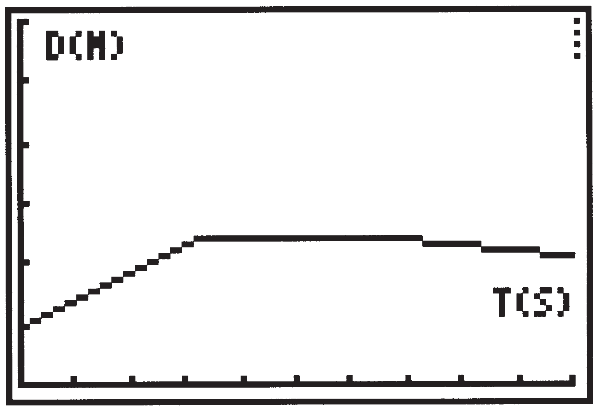


Fig. 1 A graph of a walk

from the device to an object in front of it. They asked for the students' initial interpretations of the graph. Some typical replies were these: "The flat part means you stand still" and "The other lines mean walk backwards or forwards." Students were instructed that they were going to walk in a way that would match the overhead projector's graph. Mrs. H. marked meter intervals with masking tape on the floor directly in front of the CBR and told students that the distances are measured as the CBR ticks off the seconds. Many enthusiastic students volunteered, but before a student tried a walking graph, McGehee asked the class to consider the following questions:

- How will the tape measures on the floor help you decide where to start your walk?
- Do you move toward the motion detector or away from it?
- What do you do when your walk matches the level part of the graph?
- How do you know when to stop?
- How do you know when to move again? And in which direction?
- How fast should you be moving?
- Should you move faster in the last part of the graph or slower?

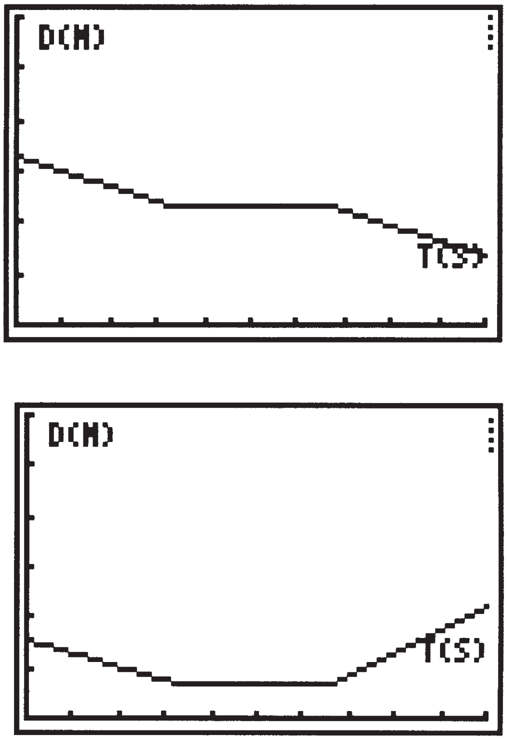
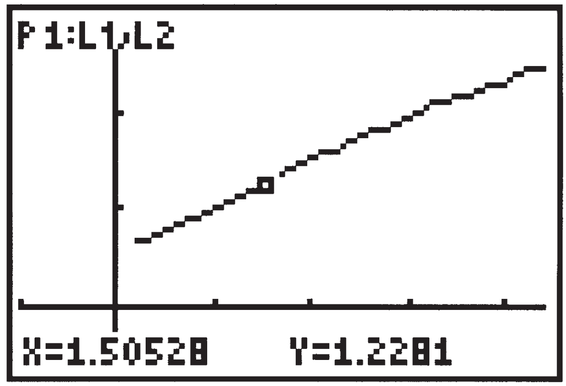


Fig. 2 Two more examples of walking graphs



The walk starts at about 0.5 meters. The distance changes about 0.46 or 0.47 meters in one second.

Fig. 3 A student's linear walk and explanation

These questions helped the volunteer walker and class analyze the graph carefully to plan the walk. As Mrs. H. directed the discussion, she made sure that the students determined a starting point, the direction of change, and the rate change for each segment of the graph. She asked students to describe important aspects of the graph, which prompted rich dialogue.

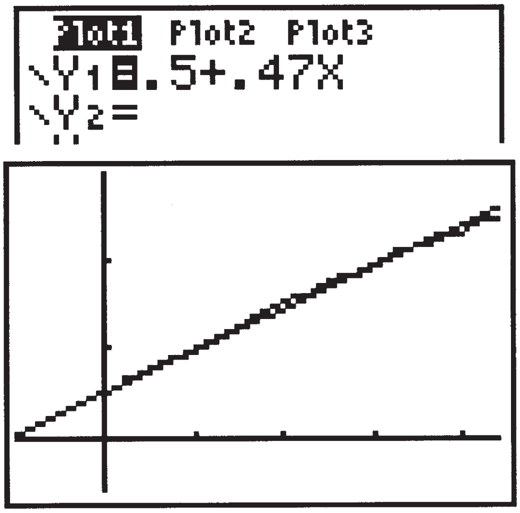
Tamara. The graph starts on almost the first mark on the *y*-axis.
Mrs. H. What does that mean?
Tamara. Start just after the first mark on the floor.
Mrs. H. What is the measure of that mark?
Eric. One meter plus a little.
Mrs. H. Now what do you do?
Aaron. You move backward, then stay still, then move forward.

At this point, Mrs. H. had to extend student thinking about how the walked distance relates to time. The notion of speed came up as she asked them to read the change on each axis from the start of a slanted part to its end.

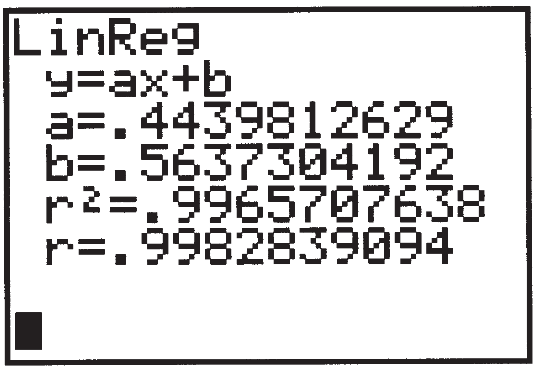
Mrs. H. You told me that for this slant you have to move away from the CBR and that you start at just 1 meter. Where does the slanted part of the line stop? What is the change from the starting point?
Emily. I have to go back to 2 1/2 meters—that's about 1 1/2 meters from start to stop.
Mrs. H. Are you moving fast or slow? How do you know?
Emily. I think I am moving kind of fast compared to the end of the graph.
Mrs. H. What makes the movement fast or slow? How is the time changing?
Hannah. On the first slant, I have to move 1 1/2 meters in 3 seconds, but on the last part, I move only 1/2 meter in 3 seconds.
Mrs. H. What distance do you move at the end?
Matt. You take baby steps and only move about 1/2 meter from the 2 1/2 meter mark to the 2-meter mark.
Mrs. H. On the flat part, do you change distance? Do you change time?
Dustin. You stay still for about 4 seconds.

The students looked at other graphs and discussed what movement would match each graph (see the two graphs in **fig. 2**). Even with numerous examples, the sixth graders did not tire of analyzing the graphs and describing the walks. These discussions were the foundation for the follow-up activity in which students created linear graphs and then found the equation to match the graphs. **Figure 3** shows one student's linear walk and explanation.

The CBR stores the data in the calculator lists so that when the student quits the application, the equation of the line can be found in two ways. First, students can guess an equation for a line that would match the line created by their walk and adjust the equation until they find one that covers the line (see **fig. 4a**). Another option is to select linear regression, and the calculator will find the exact values for a and b in the equation $y = ax + b$ (**fig. 4b**). Because these students had routinely focused on the starting point of a walk and had talked about rate of change, McGehee was able to help them discover the change in meters per second by using the TRACE function on the calculator. In this walking context, the sixth graders made a good estimate for the line that fit their data.



(a)
A student predicts an equation and adjusts it until it covers the line that was created by the walk.



(b)
The regression model shows the walk started at 0.44 meters and changed 0.56 meters each second.

Fig. 4 Students can learn to estimate equations of "closest fit" using the graphing and regression modeling functions of a graphing calculator.

With additional experiences like this one, students will more formally connect rate of change to slope of a line for a linear function. The CBR enabled students to begin to build these connections informally. Without the technology, these important algebraic concepts would not have been accessible to these sixth graders who are not skilled in creating graphs. In addition, fewer graphs could have been analyzed in one class lesson. The sixth graders were actually working with piecewise functions and the slope-intercept form of a linear equation. Instead of becoming bogged down with the procedures of symbolic manipulation, Mrs. H. was able to get them to guess equations that fit the walking data. Their guesses made sense in terms of a starting point and rate of change. They were delighted that they could adjust these numbers

Number	Quotient of number divided by 9
1	0.111111111
2	0.222222222
3	0.333333333
4	0.444444444
5	0.555555556
6	0.666666667
7	0.777777778
8	0.888888889
9	1
10	1.111111111
11	1.222222222
12	1.333333333
13	1.444444444
14	1.555555556
15	1.666666667
16	1.777777778
17	1.888888889
18	2
19	2.111111111
20	2.222222222
21	2.333333333
22	2.444444444
23	2.555555556
24	2.666666667
25	2.777777778
26	2.888888889

Fig. 5 An Excel spreadsheet is used to show patterns of dividing by 9.

and produce a line that closely fit the data. The algebra activity also gave this class a point of reference for constant rate of change in other contexts later in the year. For example, when the class studied unit pricing, they referred to the "match the graph" lesson.

Number and Operations

TECHNOLOGY CAN SUPPORT STUDENTS' UNDERstanding of decimal representations. Consider the following task framed as a question to pose to students:

> What patterns can you identify by examining the quotients found by dividing the numbers 1 through 30 by 9?

By using a graphing calculator or a spreadsheet, students can efficiently generate lists of quotients that can be analyzed for patterns. The patterns they see will contribute to the development of intuition about the relationship between repeating decimals and rational number representations (see **fig. 5**).

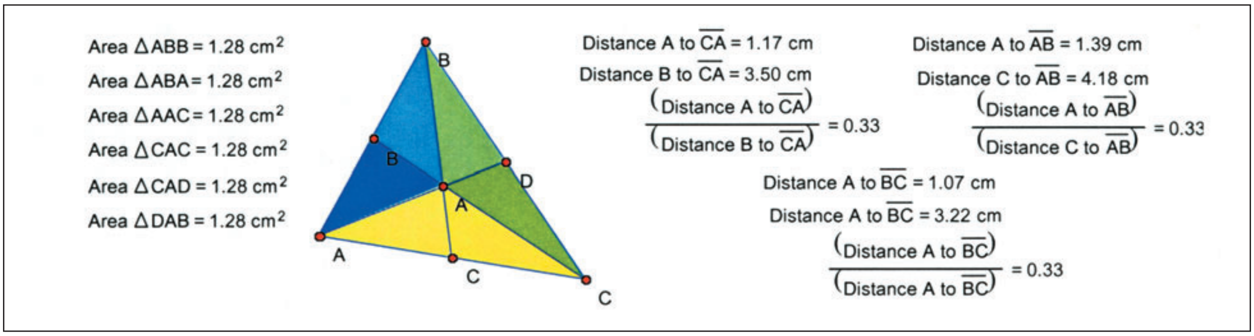


Fig. 6 Measurement relationships for the centroid and medians of any triangle, as completed with The Geometer's Sketchpad

Students can discover that if a number is one more than a multiple of 9, then the fractional portion of the decimal representation is 0.111. . . . Similarly, if the number is two more than a multiple of 9, they will see repeating 2s in the fractional portion of the number. In general, the integer remainder that occurs when a number is divided by 9 will appear as the repeating fractional part of the decimal representation of the quotient. The technology becomes an aid in finding a pattern to develop mental-math skills. The student should be able to recognize 11.444. . . as being 11 4/9 and mentally calculate 46/9 as being 5.1111. . . .

Geometry

GEOMETRY SOFTWARE, SUCH AS CABRI AND THE Geometer's Sketchpad (Sketchpad), allows students to make connections between empirical activities with shapes and designs and deductive thought about geometrical figures. In other words, students first learn to "play" with sketches that are provided by the teacher so that they can discover properties of figures and make conjectures. They may drag points to change shapes of figures and use measurements to discover patterns. Later, they learn to apply these properties to construct their own sketches and to explain and verify their conjectures. Constructions are an excellent topic to explore through technology. For the following prompt, consider the time involved to do the construction by hand versus with geometric software:

> Given any triangle, what do you observe about the three medians? (A median is a segment that connects a vertex to the midpoint of the opposite side.)

Using Sketchpad, students can be given a sketch in which the medians are constructed. Students can drag one vertex of the triangle to change its shape; as the triangle moves, observe the change in the medians. They will discover that regardless of the length of the sides or the shape of the triangle, the three medians always intersect in a single point in the interior of the triangle called the *centroid* (see **fig. 6**). This visual approach is much more powerful for students than being told that the property exists. Students can construct their own triangles and their medians to further verify the definition and centroid property of medians.

Measurement

THE MEASUREMENT CAPABILITY OF DYNAMIC interactive software allows students to explore relationships among measures. Look again at the triangle medians and the centroid. This center of the triangle is known as a balancing point because the medians divide the original triangle into six triangles of equal area. Consider the task posed in these questions:

> How are the areas of the six triangles formed by the medians related? How does the distance between the centroid and a side of a triangle compare with the distance between the opposite vertex and that side?

The six areas are equal, and the distance from the centroid to a side is one-third the distance from a vertex to the side (the height of the triangle). These relationships will hold for any triangle, a fact that can be verified with the dragging feature. The software can calculate the ratios, or students could use handheld calculators. In either situation, they will see that the exact answer is .333. . . , which they will recognize as 3/9 or 1/3. Without technology, calculating *all* the areas and distances with precision would be difficult, and students would be unable to view multiple triangles to look for patterns.

Data Analysis and Probability

TECHNOLOGY TOOLS ARE INVALUABLE IN THE study of Data Analysis and Probability. It is often necessary to use graphical representations to visualize data sets. Technology allows students much more flexibility in designing graphs and trying different graphical representations in a shorter amount of time. Al-

Shoes that lace up	150 150/280 is about 1/2 0.54 = 54%
Shoes with fasteners	40 40/280 simplifies to 1/7 0.14 = 14%
Shoes that slip on	90 90/280 looks like 1/3 0.32 = 32%

Fig. 7 Shoe data for 280 students

though using data makes mathematics easier because it is more concrete to students, data are also challenging in that students need to make predictions and inferences. Accurate graphs demonstrate patterns and trends in the data and are the basis for making good predictions and inferences. Technology also allows students to conduct simulations to explore the differences in theoretical and experimental probability. Electronic simulations make a large number of trials manageable in a classroom environment. The following task first engages students in collecting, representing, and analyzing data, then allows students to compare theoretical probability with experiments of different sizes.

> The manager of a shoe store needs your help in determining how she should order different shoe types in these categories: shoes that lace up, shoes with fasteners (Velcro or buckles), and shoes that slip on. Collect data, and write a report to the shoe store manager.

Suppose that a class collects the data in **figure 7** for 280 students. The students can represent these data in a circle graph that is drawn by hand; completed with a spreadsheet program, such as Excel; or produced by an interactive statistics program, such as Fathom. On the basis of this sample, the students could recommend that for every 100 shoes that the manager orders, she should buy 54 shoes that lace up, 14 with fasteners, and 32 that slip on. However, students might first test the theoretical probability by using a spinner that matches the circle graph to get frequencies close to the empirical results of the survey. The ProbSim application on the TI-73 is an ideal way to quickly conduct the simulation. Set the spinner with the percents from the circle graph, then spin as many times as necessary. As the students watch spins change the bar graph, they become curious about how a probability experiment will match data.

After ten spins, the experiment may not yield the predicted percents. As the number of trials increases, however, the experiment will resemble the theoretical probability (the law of large numbers). Technology enables students to complete large experiments in a reasonable amount of time.

Implications of Using Technology

IN THE FIVE EXAMPLES DISCUSSED ABOVE, WE have included the basic calculator, a calculator that can do simulations, spreadsheets, software that creates geometric shapes, and a CBR that tracks movement. Across these examples, one can see that the mathematics is challenging and interesting. In addition, the explorations could not have been done efficiently without the use of technology. The technology *prompts* student thinking; it does not limit it. The tools used in the investigations discussed here allow teachers to choose worthwhile mathematical tasks "that take advantage of what technology can do efficiently and well—graphing, visualizing, and computing" (NCTM 2000, p. 26). Because much technology is available and applicable across the Content Standards, it should be considered essential to mathematics teaching and learning.

Technology is not only important across the content strands, it is also an effective tool for implementing the five Process Standards (Problem Solving, Reasoning and Proof, Communication, Connections, and Representation). For example, the data investigation allowed students to see connections among multiple representations (data collection, tables, and various graphs). The students began to be able to translate between these representations. In the vignette where students were determining their walks, significant reasoning and communication occurred to determine what the walk would look like.

Attaining and using appropriate technology can be a challenge. Although all the tools discussed here are not necessary, having no technology in the classroom can limit student access to important mathematics. Using one particular form of technology is a good place to start, whether it is a software program (such as The Geometer's Sketchpad) or hardware (such as graphing calculators or CBRs). To incorporate technology requires support beyond the classroom. Schools, districts, and states need to help teachers acquire the needed equipment. Teachers need the opportunity to learn about what technologies are available and how to effectively use them to teach important middle school concepts. Given the tools and the professional development, technology can have a significant impact on teaching strategies, on what is taught, and on what students learn about mathematics.

Reference

National Council of Teachers of Mathematics (NCTM). *Principles and Standards for School Mathematics.* Reston, Va.: NCTM, 2000. □