



The Challenge of High-Stakes Testing in Middle School Mathematics

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KEY CONCEPTS

- Students moving from concrete to abstract mathematical concepts using Thinking Maps®
- Multiple-year results from research on Thinking Maps applied to procedural knowledge by students with special needs
- Fostering clear and meaningful communication between students and teachers in mathematics classrooms

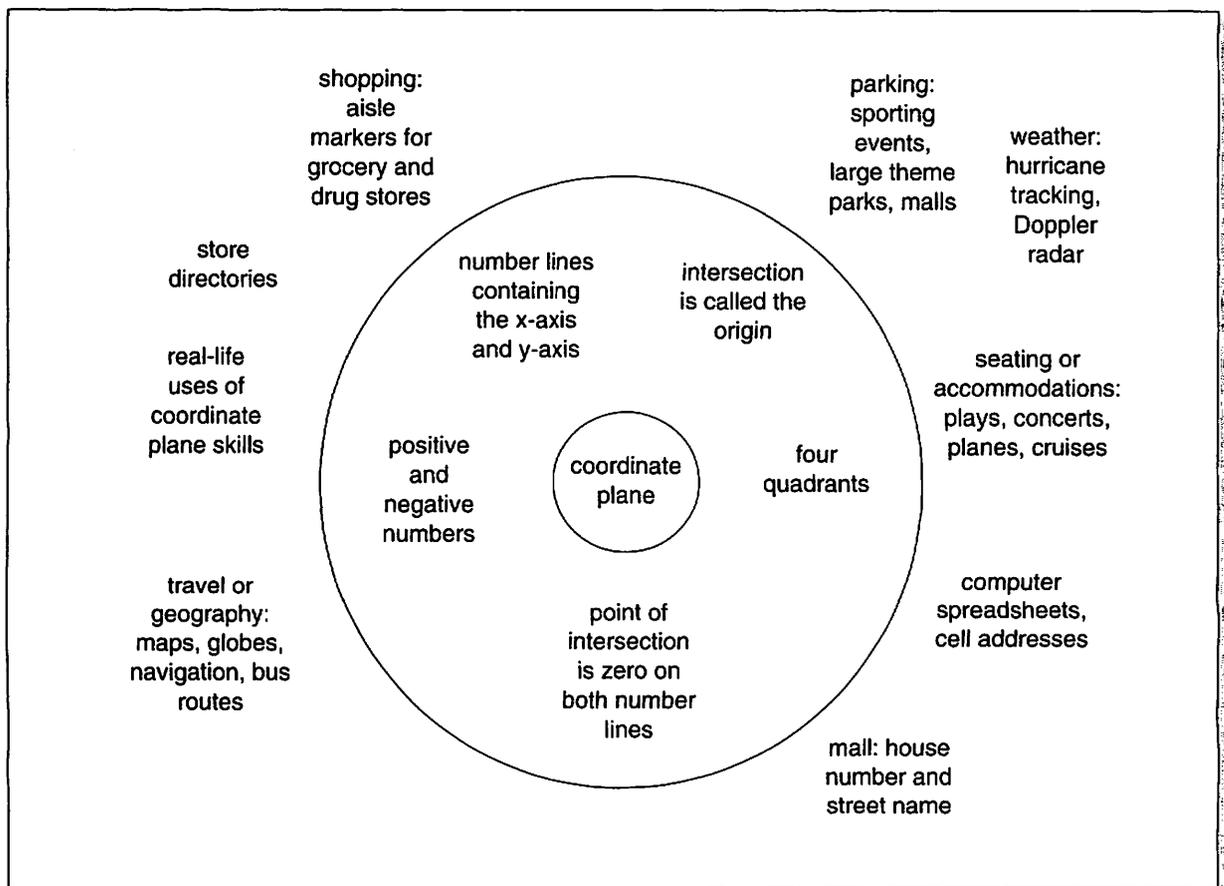
FACING MYSELF AND MY STUDENTS

In the early 1990s, North Carolina initiated major educational reforms that continue to become more rigorous. Student proficiency must be demonstrated on annual statewide math and reading end-of-grade tests for elementary and middle schools. Secondary school assessment is conducted through end-of-course tests in core areas. Student performance and proficiency are directly linked to promotion, unit credit, and graduation. With the knowledge that students with special needs would have to meet the same standards as their regular education counterparts to be eligible to receive a high school diploma, a pivotal personal and professional realization occurred. Morally, and with full awareness that my students were counting on me and others like me, it became essential to find and develop strategies that would allow them to adapt to and compensate for learning difficulties, differences, and deficits to have an opportunity to earn what would represent the pinnacle of formal education for many of my students: a high school diploma.

Prior to the reforms, the underachieving students in my seventh-, eighth-, and ninth-grade mathematics classes at George R. Edwards Middle School in Rocky Mount—both those coded as having a learning disability and those achieving in the lower quartile—performed basic computation for whole numbers and decimals, learned to tell time to the nearest 5 minutes, made change for purchases of under \$20, and, perhaps, studied fractions. Today, my students have made cognitive leaps and are successfully mastering concepts of solid and plane geometry, exponents and scientific notation, two-step equations, and graphing linear and nonlinear systems of equations, to mention only a few. Students are truly light-years ahead of where they were and are able to access and master those concepts, as our research has shown, because of Thinking Maps.

From the onset of Thinking Maps implementation within the instructional process, I have been astounded by the ease with which students with learning disabilities and those in the regular education program have been able to not only grasp new concepts but also demonstrate comprehension and application with accuracy. For over a decade, teachers at my school have observed that Thinking Maps provide the vehicle by which students with special needs are able to adapt to and effectively compensate for learning difficulties and perceptual deficits with tremendous efficiency and success. This inherently concise, consistent, and flexible visual language transcends age and ability and aids students by providing accurate, concrete connections between what is already known and new skills to be acquired. For example, by using a Circle and Frame Map with my students (see Figure 8.1), I was able to connect the concrete ideas of coordinate planes within a real-world context for their reference.

Figure 8.1 Coordinate Plane Circle and Frame Map



While I intuitively knew the value of Thinking Maps from over a decade of results gained from examples as shown in the figure, I also knew that in today's data-driven field of education, increases in student performance need to be stated in observable, measurable, and replicable terms to be valid. I used my opportunity as a Christa McAuliffe Fellow in 1999–2000 to conduct a control group study to determine the impact of Thinking Maps on math achievement. I found that after an entire year of Thinking Maps implementation, end-of-grade test results for both exceptional and traditional students indicated four years' worth of developmental gains in one year's time.

BEYOND INTUITION

During the first two years of integrating Thinking Maps, a variety of experiences convinced me that Thinking Maps positively influence student performance. Many times in sharing student accomplishments I was told, "Yes, but Janie, you are a wonderful teacher." In response I would state, "I know I'm a good teacher, but this is not my magic—this is because of Thinking Maps!" I used Thinking Maps throughout all stages of the instructional process: from determining prior knowledge of a given topic through directed and independent instruction to assessment and self-evaluation of curricular growth. If we were working on a particular skill, I could use the same tool to differentiate instruction depending on the developmental level of the students involved. In Figures 8.2a and 8.2b, two students were working through a process of how to make a graph using a Flow Map for sequencing. Notice the different levels of sophistication each student applied.

Figure 8.2a How to Create a Graph Level 1 Flow Map

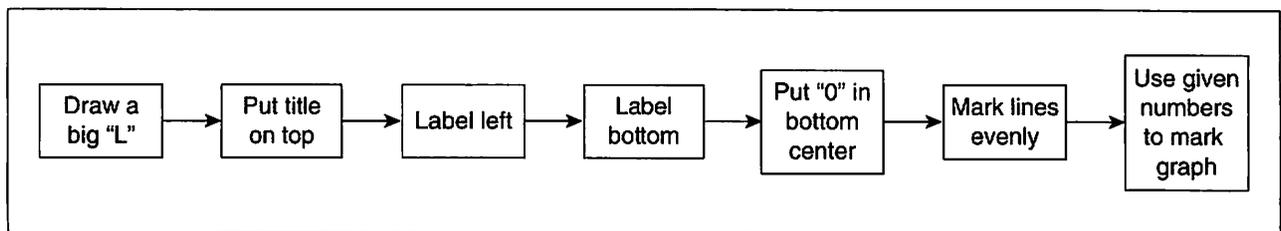
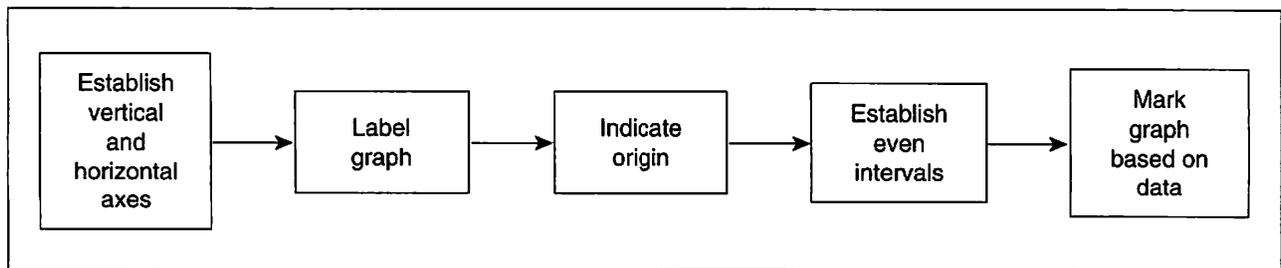
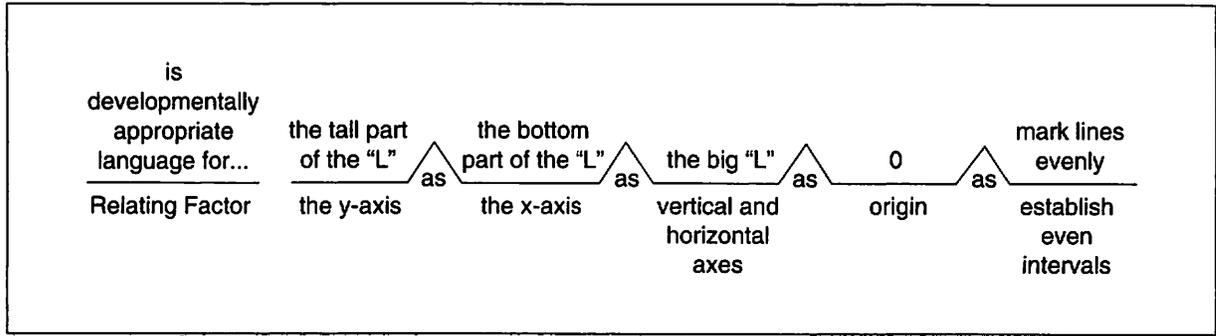


Figure 8.2b How to Create a Graph Level 2 Flow Map



In Figure 8.3, the Bridge Map, used for analogies, was applied to transfer familiar language to the mathematical language needed for this concept. This is just one example in which Thinking Maps scaffold the learning of mathematical language and processes.

Figure 8.3 Bridge Map for Building Math Language

Not only did the maps foster students' increased personal awareness of their individual cognitive and metacognitive style, but they allowed me to glimpse students' metacognition, thus enabling me to assess areas of inherent student strength and weakness.

As a result of this type of instruction in my math classes, 6 out of 11 students with special needs scored "proficient" or "exceeds expectations" in math. Eighth graders were learning 46% beyond what they were expected to learn in one year's time, with one student demonstrating a remarkable 21-point gain in developmental growth. In an even more needy population, in an intensive math remediation class for ninth graders who had previously failed the eighth-grade exit exam, 84% passed the retest. It was apparent that when Thinking Maps applications were incorporated consistently and frequently within the math instructional process, these exceptional students were able to demonstrate, on average, two years' worth of growth in one year.

RESULTS: GAINS IN DEVELOPMENTAL GROWTH

In 1999–2000, I was selected to serve as the North Carolina Christa McAuliffe Fellow. I structured independent research to measure the impact and statistical significance of Thinking Maps instruction on North Carolina eighth-grade end-of-grade developmental growth of lower-achieving students in math. The research targeted the 291 lower-achieving, rising eighth graders in the Nash-Rocky Mount Public Schools. The schools in Rocky Mount, located in eastern North Carolina, serve both an inner city and a rural population of middle- to lower-class families. Over time the area has changed from an agricultural economy of mainly tobacco farms to a more diverse economy including bank, restaurant, mechanical engineering, and biotechnology headquarters and facilities. The student body also reflects this diversity, with students who are about 50% African American and 50% White, including a small migrant and ESL (English as a second language) population.

Approximately 30 system-wide eighth-grade math teachers attended Thinking Maps professional development throughout the year, including monthly follow-up sessions that provided model and videotaped demonstration lessons, classroom observations, and coaching opportunities, as well as assistance in the collection of anecdotal evidence and documentation logs indicating the frequency and types of Thinking Maps being used. Participants were provided with over 200 Thinking Maps applications in math that were aligned to all curricular goals and objectives and the state-adopted text.

Due to the pre- and posttest design model used by the state to determine a student's developmental growth, test scores from the sixth and seventh grades determined developmental growth prior to Thinking Maps applications. Seventh- and eighth-grade scores determined developmental growth subsequent to the implementation of research strategies. Therefore,

North Carolina end-of-grade math tests for three consecutive years were mandatory to be included in the project's comparisons. A variety of factors may prevent the administration of a test to individual students, including illness, exemption, transfers into a system, or moving. Of the 291 students identified in the research, 133 possessed a score for all three consecutive years. Based on individual performance, the increases in the developmental growth of these students after the implementation of Thinking Maps strategies are significant.

The average developmental growth of the exceptional children as eighth graders at all three school sites for the 1997–1998 and 1998–1999 school years, prior to the implementation of the McAuliffe Fellowship project in 1999–2000, is shown in Table 8.1. I included data from the students in my classes (*MacIntyre*) who had used the Thinking Maps during both the 1997–1998 and 1998–1999 school years. The students in my classes exceeded exemplary growth in both years, and, in one case, their growth was almost as much as 7 times that of seventh graders at another site. Shown in Table 8.2 are the scores that indicate the 1999 pretest and 2000 posttest developmental growth scores for eighth graders who participated in the Thinking Maps implementation during the McAuliffe Fellowship project in 1999–2000.

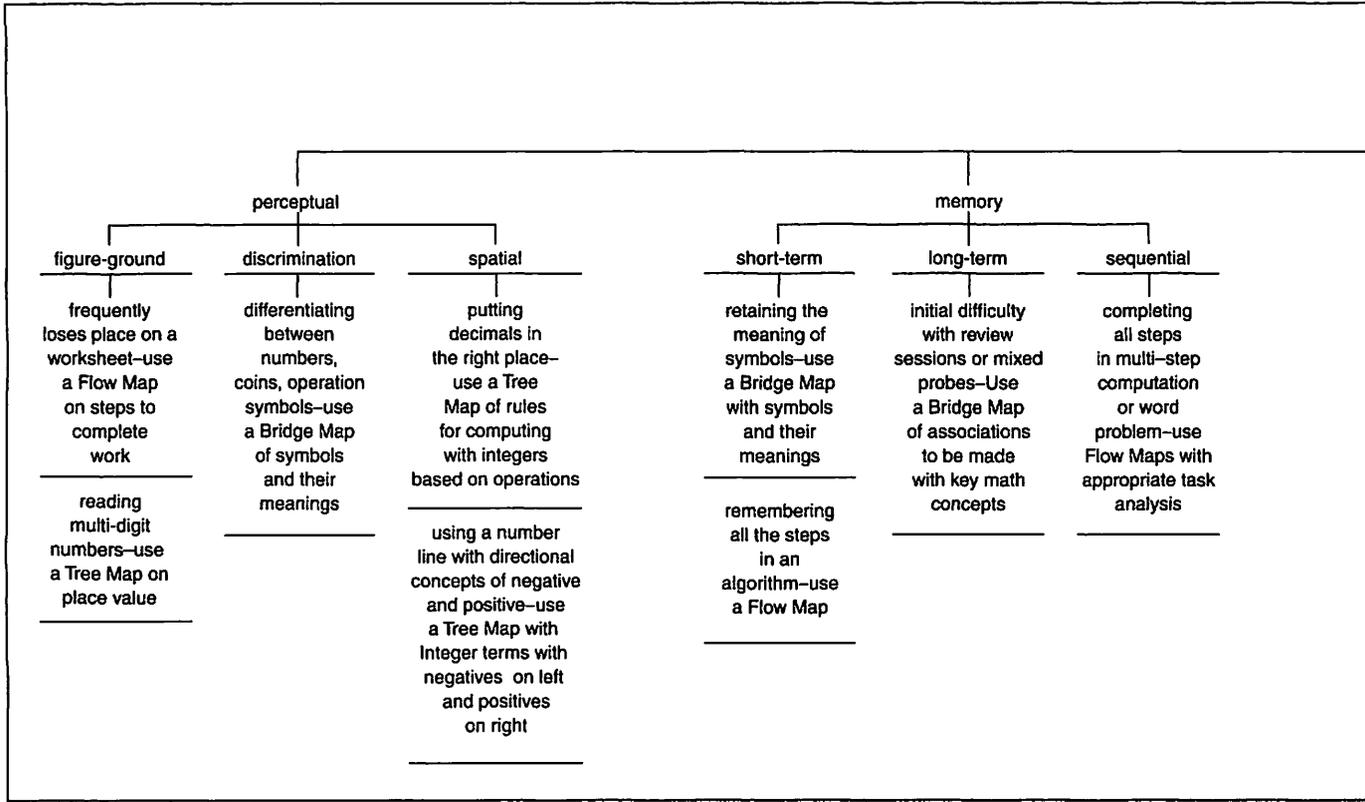
Table 8.1 Test Results for Seventh-Grade Developmental Growth

School Sites	Exceptional Children Developmental Growth in Math	
	1997–1998	1998–1999
Expected	5	3.8
Exemplary	5.5	4.3
Edwards	6.25	3.7
Nash Central	4.33	1.6
Southern Nash	3.88	2.7
MacIntyre	7.33	7.6

Table 8.2 Test Results for Eighth-Grade Developmental Growth

School Sites	McAuliffe Fellowship Developmental Growth 1999–2000	
	Pretest	Posttest
Expected	3.8	3.7
Exemplary	4.3	4.2
Edwards	4.93	8.02
Nash Central	1.28	6.94
Southern Nash	1.33	9.71

At the time of the 1999 pretest, expected developmental growth for these students was 3.8 points, while exemplary developmental growth was 4.3 points. As the figure indicates, the actual pretest developmental growth for the students involved in the research was measured at 1.28 points for Nash Central Middle School and 1.33 points for Southern Nash Middle School. Therefore, at the time of the pretest, only students at Edwards Middle School, who had to some extent used Thinking Maps, met the expected growth. In fact, they exceeded it.

Figure 8.4 Thinking Maps Applications to Diminish Learning Difficulties Tree Map

In the 2000 posttest, given after Thinking Maps implementation, the results show a fivefold increase in the average developmental growth scores of the research participants at Nash Central Middle School and a sevenfold increase in the average developmental growth scores at Southern Nash Middle School. As expected, the more profound change in individual developmental growth occurred overall at our sister schools that had not previously used Thinking Maps at all. The less dramatic increase in scores at Edwards could have been due to my six-week absence from my classroom to conduct the Thinking Maps training as part of my fellowship. Of the 133 students formerly labeled as low-achieving, 71 demonstrated proficiency on the first trial.

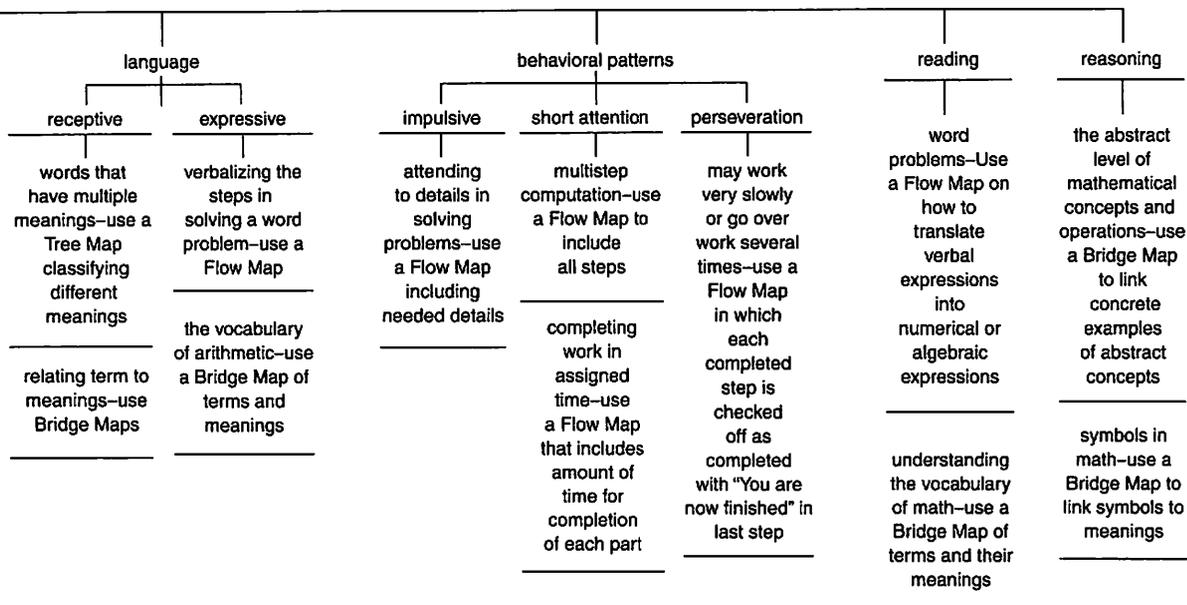
What we have learned about Thinking Maps during this era of high-stakes testing and accountability continues to evolve, but this study confirmed two findings:

1. When Thinking Maps are utilized in daily math instruction, student learning and demonstration of mastery exceed exemplary developmental growth expectations on state tests.
2. Thinking Map strategies and applications in math are replicable.

THINKING MAPS: A BRIDGE TO SUCCESS

The statistics indicate considerable growth in mathematical achievement, so how and why does applying Thinking Maps in math instruction improve math ability as measured on these tests? Qualitative results in the form of student and teacher anecdotal reports and instructional logs indicate that Thinking Maps support mathematical thinking by enabling students and

Thinking Maps Applications to Diminish Common Learning Difficulties of LD Students Affecting Math Performance



teachers to clearly and visually explain, understand, monitor, and assess mathematical processes and problems.

Students who typically find math enjoyable and readily grasp new concepts are those who have developed and use analytical skills. According to some researchers, “giving students advanced organizers does have the desired effect of increasing recall of critical information” (Deshler, Schumaker, Lenz, & Ellis, 1984). In addition, students with learning disabilities “experience deficits in cognitive processes including disorganization, acquisition, retrieval, integration or association, expression, sequencing, analyzing, and evaluating information,” according to Wallace and McLoughlin (1988). With Thinking Maps, teachers are able to graphically demonstrate and model analytical thinking to students, furthering opportunities for them to develop, practice, enhance, and apply the analytical skills necessary to be able to truly understand and apply mathematical concepts.

In addition to analytical skills that may be immaturely developed, some students possess learning difficulties, differences, or disabilities that can directly impact math performance. In the following Tree Map, Cecil Mercer’s (1983) work has been expanded to include sample Thinking Maps applications (see Figure 8.4). The application of Thinking Maps is directly targeted to diminish the impact of the acquisitional and behavioral problems experienced by students with learning disabilities in math. From this Tree Map, it is clear that language and procedure play a large role in contributing to mathematical understanding.

Students need support not only with the concepts of math but also with the symbols and multiple steps involved in the construction of the concept. In the following multiple map example (Figures 8.5a–c) introducing and explaining “the coordinate plane,” teachers and students work together to understand the language, processes, points, and purposes of plotting and using coordinates.

Figure 8.5a Coordinate Plane Tree Map

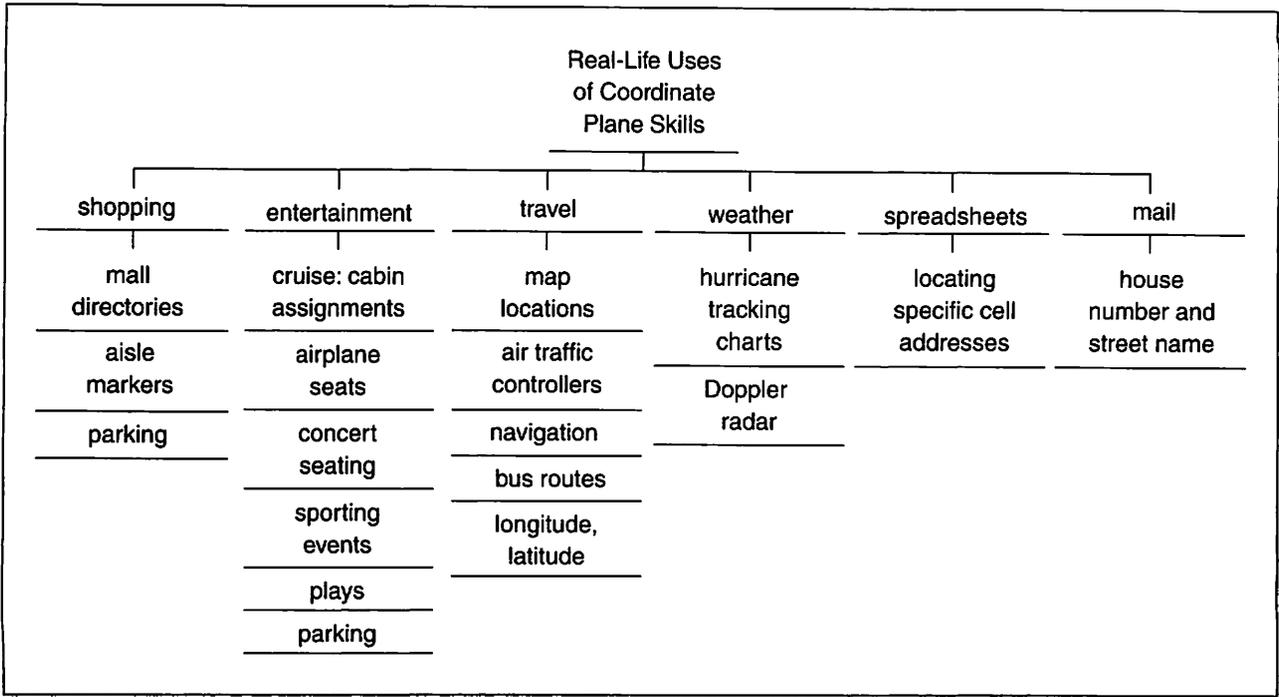


Figure 8.5b Determining Points on the Coordinate Plane Flow Map

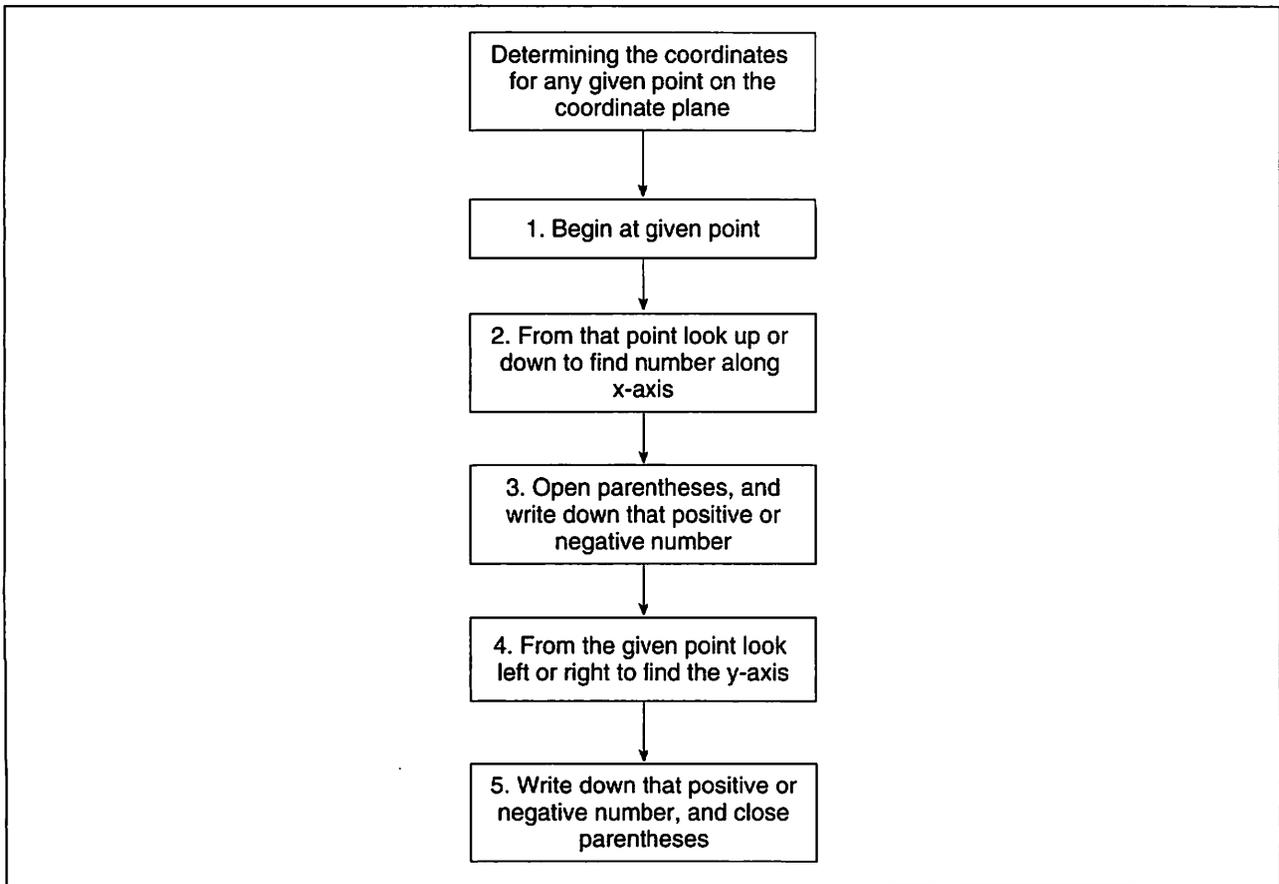
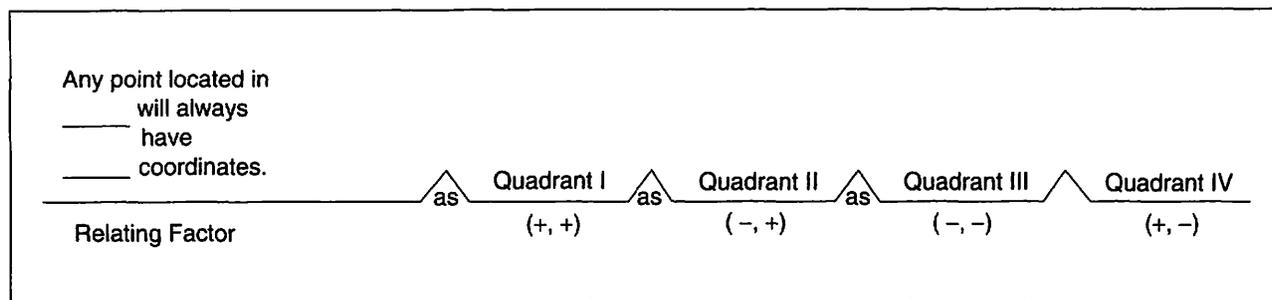


Figure 8.5c Finding Points on the Coordinate Plane Bridge Map

We also know from theories of brain-based research and theories of emotional intelligence (Goleman, 1995) that for learning to occur, new information must have either personal relevance and meaning or an emotional connection to the learner. Through the use of Thinking Maps, particularly the Frame of Reference, graphics can be constructed depicting the relevance of math goals to real-life applications in ways that are compatible with the triune brain's innate, natural preferences for pictures, determining patterns, establishing order, making connections, and completing processes. While students should realize that perhaps only in a math class would they be asked to determine the coordinates for a point on a coordinate plane, those skills are used often in real-life situations without being referred to specifically by name. Real-life applications can and should be made for every goal and content area to enhance student awareness of personal relevance and the need to acquire those skills.

We can see that Thinking Maps foster clear, deliberate, and meaningful communication between students and teachers. When students are involved in study where instruction is effective, goals are clear, and opportunities for success are frequent, enhanced levels of self-confidence will emerge and render students willing to take more frequent appropriate academic risks leading to upward spirals of student achievement.

In applying the theory that all knowledge is either declarative or procedural to the area of mathematics, declarative knowledge would include content vocabulary, theorems, laws, rules, and contributions of mathematicians—the factually based, continually true information, or the absolutes. Procedural knowledge would include everything else: How to bisect an angle or use the Pythagorean theorem to determine a missing measurement of a right triangle; how to graph a point on a coordinate plane; and how to determine the mean, median, mode, and range of a set of data are all examples involving procedural knowledge. Because of the inherent procedural nature of math, the list could go on and on. Using a Flow Map for a procedure, students can guide themselves or can be guided from where they presently function toward the acquisition and subsequent mastery of curricular goals with amazing rates of growth.

A student from Edwards Middle School explained how Thinking Maps scaffolded her learning by translating abstract thinking processes and mathematical processes into explicit and tangible visual representations: "Thinking Maps help me in math class by explaining something complex or abstract in a simple way. They allow you to see where you have made your mistake, and how to *show* your math in words that make sense. I wish someone had taught me math this way before. Now, I can understand exactly what we're doing in class." The student added, "The more we use Thinking Maps, the more I understand, and the easier the work becomes to do."

Teachers also celebrate the changes in students' organizational ability, self-efficacy, and attitude toward learning: "Students get excited and are becoming much better at organizing and maintaining their 'map' notes. . . . Students are consciously aware of wanting to have their math Thinking Maps with them. The students know the tools are helping and will refer to

previous maps to verify their current work. It is very encouraging to me to assist students to develop strategies that enable them to become independent learners." Students and teachers indicated that Thinking Maps fostered students' ability to articulate how they were thinking or to reflect with a metacognitive stance to self-assess. Students who previously had trouble organizing now had a predictable road map that they could navigate.

Math teachers in general have a tendency to be highly organized and analytical. Because that can be such a natural part of our way of thinking and frame of reference, we sometimes fail to remember that others don't necessarily think that way, particularly adolescents who are still developing cognitively. The use of the Flow Map for procedural knowledge acquisition in math forces highly organized, analytical teachers to view concepts and skills from the student's perspective to determine what is truly needed to ensure student mastery while incorporating the language that is developmentally appropriate for that particular group of students.

The Flow Map used for sequencing is the same graphic design used in math, English, science, social studies, physical education, art, foreign language, or any other subject being taught. This repetitive and consistent link to cognition is extremely positive and beneficial in helping students, particularly students identified as having special needs, to become more efficient and organized in their thinking across all facets of educational pursuit. This success breeds increases in self-esteem and the willingness of students to take appropriate academic and responsive risks during the instructional process. Through the use and internalization of this consistent language, students are enabled to quite literally state a more figurative phrase: "I see what you mean."

BEYOND TEST SCORES

Developmental and cognitive gains like these have tremendous implications for instruction, assessment, services, and expectations of this population. By examining data scored in groups with decimal points and percentages, we might forget that those numbers represent individual students. The data validated my suspicions about Thinking Maps as tools for learning. Thinking Maps affirm students' ability to think, with a positive ripple effect on their sense of self-worth. The gravity of this situation struck me when I told one of my students his test results. Tension filled the air as he approached my desk. Anticipating failure, he lowered his head and said, "I didn't make it, did I?" "As a matter of fact," I replied, "you did." With tears in his eyes, this towering eighth-grade boy picked me up and spun me around. We immediately called to share the great news with his mother. It was during that interaction that I understood the true meaning of my results. Relief and praise washed over this student and his family. He exclaimed, "I am smart—I can do this!"

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