The Mathematical Brain

Differentiated Instruction and Mathematical Thinking

Strategies in this chapter include the following:

• Ten Brain-Compatible Teaching Guidelines for Math Instruction
• Ten Informal Tactics To Develop Number Sense
• Games and Activities for Developing Number Sense
• Ten Teaching Tactics for Providing Instruction in Math
• A Self-Evaluation Grid for Differentiated Instruction Lesson Planning

Over the past two decades our nation has witnessed an emerging emphasis on mathematics instruction, and as a result achievement in math among students in the United States has been increasing (Harniss, Carnine, Silbert, & Dixon, 2002). In fact, within the past several years, math scores on several national indicators have increased (Strauss, 2003). However, there is still a considerable deficit between math scores of students in the United States and students in other modern nations of the world, and this deficit in math causes great concern among educators. The publication of the revised mathematical instructional standards by the National Council of Teachers of Mathematics (NCTM; 2000), the increased emphasis on national math standards in every state, and a seemingly endless series of reports that indicate many students do not achieve up to their potential in math, has placed mathematics instruction on the national agenda, second only to the
emphasis on reading. Further, the emphasis on national math standards has received much research and media attention (Jitendra & Xin, 2002; Johnson, 2000). Research has shown that the vast majority of general education teachers—some 95%—are familiar with the NCTM standards and frequently address these standards in their teaching (Maccini & Gagnon, 2002).

The emphasis of instruction has changed somewhat, however, as a result of the revised NCTM standards. Students are expected to master a curriculum that has shifted away from computation, rote learning, and routine problem-practice activities toward an increased emphasis on reasoning, conceptual understanding, real-world problems, and connections between mathematical concepts (Johnson, 2000). Thus, much has changed in mathematics instruction, and teachers today must employ the most effective and efficient instructional methods possible for increasing cognitive involvement of all students with the math curriculum. Teachers are searching for instructional ideas that will assist in this regard.

The concept of differentiated instruction can be of great benefit to teachers in developing and designing their mathematics instruction for students with varying ability levels in the elementary education classroom. Moreover, the emphasis on brain-compatible instruction, one founding principle of differentiated instruction, can now inform teachers concerning what specific instructional tactics may be more useful (Bender, 2002; Tomlinson, 1999). While studies of how the human brain functions in reading tasks or math tasks have been undertaken for the past two decades, only recently has this emerging biomedical research—often referred to as brain-compatible research—progressed enough to inform teachers concerning effective instructional strategies for the math curriculum (Fuson & Wearne, 1997; Geller & Smith, 2002; Gersten, Chard, Baker, & Lee, 2002; Sousa, 2001). In particular, one aspect of the emerging research—multiple intelligences—seems to have struck a chord in the hearts and minds of educators within the past decade (Gardner, 1983, 1993). This perspective has provided one basis by which many math teachers have reformulated their instructional strategies. In fact, in several mathematics textbooks a multiple intelligences perspective is incorporated into the curriculum as well as in the teachers’ instructor’s manual!

This chapter will look at these two bases of differentiated instruction—multiple intelligences and brain-compatible instruction—with an emphasis in math instruction for students from kindergarten through Grade 8. First, the emerging research on brain-compatible instruction in math will be presented with a focus on practical classroom implications. Next, multiple intelligences will be presented as a viable basis for differentiating instruction in mathematics in order to accommodate the needs of all learners in the class. Finally, emphasis will be placed on the concrete, representational, abstract instructional construct common to math curricula today. This construct, though dated, can cross-fertilize the instructional suggestions from the more recent research areas, such as multiple intelligences, and provide the teacher with a new and interesting way to view all instruction in mathematics. In turn, this new sense of what mathematics instruction is will impact how teachers plan the instructional activities within the math curriculum.
Regions of the Mathematical Brain

Studies have demonstrated that, like most complex thought processes, there are a number of brain areas or different brain regions involved in mathematical processing (Sousa, 2001). The frontal lobe and parietal lobe of the cerebrum (i.e., the areas of the brain that are responsible for higher order thinking skills) are highly involved in mathematical understanding. The visual cortex is also involved, since students need to see most math problems, and the involvement of the visual cortex may be more complex than merely seeing the problem. Sousa (2001) suggested that the involvement of the visual cortex in almost all mathematical thinking indicates that math requires one to visualize math problems. Further, this would seem to be supported by studies over the years that have reported correlations between a child’s mathematical ability and visualization capabilities (Grobecker & De Lisi, 2000; Jordan, Levine, & Huttenlocher, 1995).

Math is a highly complex skill that rests on many other brain functions as well. While reading is a complex skill that can be mastered relatively independently of other skills, math is not. Whereas a child does not need to learn math (or any other subject) in order to learn reading, the child does need to learn reading in order to master math, since so much of math involves reading either math problems or word problems. Even having students do a set of vertical or horizontal math facts problems requires the students to read the numerals within the problems (Barton, Heidema, & Jordan, 2002). Thus, reading is highly involved in most mathematical work in the public school classroom, and understanding the complex reading process may help show how complex math can be. Sousa (2001) presented a model of the “reading brain” that may be helpful here (see Figure 1.1).

As shown in Figure 1.1, four areas within the brain are primarily responsible for reading. First, the visual cortex takes in the stimulus of several squiggly lines on a page; for example:

$$6 + 3 =$$

Next, this stimulus is sent simultaneously to both the angular gyrus, which is the area of the brain that decodes sounds and processes written
language, and to Wernicke’s area—the area of the brain that is involved in comprehension of language. Next, Broca’s area becomes involved; this brain area searches for meaning in the context of the numeral and its relation to other numerals presented in the problem. At this point, the frontal lobe and parietal lobe of the cerebrum become involved in “thinking through” the problem. These areas “imagine” the number problem and may even plan a strategy for solving it such as . . . “Hold up six fingers, and count them, then hold up three more fingers and ‘count on,’ beginning with seven. Then say the answer.”

As this model demonstrates, mathematical thinking is a highly complex process that involves a number of areas within the human brain, including at a minimum the frontal lobe, the parietal lobe, the visual cortex, the angular gyrus, Wernicke’s area, and Broca’s area. Other areas beyond these may also be involved in the mechanics of thinking through math problems.

Thus, teachers must take the time to show the importance of mathematics in student’s daily lives, in order for early learning to be successful. Motivation to learn math is discussed in more detail later, under “Priorities of the Emotional Brain.”

**Gender Maturation Within the Brain May Explain Early Achievement Differences**

Research has recently examined how young boys and young girls experience math. Teachers have often noted that young girls mature a bit earlier than boys, particularly in areas such as linguistic skill and fine motor control. Of course, these are exactly the skills that early schooling depends upon for reading and writing, and when girls excelled in schools it was often assumed that girls simply matured faster overall. That concept is now being challenged. Brain research has documented that while young girls’ brains do mature faster in these several areas, young boys seem to mature faster in certain other areas, including spatial and visual abilities. This may explain why young boys seem to do better in math than young girls (Strauss, 2003). At a minimum, it is not correct to assume that girls mature faster in all areas or in some overall way compared to young boys. Rather, the specific abilities associated with gender must be more carefully studied.

**Hardwired Numbers in the Brain: One, Two, Three, Many . . .**

A number of researchers have studied the normal maturation process of the developing brain in infancy and early childhood and have inquired about basic math skill. This research seems to suggest that only minimal math skills are hardwired into the brain during the normal maturation process (Geller & Smith, 2002; Sousa, 2001). These simple number recognition skills, like the development of language skills, would seem to be associated with normal maturation of the brain and central nervous system rather than schooling or preschool learning experiences.

In survival terms, this is quite understandable. Our ancestors’ brains learned early in our evolutionary history to distinguish rapidly between one
tiger that might be attacking and two tigers attacking in a coordinated attack plan, because the numbers and location of the tigers would suggest the best escape route or the best direction to run. Because movement was associated with survival, it also became somewhat hardwired in our brains—a point to which we will return later. Counting past the lowest numbers (i.e., numeration higher than 2 or 3), however, was not a selective survival skill, since that many tigers presumably left no viable escape route. Thus, the brain seems to be able to reflexively interpret the lowest numbers (i.e., 1, 2, and perhaps 3) and even to understand the numeration sequence of these numbers, but it cannot distinguish higher numbers without some instruction. Therefore, one way to understand the brain’s response to observed objects in a set can be summed up in the phrase, “One, two, three, many . . .”

From the perspective of the math teacher, this means that instruction in math will be built almost entirely on prerequisite learned skills rather than on maturational-based knowledge. Thus, the importance of mastery of prerequisite skills prior to moving on to higher level skills cannot be overstated in the math curriculum from even the earliest levels on math instruction.

The Priorities of the Emotional Brain

Because of the research completed within the past 15 years, educators have realized that emotion and emotional intent play a much larger role in learning than previously thought (Bender, 2002; Sousa, 2001). For example, much of the information taken into the brain by the senses is first processed in the midbrain or the “emotional brain.” Further, this emotional brain often serves as a filter through which stimuli must pass prior to being “considered” by the cerebrum (i.e., the forebrain and parietal lobe—or the “thinking” areas of the brain). Thus, a negative emotional response to a stimuli or particular type of task—such as a math problem—can in and of itself set up a lack of higher brain function involvement with the problem.

Of course, research has frequently shown that many students perceive math quite negatively or even fear math (Montague, 1997). In fact, such fears often provide a significant emotional barrier to mathematics achievement. For this reason, attending to a student’s attitudes toward math and a student’s motivation in learning math are critical. Teachers should both find ways to use “math-play” activities to make math less threatening, as well as scaffold students’ work to assist students in their mathematics learning. Scaffolded instruction can offer support in mathematics that can, over time, offset the negative feelings many students have toward math.
student who answered the question wrong and may lead to negative emotional reactions to math. One option for reducing such potential embarrassment, involves the “Right answer, different question” tactic. When given a wrong answer by a student, teachers merely state, “There are no wrong answers, just answers to different questions.” Here’s an example.

Imagine instructing students on double-digit addition with regrouping, using the problem: 64 + 28.

Some excited student—a student who only last week learned double-digit addition without regrouping—may well answer “82!” Rather than immediately correcting him, the teacher could say something like, “I like that answer, but it really answers another question better. Let’s figure out what question it answers. Who can help with that?”

At that point, rather than continuing with the problem above, the teacher should elicit answers from the class about how the problem above could be modified to result in an answer of 82. For example, one could change each digit in the ones place above, resulting in a problem of 61 + 21 = ____, or even 60 + 22 = ____. Teachers should stay with this line of discussion for a minute or so, having students generate several possible answers. To finish, the teacher should have the student who answered “82” come write his or her answer in the blank at the end of one of the new problems. That way, that answer is not wrong—it is just the answer to a different problem. Note that good instruction is taking place, even during the minute or so that the class is generating new problems. Further, this tactic reduces the negative emotions that are sometimes associated with math, and students become more inclined to participate in class questions. Note that once the teacher has finished the activity above, he or she should have the class return to the original problem.

### BRAINS AS PRIORITIZING FILTERS

In the same fashion as the midbrain, or the “emotional brain,” filters out information, many other brain areas function as filters, and any of these filters may prohibit learning in mathematics. When we consider the amazing number of stimuli to which our five senses are exposed every second, we can readily understand why the brain requires a variety of filtering mechanisms. Yet as teachers, we must make certain that the concepts we wish to teach get past the brain’s filters that nature has provided.

There are several effective ways to do that. First, using novelty in teaching is critical. Tactics such as color coding or novel presentations of new information can greatly assist students in focusing on the mathematical content to be mastered. These tactics will assist every learner in mastering mathematics.

Perhaps more important is the teacher’s presentation of the material. One brain function that allows the brain to filter information involves the brain’s search for patterns, broad concepts, or organizing principles (Fuson & Wearne, 1997). Such broad concepts allow the brain to categorize and classify knowledge, and thus provide a type of “brain shorthand” by which concepts may be classified and mentally stored.
Many researchers are stressing instruction based on these “big ideas” or “essential questions” within the mathematics curriculum. These would include ideas such as the base-ten number system and concepts based on that system such as place value; expanded notation; commutative, associative, and distributive properties; and so on (see Harniss et al., 2002; Wiggins & McTighe, 1998). In order to get past the filtering function of children’s brains, teachers should address, explicitly and repeatedly, the “big ideas” in each math unit. Further, teachers should assist students in making connections between these big ideas across instructional units. With appropriate instruction based on these critical concepts, almost all learners can master the basic mathematics curriculum content in the elementary grades.

A number of researchers have begun to discuss the concept of “number sense” (Gersten & Chard, 1999; Griffin, Sarama, & Clements, 2003; Whitenack, Knipping, Loesing, Kim, & Beetsma, 2002). Number sense may be best understood as a student’s conceptual understanding of basic number and numeration concepts such as counting, or recognizing how many objects are present in a set, and how a number may be used to represent that set of objects. The concept of number sense also involves recognizing that patterns make up the sequence of numbers. Gersten and Chard (1999) defined number sense as “fluidity and flexibility” with numbers.

For example, students with number sense can translate real-world quantities and the mathematical world of numbers and numerical expressions (Gersten & Chard, 1999). These students are often quite capable of expressing the numbers in several different ways. They can show eight fingers by holding up five on one hand and three on the other, or when asked to show the same number another way, they can hold up four on one hand and four on the other. Students with number sense know that five objects are more than two objects; they recognize the relative size of the numbers though they may not know the actual difference between the two numbers.

In contrast, younger students without number sense may be able to count and recognize the figure that symbolizes the number (Gersten & Chard, 1999). They may be able to write or point to the numeral “5,” but they do not comprehend the actual meaning of the number. They cannot yet tell if seven is more than five. While many children can count, children without number sense do not seem to have the concept of what the numbers mean or of the fact that numbers may be used to represent objects in a set. These problems may stem from a lack of understanding of one-to-one correspondence or simply from lacking the insight that higher numbers represent more “things” in a set. For
older children, deficits in number sense would stem from the types of problems noted above. For example, students in the middle grades should realize that both \( \frac{2}{3} \) and \( \frac{5}{8} \) are larger numbers than \( \frac{1}{2} \), because of the numerator/denominator relationship (e.g., when the numerator is larger than half the value of the denominator or it is almost as large as the denominator, the fraction is more than \( \frac{1}{2} \)). Without such recognition, students in the middle grades will show deficits in their understanding of fractions.

Initially, a child’s early concept of number sense is acquired through informal interactions with the child’s family prior to the school years. Unfortunately, if a child has not acquired number sense prior to kindergarten, the typical curriculum in school will not usually help him or her catch up (Gersten & Chard, 1999). Further, children raised in low socioeconomic environments tend to have less knowledge of number sense than students raised in middle to high socioeconomic homes (Gersten & Chard, 1999), because children from lower socioeconomic backgrounds have less of a chance to “double,” “add,” “subtract,” and so on (Gersten & Chard, 1999).

Gersten and Chard (1999) suggest that number sense is critical to early education in math, and children without number sense will be at a great disadvantage. Further, number sense is necessary, but not sufficient, for problem-solving skills. Children must learn number sense in order to interpret mathematical problems in the real world, but they must also learn simple operations in order to begin mastery of problem solving. With this growing importance associated with number sense, it is unfortunate that few math curricula provide instructional tasks that address this critical phase in mathematics achievement. For this reason a series of instructional activities that will enhance students’ number sense is provided later in this chapter.

MULTIPLE INTELLIGENCES: AVENUES FOR LEARNING MATH

The work of Howard Gardner, PhD, in multiple intelligences (Gardner, 1983, 1993) has had a profound influence on how mathematics is taught across the nation (Hearne & Stone, 1995; Katz, Mirenda, & Auerbach, 2002). As one example, Tomlinson’s critically important construct of the differentiated classroom is based, in part, on the work of Dr. Gardner (Bender, 2002; Tomlinson, 1999). Dr. Gardner, in 1983, proposed that intelligence should be conceptualized as a variety of relatively discrete and independent intelligences rather than one overall measure of cognitive ability. He has now identified eight intelligences that represent different ways a child may understand or demonstrate his or her knowledge (Gardner, 1993). These include the following:

*Linguistic:* One’s ability to use and manipulate language

*Bodily/Kinesthetic:* One’s sense of one’s body in space, and one’s ability to move one’s body through space
Logical/Mathematical: One’s ability to understand logical propositions; one’s “number sense”

Musical: One’s ability to understand the structure of music as well as the rhythms, patterns that make up music

Spatial: One’s ability to interpret spatial relationships, or to cognitively manipulate spatial relationships

Interpersonal: One’s ability and skill at influencing others, reading subtle facial or bodily cues, and getting along with others

Intrapersonal: One’s sense of self, including awareness of one’s self and satisfaction with one’s self overall

Naturalistic: One’s ability to perceive relationships in the natural environment, to perceive categorical distinctions and various classifications, as well as the relationships between the classifications

While there is still considerable discussion of what these intelligences constitute, or even if other additional intelligences exist, the fundamental thrust of this work has been the effort to develop a wider array of instructional activities that offer learning options for each of these intelligences (Bender, 2002: Hearne & Stone, 1995). The proponents of multiple intelligences research encourage teachers to view these intelligences as avenues to learning or opportunities for learning. Students, in turn, are viewed as having various strengths and weaknesses, and the effective teacher must implement lessons that provide learning activities that address a wide variety of these intelligences in order to provide the best opportunity to learn for students who may have different strengths in particular intelligences. Teachers are encouraged to specifically plan their lesson activities with these intelligences in mind. Thus, over the course of a unit involving math facts content, a teacher would endeavor to have some activities that involved different intelligences, as exemplified in Box 1.1.

**Teaching Tactics**

**Sample Tips for Teaching Using Multiple Intelligences**

**Musical Intelligence Examples**

1. Chanting of math facts is a good activity, and using rhythmic activities can greatly assist learning. Using the rhythm, “We will, we will rock you” and changing the addition facts (repeat that chant “One, two, three, rest” or “slap, slap, clap, rest” rhythm twice per fact and saying “one plus one is two; one plus two is three,” and so on).

2. Other great tunes used by many teachers are the theme song from the old television show “The Addams Family” and “Row, Row, Row your Boat.”

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DIFFERENTIATING MATH INSTRUCTION

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Spatial Intelligence

1. Visual aids such as manipulatives or representations of concepts (e.g., fractional parts) will assist spatial learners because they can often see the relationships.

2. As one variant, teachers may challenge groups of students in the class to write “a picture example of this problem.”

Interpersonal Intelligence

1. Group work on math facts problems; have students debate mathematical intelligence points or concepts to each other; every 15 minutes during math class, the teacher could say, “Turn to your partner and explain that concept to each other. See if you both understand it the same way.”

Bodily/Kinesthetic Intelligence

1. Movement along a number line on the floor during instruction on operations involving positive and negative integers is one example of a math movement activity.

2. Movement through an addition or subtraction math problem is another example. For the problem $6 + 8 = ?$ the teacher should have 6 students stand on one side of the room and 8 stand on the other side, then have the groups move together. This can be adapted to teach a “counting on” tactic. Begin with the group of 6 kids (because that number came first in the problem) and, one at a time, have the other students join the group while the teacher demonstrates “counting on” (e.g., begin with the number 6, and when the first student joins, say, “7,” etc.—thus “counting on” from 6).

Clearly, this emphasis on varying strengths of students in these discrete intelligences will necessitate that teachers develop a larger variety of instructional activities in order to offer all students an opportunity to learn. This approach is particularly useful in the inclusive class (Katz et al., 2002). For students who do not have a strength in linguistic learning, or even logical/mathematical learning, various activities that involve other intelligences may result in the same level of mastery of the content. Thus, proponents of multiple intelligences instruction urge teachers to teach using a wide array of instructional tactics for mathematics.

SUMMARY OF BRAIN RESEARCH

With this emerging understanding of how brains function in learning math, some preliminary conclusions can be provided for teachers. The boxed text that follows provides a brief summary of the research on how the brain learns mathematics.
Summary of Brain Research on Mathematics Learning

1. Basic counting is hardwired into the brain and seems to be present at birth. This is a survival skill (e.g., how many animals are after me?), making this early math skill a high brain priority. Anything more complex is a much lower brain priority and requires formal or informal schooling.

2. Mathematics involves a variety of brain areas and thus is highly complex. The frontal lobe and parietal lobe—areas of the cerebrum—seem to be most heavily involved in math, but the visual cortex is involved also, suggesting that students may need to “visualize” math problems. Also, because mathematical skill is often dependent upon reading, the regions of the brain involved in the complex reading process are also often involved in mathematical tasks, including the angular gyrus, Wernicke’s area, and Broca’s area.

3. Gender maturation within the brain may explain early achievement differences. Brain research has documented that the brains of young boys mature faster in certain areas, including spatial and visual abilities, and this may explain why young boys seem to do better in math than young girls (Strauss, 2003).

4. Motivation is critical to learning; it provides an emotional rationale for learning new material. Errorless learning, scaffolded instruction, and charted progress reports motivate almost all students.

5. Brains conceptualize mathematics in a variety of ways. Because students may have varying strengths and weaknesses in several of the multiple intelligences (Gardner, 1993), teachers must develop an array of activities that address a variety of these intelligences. In short, teachers should be teaching the same content numerous times (Bender, 2002), in a variety of ways, using novel teaching approaches that capture students’ attention, and offer a variety of learning opportunities tied to various intelligences.

6. Brains seek patterns and “big ideas” in mathematics. Because students learn best when presented with the same concept repeatedly in various contexts, the big ideas within the mathematics curriculum should be repeatedly stressed in different contexts.

Based on the research that has been undertaken, some preliminary guidelines for how teachers should conduct mathematical instruction may be provided. The following list of ten brain-compatible instructional guidelines should provide you with food for thought on how you teach math. Of course, these should be viewed merely as general guidelines; different students may require different approaches to instruction, based on their particular learning style.

**BRAIN-COMPATIBLE GUIDELINES FOR MATH INSTRUCTION**

1. **Less Is More.** Students with math problems will master more if exposed to less. Teachers should adapt content in the math curriculum based on the needs and learning profiles of the students. Generally it is much more advisable to truly develop understanding of
(Continued)

a few problems rather than assign many problems. Also, some students may not be as successful as others in mastering problems in the same time frame. Fewer problems that are similar in structure and that allow students to develop deep understanding is preferable to many problems of varying types.

2. Present Information at Three Levels. New concepts in math should be presented at three levels: concrete (e.g., manipulatives), pictorial or representational, and abstract. Visualizing math problems through the use of concrete examples and/or representational examples assists many students in mastery at almost every grade level (Thompson, 1992). Manipulatives should be used across the grade levels for students with learning problems. Teachers should have students visualize problems using manipulatives and then explain the result to each other. Have other students develop a representation of the problem, while still others consider it abstractly. Have students consider the question, “How can we make math representational?” This will assist learners who have a strength in spatial intelligence.

3. Teach the “Big Ideas” in Mathematics. Teachers should assist students in searching for and emphasizing the big ideas in math that cut across problem types (Harniss et al., 2002; Wiggins & McThigh, 1998). We now know that brains seek patterns, or “shorthand ways of understanding,” and our teaching should explicitly address these ideas.

4. Emphasize Mathematical Patterns. Using the patterns of counting by threes or fives can help with multiplication math facts. If possible, present patterns or steps in problem solution as an outline that remains posted on the wall for the entire unit. Use math patterns as classroom “games” with fluid, fun, “quick check” questions fired out to the class at various points in the day (Fuson & Wearne, 1997).

5. Teach Math Facts to a High Level of Automaticity. Students can proceed successfully in math only after the math facts are learned at a high level. The use of chants, music, and other novel teaching tactics will enhance memory for facts. These techniques are quite enjoyable, and will assist students who learn better via using their strengths in musical intelligence.

6. Use Novelty to Build on Students’ Strengths. Novelty increases learning and allows you to present information in various ways. Make certain to identify three or more intelligences to address in the presentation of new information, and use novel teaching ideas to present that information. Use the learning styles/multiple intelligences concept to identify and teach to strengths. I suggest that on every day of instruction, teachers should develop some movement-based activity to represent concepts. For every graph or chart, teachers should find creative ways to represent the sections of the chart with bodily movements (touching the head, shaking the fingers, etc.). Alternatively, teachers may stand students in the positions of various math problems and then move them through the problem. Such novelty will enhance the learning and result in better retention.

7. Teach Algorithms Explicitly. Have students identify word problems that do and do not involve the same algorithms. Teachers should model both examples and nonexamples of the
new concept. Further, teachers should emphasize concepts when correcting student work, and in this fashion assist students in developing a deep understanding of the concept. Research has clearly shown that merely informing students of their correctness or errors shows no positive effects on student learning (Gersten et al., 2002), so teachers should always strive to develop deep understandings, as encouraged by the NCTM standards.

8. **Teach to Both Brain Hemispheres.** While some math is hardwired into the frontal lobe and other left brain areas, other math requires spatial understanding and other right hemispheric functions. Teachers should build lesson plans to emphasize more right hemisphere involvement, since most classrooms are traditionally “left brain” oriented. Activities may include “visualization” activities, number chants, or rhythms (Sousa, 2001).

9. **Scaffold the Student’s Practice.** Teachers should use real-world examples and provide scaffolded assistance to students throughout the learning process (various examples of scaffolding are presented later in this text). Applications of constructs should be emphasized in varying levels of complexity, using various authentic instructional and authentic assessment techniques. Teachers should make connections between student’s prior knowledge and new concepts using real-world examples, as emphasized in the NCTM standards (Johnson, 2000). Also, use students to teach each other, to summarize main points, and to tutor each other in new concepts in short (e.g., five-minute) tutoring lessons. These types of activities will enhance student motivation to learn math as well as stress interpersonal learning activities.

10. **Understand the Fear and Explore the Beauty.** Many students fear mathematics (Montague, 1997) because they may remember early failures, and this negative “affective response” to mathematics can be quite debilitating. Teachers should intentionally plan activities that assist students in developing a more positive response to mathematics (Montague, 1997). For example, teachers may offer error-free learning practices or buddy-learning activities that may remove some embarrassment from periodic failures. Also, many students study math for years without having a Gestalt or excitement-in-learning experience. Showing the beauty of math patterns can be quite satisfying for a naturalistic-oriented person. It is the patterns, the constructs, the logical progression of algorithms that make math like music—a symphony to share with students.

SOURCES: Geller & Smith, 2002; Gersten et al., 2002; Harniss et al., 2002; Johnson, 2000; Montague, 1997; Thompson, 1992; Sousa, 2001.

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**Web Site Review: Brain-Compatible Instruction and Multiple Intelligences**

There are literally hundreds of Web sites that address brain-compatible instruction and/or multiple intelligences, and only a few can be presented here. You could easily do a Google search on “brain-compatible instruction/math” or on “multiple intelligences” and find numerous Web sites. Still, this list and the links on these pages will get you started.
This Web site ties brain-compatible instruction and math together and presents a large number of mathematical brainteasers. Each presents a problem as number play. In using this site, some math teachers have presented a brainteaser at the beginning of each period, as students are coming into the classroom, and have had students share their answers as they finish the period.

www.brainconnection.com

This site presents periodic articles by some of the leaders in the brain-compatible research field, such as Robert Sylwester, Ph.D. While the site is related to a marketing site for a brain-compatible reading program, useful information is often presented in these monthly articles, and many additional links may be found here.

www.ldrc.ca/projects/miinventory

This location is the site for the learning disabilities resource community, and provides some good information on multiple intelligences (MI). I like this site because it provides a printable, informal inventory that teachers can use with their students to roughly determine the various multiple intelligence strengths of each student. That is a great activity to introduce the concept of MI to your students.

www.Campbell.k12.ky.us

This is the Web site for the Campbell County School District in Kentucky. That district has begun a districtwide initiative on “Building Better Brains.” Professional development activities are tied to that effort, as are the district’s efforts to improve test scores in a variety of areas. This site shows that a well led, determined school district can create a very positive environment for exciting learning based on the very latest information on how brains learn.

INSTRUCTIONAL PHASES FOR DEVELOPING MATH SKILLS

Stepping Stones to Number Sense

Because the early development of number sense is so critical to success in math, several researchers have investigated number sense, and some teaching guidelines for development number sense are available today. For example, Gersten and Chard (1999) identified several levels of number sense among children with difficulty in math. These researchers likened the construct of “number sense” in mathematics to the concept of “phoneme instruction” in reading. Within the past decade, research has demonstrated conclusively that “phoneme manipulation” skills—that is, the ability to recognize and intentionally manipulate different speech sounds—represent a more fundamental and earlier prerequisite skill for reading than “phonics” (i.e., letter shapes/sound
skills). Of course, phonics had, for the past four decades, been the first step in reading instruction; only now have teachers realized that phoneme manipulation skills are a prerequisite to phonics. In short, if students cannot detect and manipulate sounds independent of letter recognition, they cannot succeed in phonics, which associates different sounds with specific letters. To pursue this comparison a bit farther, the concept of number sense may be as fundamental in learning mathematics as phoneme instruction has become in learning to read (Gersten & Chard, 1999).

Gersten and Chard (1999) identified several stepping stones that allow teachers to evaluate a child’s understanding of number sense. These stepping stones represent increasingly complex levels of a child’s understanding of number sense.

In short, without number sense, the child may never succeed in math at even the lowest levels, since concepts such as numeration, addition, or subtraction would have no substantive meaning. Clearly, development of number sense is a critically important first step in math instruction.

**Stepping Stones for Number Sense Development**

**Level 1**

Children at this level have not yet developed number sense or show any knowledge of relative quantity. A child at this level will not be able to answer questions involving “more than” or “less than.” Further, children at this level would not have the basic concepts of fewer or greater.

**Level 2**

Children at this level are beginning to acquire number sense. A child here would be able to state and understand terms like “lots,” “five,” and “ten.” These children also are beginning to understand the concepts of “more than” and “less than.” These children do not understand basic computation skills, but they do understand greater/lesser amounts.

**Level 3**

Children at this level fully understand “more than” and “less than.” They also have a general understanding of computation and may use a “count up from one” strategy to solve problems. These children may use their fingers or manipulate objects to solve a problem. While these children are beginning to understand computation, there will still be many errors in counting. For children at this level, adding four and three may involve holding up four fingers on one hand and three on the other. They will start at one and count to four, and then look at the other hand, and count from one to three. Finally they will count all of the fingers together to get an answer. Errors are seen more often when the child is calculating numbers higher than five, because these computations involve using fingers on both hands.

(Continued)
(Continued)

**Level 4**

Children at this level use a more sophisticated “count up” or “counting on” process, rather than the “counting all” process just described. For example, these children may hold up fingers to represent each addend, begin with the number of the first addend, and then “count on” to the second. For adding four and three, the student starts at four and adds the three, using fingers and counting out loud: “Four, five, six, seven.” At this level the child can keep track of the first addend while counting to the second. Thus, these children understand the conceptual reality of numbers (i.e., they do not have to count to four to know that four exists). Children at this level may not even need to use their fingers or manipulatives to count to find a solution. Children at this level can solve any digit problem presented to them, provided they can count accurately.

**Level 5**

Children at this level are at the highest level of number sense. They can use a retrieval strategy. They can respond quickly and correctly, pulling from memory the answer to a problem. They have learned addition math facts to a highly automatic level and have memorized some basic subtraction facts. These children can recall that $4 + 3 = 7$. They can also turn the fact around to state that $7 - 3 = 4$.

With these stepping-stones in mind, teachers need strategies for developing number sense in children, including older children, perhaps throughout the elementary school years. The section below describes several activities that early education teachers can use for teaching number sense. These activities will improve the number sense of students who already have the basics. Further, these tactics will help students with deficits in number sense to catch up with other students.

**Mathematical Play to Develop Number Sense**

A number of strategies have been suggested for developing number sense, and many of these are based on informal games and mathematical play for students (Checkley, 1999; Griffin et al., 2003; Gurganus, 2004; Whitenack et al., 2002). Initially, teachers should emphasize mathematical terms as “play” in the typical routines of the classroom; a number of ideas for this informal instruction in the early grades are presented below.

<table>
<thead>
<tr>
<th>Teaching Tactics</th>
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</thead>
<tbody>
<tr>
<td><strong>TEN INFORMAL TACTICS TO DEVELOP NUMBER SENSE</strong></td>
</tr>
<tr>
<td><strong>1. Pair Numbers With Objects.</strong> In the class routine, when discussing objects in the class or pictures in a storybook, pair numbers and objects. For example, there are two wheels on a bicycle, three wheels on a tricycle, and four wheels on a car. Students will thus begin to associate numbers with different values rather than merely as labels (Gurganus, 2004).</td>
</tr>
</tbody>
</table>
2. **Begin Class With Counting.** Even young children can typically count to ten, and choral counting out loud emphasizes counting without the embarrassment of being wrong (e.g., “Let’s count together how many objects are on this shelf in the front of the class”). After a few days of counting, pair the counting with written numbers on the dry erase board.

3. **Extend Counting to Other Number Patterns.** In some of the early counting activities, students should extend their counting to other, larger numbers. Rather than counting from one to ten, teachers could have students count from 101 to 110 (Gurganus, 2004).

4. **Use Finger Patterns.** Finger patterns are a way children use their fingers to represent the numbers one through ten (Whitenack et al., 2002). Provide students varied exercises that allow them to represent the numbers with their fingers. Students at first only use their fingers the same way they have learned how to count. Part of number sense is recognizing that there are several different ways to represent numbers, and playing games with finger patterns allows children to think unconventionally. Students need the exercises to see that three fingers on one hand and two fingers on the other hand represent the same number as five fingers on one hand. Class discussion during the finger pattern game allows students to see the differences and the similarities between the different ways of representing numbers. Having students explain why they picked three fingers on one hand and two fingers on the other lets the students that held up five fingers on one hand see a new pattern and visa versa. This is a good type of instruction to use in a “buddy” game, where kids are paired together to generate an alternative solution.

5. **Plan Estimation Experiences.** Discuss “less than” and “more than” with students and encourage estimation. Some students are uncomfortable with estimation since students typically strive for the “right” answer. Encourage students to provide an estimation within a certain range (e.g., “How many shoes are in class today? Give me a number between forty and seventy,” or “How many students are sitting in a single group in the media center?”).

6. **Counting-Off in Line.** Students in lower grades frequently line up to go to the lunchroom or elsewhere. Every time students line up, teachers could encourage them to count off, and thus stress number sense (Griffin et al., 2003). As an interesting variation in the upper grades, have students count off when in line using a “quiet voice” but have each person who is a multiple of a certain number (say a multiple of five) say his or her number louder. This makes learning multiplication more interesting since multiples will be frequently used in the classroom.

7. **Stress Numbers in Other Subjects.** When encountering a number in a reading story, take a few moments to explore the number. When a group of characters in a story does something together, stop for a moment and say, “I want to get a sense of how many are doing that in this story. Let’s have students in the first row stand up to represent that number.”

8. **Emphasize Measurement.** From the early days of kindergarten, teachers should take measurements of objects and discuss them with the class. Teachers may use a short tape measure to measure the length of the teacher’s desk or a student’s desktop. When measuring distances on the floor, teachers may add the element of counting steps (e.g., “How many steps are there in the ten feet between the front row of student desks and the...

(Continued)
teaching strategy: mathematical games to develop number sense

In addition to the informal tactics noted above, other more structured mathematical games and activities can also assist in developing number sense. Generally, these will be more effective if this instruction is managed as mathematical play, rather than instruction. Teachers should be creative with these general ideas. In using these mathematical play activities, it is critical that teachers develop the theme or “big idea” that they wish to teach, and emphasize that theme repeatedly. Teachers should summarize each problem by talking with the students about the problems. Teachers may make summary statements about work completed by the students. Statements such as, “If you add, then the amount you finish with is larger than what you started with” will assist students in developing number sense (Griffin et al., 2003).

9. chart making money. Using charted data in higher grades (which takes only one or two minutes at the beginning of the class period) can encourage students to use numbers in a real-world environment. A teacher might start each student with $1,000 in make-believe money in the stock market, and have each student pick stocks to buy and to chart stock price changes for. This can be a fun learning activity with real-world significance.

10. model enjoyment of numbers. Perhaps the most important legacy a teacher can leave with a student is enjoyment of number play. Gurganus (2004) emphasizes the importance of the teacher modeling the enjoyment of numbers and establishing a climate for curiosity in mathematics.

Teaching Strategy: Mathematical Games to Develop Number Sense

In addition to the informal tactics noted above, other more structured mathematical games and activities can also assist in developing number sense. Generally, these will be more effective if this instruction is managed as mathematical play, rather than instruction. Teachers should be creative with these general ideas. In using these mathematical play activities, it is critical that teachers develop the theme or “big idea” that they wish to teach, and emphasize that theme repeatedly. Teachers should summarize each problem by talking with the students about the problems. Teachers may make summary statements about work completed by the students. Statements such as, “If you add, then the amount you finish with is larger than what you started with” will assist students in developing number sense (Griffin et al., 2003).

Teaching Tactics

Games and Activities to Develop Number Sense

1. “Catch the Teacher” Games. Teachers may occasionally wish to make mistakes and have students point out these counting mistakes. This is a tactic that can work for students in a variety of grade levels. For example, teachers may skip numbers or repeat numbers while counting and instruct the students to quietly raise their hands if they hear a mistake. Students must then describe the mistake that the teacher made (Griffin et al., 2003).

2. Greater/Fewer Games. Students who need to learn the concepts of greater or fewer can generally be taught using manipulatives such as the same-size blocks, papers with dots,
and the like. Having the students line up and each take a different number of steps may assist students to see relationships between numbers (e.g., that a student who took four steps went farther than a student who took two steps). Teachers should use several different methods that students will be able to understand to concretely illustrate various number facts, such as the fact that seven is always greater than four. For example, teachers should use different-size blocks to illustrate the same number concept (e.g., seven is greater than four regardless of the size of block).

As an example of a number sense activity for older children, teachers may challenge the students with questions such as the following:

I have ten candy bars. We’ll just pretend my fingers are candy bars. Here are some candy bars in this hand. (The teacher should hold up four fingers, while hiding the other hand behind his or her back.) How many am I hiding from you?

3. Moving on Down the Road. Using a number line on the floor, have students move “down the road” by noting the numbers as they pass. Emphasize that six steps are more than five steps, and so on. For older students, this number line activity can be done with both positive and negative integers.

4. Teaching Puppets. Teachers can teach beginning addition and help increase number sense at the same time. Using a puppet, the teacher would place a specific number of cookies in a bag (e.g., three cookies). Next the teacher would have a student draw a card from a pile that has “+ 2,” “– 3,” or “+ 4,” or other such number facts on it. The teacher should ask groups of students to think through the problem and then do the problem using the puppet by calculating how many cookies are left. This can assist spatial learners as well as students with a strength in interpersonal intelligence.

5. Pocket Games for One-to-One Correspondence. Use a hanging shoe bag with at least ten pockets (Checkley, 1999) and put a different number on each pocket. Give students cards that have varying numbers of objects on them. Have the students match the number and the card by placing the card in the appropriately labeled pocket. Students may even make their own cards.

6. Snap-Together Objects. Kindergarten and first graders need to practice addition and subtraction repeatedly in various game formats. Teachers may use a group of cubes or objects that snap together to assist in this practice. First, divide the students into groups of two. Next, give each group a chain of ten snap-together objects. Then, one student should break the chain and give the other student the portion of the chain that is left. The second student would then be required to tell how many objects are missing (Checkley, 1999). This will assist bodily/kinesthetic learners.

7. Using Mathematical Models. Allow students to make mathematical models for the problems they are asked to solve. For example, consider the following problem: “There are seven children; how many eyes are there?” Teachers may wish to allow the students to create their own drawing for this problem in order to help them find a solution—a technique that will be of great benefit to visual/spatial learners. Some students may just draw a circle with two dots. Other students will draw more elaborate drawings that have noses and mouths. In this approach, the students are allowed to use their creativity to solve math problems (Checkley, 1999).

(Continued)
8. Use Manipulatives. Many students unfortunately feel that blocks or other manipulatives are “baby toys,” and some students even put them away by first or second grade. For other students, however, manipulatives need to be used for as long as possible in the early grades. When students ask about manipulatives, point out that almost all teachers are using sections of a round pie for fractions in Grades 3 and 4, and even Grade 5. Also, teachers should not insist on students’ using pictures or “representations of manipulatives” before they are ready. Rather, use of manipulatives should be allowed for as long as students wish in the early grades (Checkley, 1999).

9. Make a Class Quilt. This is a creative activity that is great for spatial learners. First, each student designs his or her own “square” for the quilt. Teachers may wish to use crayons or tempera paint to color the squares of cloth. The squares are then combined and sewn together to make a quilt. This allows students an early introduction to geometry, fractions, visual-spatial reasoning, and addition, since the quilt components represent various shapes and various portions of the whole. Teachers should display or use the quilt so the students will be reminded of the concepts as well as have pride in their work (Checkley, 1999).

10. Musical Fraction Squares. In this “musical squares” game, the parts of a fraction can be demonstrated. Begin with four students and four chairs and write “4/4” on the dry erase board. Discuss the fact that the chairs represent the numerator and the students represent the denominator. Thus, if the teacher removes one chair while the music plays, there will be 3/4 or three chairs and four students. The teacher can then discuss various fractions with the students and talk about, “What is left when the music ends?” or “What has been taken away?”
frequently use movement, but the use of movement is highly recommended for learners at all ages. The musical fraction squares game described earlier presents one idea for movement. As another example, when teaching various bar graphs, stand the students in the shape of each bar (e.g., three students make a shorter line than five students, etc.).

Remember that any concept that can be graphically represented on an overhead or on the dry erase board can be a model for students. Merely have students stand in that same configuration and then discuss why it is important that they be so placed in the overall chart of the concept.

2. **Cross Out Problems.** This approach to practice work can assist children who have attention problems. On a page of math problems, the teacher may instruct the student to cross out every other problem to adjust the assignment for these kids. This adaptation emphasizes the less-is-more aspect of teaching kids with learning problems, since some students find looking at an entire page of math problems quite daunting. Crossing out some of the problems may make the work seem possible.

3. **Peer Buddies.** After the teaching phase of the math lesson, when some students are doing reteaching work, the teacher may wish to have students do math problems together as peer buddies. This involves having two students work together on the same set of problems. This can alleviate some embarrassment, since it is more fun to work together and each student can “assist” the other. This will be a great teaching strategy for students with a strength in interpersonal intelligence.

4. **Color Coding Cue Words.** Color highlights novelty in learning and results in increased attention from the learning brains within the classroom. Teachers should use colored markers frequently. For example, in subtraction problems the teacher may wish to color subtrahends a specific color. Further, in word problems, teachers may color the “cue words” that usually specify one operation or another. On math worksheets that involve several types of problems (e.g., adding fractions with like or unlike denominators), teachers may color code the problems of one type or another (e.g., like-denominator problems all in red, and unlike-denominator problems all in black). This will assist students in recognizing the types of problems.

5. **Teach With Edibles.** For younger kids, using an individual supply of edibles (fruits such as raisins work well here) can make using manipulative counters more fun! Use edibles as the counters, and after each correct problem, the student can eat one of the counters. The child’s lesson is finished when the edibles in his or her pile are gone!

6. **A Chart Teaming Activity.** The teacher begins by dividing the class into teams. At a signal from the teacher, one member of each team runs to the team’s chart to write a relevant fact on the chart about that topic. The other team members should make certain the fact is correct. At the next signal, the next team member writes down another fact. This activity involves movement and cooperation among team members as well as competition between the teams.

7. **Personal Learning Timelines.** Each student should keep a timeline, illustrated with pictures of the types of problems he or she was working on at various dates during the year. This can be quite motivating for students, who see their progress in mathematics. These timelines should also be shared with parents at various points in the school year.

(Continued)
8. **Math Facts Call-Outs.** Teachers begin this activity by dividing the class into four teams and having the teams line up in rows. Then the teacher calls out math facts problems for one member of the first team. If that member calls out the math fact correctly, the team gets two points. If he or she needs help from a team member to get the math fact right, the team gets one point. If that person gets a math fact wrong, the team gets no points. This will assist in learning math facts at a high level of automaticity.

9. **Use a Math Portfolio.** Teachers may wish to save a series of worksheets, activities, and group projects in which a child has participated. As a guideline, teachers should save one assignment each week throughout the year. This portfolio can provide a critically important indicator of how a child is doing in math and, like the timelines above, can be shared with the child’s parents or even with the child’s teacher for the next year.

10. **Use Multiplication Charts.** Beginning at the top left of a sheet of paper, form a multiplication chart by writing the numbers 1–12 on both the horizontal and vertical axis. Then write the products at each intersection. Note for the students how they may find products (e.g., lay two sheets of paper across the lines, and the intersection of the papers shows the product of any two numbers). Also note that the rows represent the same as “count by . . .” for each number in the chart.

**SOURCES:** Bender, 2002; Forsten, Grant, & Hollas, 2002.

Further, in addition to understanding these basics of instruction in math, teachers need a clear concept of what differentiated instruction in math is. While volumes of texts can be (and have been) written that detail a wide variety of specific mathematical instructional strategies, teachers need to develop a deeper understanding than most of the “lists of good teaching ideas” that books present. Rather, teachers need to understand how the various instructional ideas and tactics fit together to form a coherent instructional approach for differentiation in the math curriculum.

This chapter has provided a basis in both multiple intelligences and brain-compatible instruction in order for teachers to have a better understanding of the differentiated instructional strategies that may be used for all students in the elementary classroom. Further, in order to get a clear understanding of differentiation, teachers may wish to use a self-evaluation tool that involves many of the basics of brain-compatible instruction in the act of lesson planning. One option for teachers is a lesson planning grid that cross-references multiple intelligences and the levels of instruction, as presented in Figure 1.2.

Teachers should copy this figure and use it in their lesson planning for mathematics. In fact, this tool can be of assistance when planning an instructional unit at any level. Imagine the following example for teaching students in the early grades how to tell time. In this unit of instruction teachers should strive to design activities that address each of the areas of the self-evaluation grid. For example, consider the mix of activities for instruction in telling time found on p. 24.
## Representational Levels

<table>
<thead>
<tr>
<th></th>
<th>Concrete</th>
<th>Pictorial</th>
<th>Abstract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bodily/Kinesthetic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Musical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spatial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inter/Intrapersonal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naturalistic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linguistic</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Logical/Mathematical</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1.2**  A Self-Evaluation Grid for Lesson Planning
Ideas to Teach Telling Time

Clock Face Movement Activities

Teachers should prepare a large clock face (perhaps six feet in diameter) on the floor, using masking tape to make the circle, and placing digits 1 through 12 in the appropriate spots. A meter stick may be used as the minute hand and a ruler as the hour hand. Students, working in teams of two or three, should be required to display various times on the large clock by moving the hands as necessary; they may be told, “Make the clock say 1:20.” In order to assure involvement of all students, each student should hold a small clock face and individually complete the same task when a team of students is working on the large clock face.

Musical Intelligence/Repetition

Couple the activity above with the use of the song below, to the tune of “The Wheels on the Bus Go Round and Round.”

The short hand says its number first,
Number first, number first.
The short hand says its number first,
When we’re telling time.
The long hand is tall and counts by five,
Counts by five, counts by five.
The long hand is tall and counts by five,
When we’re telling time.

A Number Line of Fives

Much of telling time involves increments of five minutes, so students need to be able to count by fives. To facilitate that, teachers can create a large number line across the top of the dry erase board, with every multiple of five printed in red and other numbers printed in black or blue. Student who cannot yet count by fives can merely read the numbers printed in red.

Web Site Review: Telling Time Instruction

The Web site below has a wide variety of math activities, and it particularly includes the option to print out worksheets that present a clock face and require the students to draw hands on the picture. While there, investigate the many other options for instruction mathematics in a wide variety of areas.

http://math.about.com
In the set of simple activities earlier, a series of differentiated teaching tactics have been used that are novel and address a variety of multiple intelligences. Specifically, the activities address bodily/kinesthetic learning in a concrete fashion, through movement across the floor, as well as the students’ manipulating their own clock faces. Spatial intelligence is addressed concretely in the spatial aspect of clock face manipulation. Linguistic skill is emphasized in the use of the song, as is musical intelligence. Interpersonal intelligence is involved in the teamwork aspect of the clock face activity. Also, a variety of big ideas are addressed, including aggregation of data and numeration.

Further, when an activity includes a concrete example, as have these tactics, and teachers have thoroughly discussed the example, then both representational and abstract learning have also taken place. Thus, after such instruction, teachers can draw an arrow across the grid from left to right for each of these intelligences, since instruction has been offered at each level. Finally, many of these activities (e.g., the song and the large clock face activity) could be repeated several times in this instructional unit of telling time.

Note that while concrete examples will, of necessity, include both a representational and an abstract component, the inverse is not true. That is, abstract examples do not necessarily include concrete and/or representational components. Rather, teachers offering abstract instruction should devise and employ a variety of additional techniques that will offer concrete or representational levels of instruction on the same “big idea.”

**WHAT’S NEXT?**

In the next chapter we will cover some of the basics of differentiation in mathematics lessons and explore how teachers can plan effective mathematics instructional lessons based on these differentiated instructional concepts.