

1

The Influence of Cognitive Gender Differences



SOURCE: Photographer: Duane Berger. Used with permission.

When I proposed to write a book about the strategies I have used and my experiences in teaching math and science to girls, I received two responses from women. One group asked me if such a book is actually needed as girls are doing so much better in the technical areas. The other group said something like, “That’s great. I wish I had had that when I was in school, and I know many girls who can use some help now.”

Many people, both women and men, have expressed the belief that the way women think is not conducive to doing well in math even though, as you have seen from the previous chapter, women have done very well in science, technology, engineering, and math (STEM) careers. What do we know about cognitive gender differences with respect to how we learn math and science, and do those differences account for the problems that some girls seem to have in math? How extreme are the cognitive gender differences present in very young children?

QUIZ

Respond to the following statements about cognitive abilities by indicating whether the statement best describes (a) girls, (b) boys, or (c) both girls and boys.

1. Hear quieter and higher-pitched sounds better
2. Are more comfortable when the room is colder
3. Are more active
4. Can focus on moving objects better at one year of age
5. Have more connections between neurons in the brain
6. The left side of their brain matures sooner
7. Can throw objects at a target better at an earlier age
8. Have a higher tolerance for pain
9. Are more likely to use a visual strategy to remember something
10. Are more likely to use concrete methods to solve arithmetic problems

Answers are on page 31.

What we know about cognitive gender differences and the applications of this knowledge to the classroom is fairly new. What follows is an account of the latest research about gender differences in the brain and cognition, which has implications for those who are interested in maximizing the potential of the female brain in the math and science classroom.

I will try to make this brief, but this will provide a basis for future discussions about learning strategies. Using this information will help you tailor your teaching so that all students have a chance to learn in the way that best suits them. Please remember that what follows refers to average differences and individuals may only exhibit some of the features.

In the recent past, the differences between genders were usually ascribed to social construction, the belief that children learn how to behave as girls and boys by observing adults, usually their parents, or by being taught what was appropriate (Witt, 1997). With new visualizing techniques, we are beginning to be able to observe what parts of the brain are functioning when an individual is involved with a task, and we note that, in some respects, males and females do not process information in similar ways. This indicates that what women and men think and how they behave may be more influenced by the brain than previously thought. The more important point is that the differences are present very early (Giedd, Blumenthal, Jeffries, Castellanos, et al., 1999), in some cases at birth (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000), indicating the early influence of biology. How much gender roles are influenced by biology and how much by environment is still a matter of conjecture, but it is evident that both influences are involved. With the new information about cognitive differences, we need to let girls know that they are not limited by biology and that there are many reasons why they can do well in math and science. All they need are strategies and confidence, and you can help them acquire both.

If girls and boys are not processing information in the same way, this has implications for the classroom. Teachers need to be cognizant of these differences and understand that not only do children learn differently but also good students may learn differently from the way the teacher learns. If a child approaches a learning task in a way that is different from the way the teacher would, that does not necessarily make either approach better or worse than the other, just different.

I believe strongly that using this information will help all of your students. However, there are two sides to the academic arguments about cognitive gender differences. One group looks at research on adults and concludes that because men and women don't differ a great deal on cognitive measures, education of children should focus on the similarities that exist between girls and boys. Generally, this group believes that if gendered educational principles are used, the differences between boys and girls will widen. The other group looks at research on the many cognitive gender differences present at birth and in young children. The conclusion drawn by this group is that the problems that girls have with math and science and that boys have with language arts begin early and only by using gendered educational approaches will men and women become more equal in their cognitive abilities. Just so you know, there is no research that has found definitive proof one way or the other.

PART 1: THE BRAIN AND SENSES

There is a big difference between the brain and the mind. The brain is the organ that sits inside our skull, and there is a great deal of controversy over how much influence the structure of your brain has on your thinking and reasoning abilities—your mind. With modern imaging techniques, scientists are looking closely to see what parts of the brain respond when an individual is directed to think certain thoughts. Consequently, we now know the location in the brain for some mental functions. However, what we know is similar to knowing that a key, electricity, and a starter motor are needed to start the engine in a car. Knowing what structures are involved does not help us understand the process, and that is what scientists are still looking for. What we do know is interesting, but the question remains: How are differences in brain development and function reflected by the differences in cognition?

Any discussion about the cognitive differences between the typical male brain and the typical female brain must accept that, on average, boys and girls differ, but that difference is not absolute. For example, I am tall for a woman, 5 feet 10 inches, which is the average height of a man in the United States. That does not make me a man; it just means I am a tall woman. Even though the average differences between girls and boys are small, there is a consistent and predictable difference. Consequently, many of your female students will benefit from the suggested teaching and learning strategies contained here, but not all. On the other hand, a few of the students who will benefit will be male.

What the Brain Looks Like

In discussing their abilities in math and science, one of the most common statements that many women make is that they can't do those subjects because they are not left-brained. The cerebrum, the largest part of the brain, is composed of two similar, but not identical halves, and the popular notion is that the left side of the brain performs logical tasks and the right side of the brain uses intuition to process information. Each half of the cerebrum is composed of four similar, but not identical, lobes that do different tasks.

The Lobes of the Cerebrum

The frontal lobe is located at the front of the brain and is involved in decision making, impulse control, and working memory. We now know that this portion of the brain develops slowly and is the last to complete development. On average, the female frontal lobes are completely developed by ages 16 to 20, whereas the male frontal lobes may not develop completely until age 25 (De Bellis et al., 2001; Giedd, Blumenthal, Jeffries, Castellanos, et al., 1999; Njemanze, 2007).

The occipital lobe is located at the very back of the brain and is involved in helping us translate the neural impulses from our eyes into the sensation we call vision. The left occipital lobe receives information primarily from the right eye, and the right lobe gets information primarily from the left eye. It takes both halves of our occipital lobe receiving information from both eyes to enable us to see in three dimensions.

The parietal lobe is located between the frontal lobe and the occipital lobe at the top of the head. Part of this lobe is involved in receiving and understanding sensations from the body. The section of the parietal lobe that is responsible for perceiving sensation is next to the frontal lobe at the top of the head. Another part of this lobe appears to be involved in combining those sensations to allow us to manage spatial information as well as helping with memory.

The temporal lobe is located above the ears on both sides of the brain. Because of the location of this lobe, it makes sense that it is involved in hearing. Another important function of the left temporal lobe is in developing language skills, although research indicates that females may use some of the right temporal lobe to do this as well (Shaywitz et al., 1995; Vuontela et al., 2003).

Research has revealed that parts of the brain do not develop in the same way or at the same rate in females as in males. It appears that the left side of the brain, especially the areas devoted to language, develops first in girls, and the right side of the brain, especially the areas devoted to spatial skills, develops first in boys (Shucard & Shucard, 1990). It is probably the early left-hemisphere development that is responsible for the early advantage that girls have in verbal skills (Njemanze, 2007). So contrary to popular opinion, girls are left-brained, or at least that half of their brain develops first.

Amygdala and Hippocampus

Other parts of the brain show gender differences in development, particularly two small parts of the brain below the cerebrum—the amygdala and the hippocampus. The amygdala is one of several structures deep within the brain associated with emotions, and the hippocampus, usually associated with memory, is located close to the amygdala. A longitudinal study observing developing brains of children ages 4 to 18 found sex-specific developmental differences in the amygdala and the hippocampus. The results indicated that as the children developed, the hippocampus increased more in females and the amygdala increased significantly more in males (Giedd, Castellanos, Rajapakse, Vaituzis, & Rapoport, 1997).

What do the amygdala and hippocampus do specifically? Imaging research revealed that when asked to remember something, females tend

to use the left side of the memory portion of the brain (the hippocampus) with verbal strategies while males tend to use the right side of that same structure along with visual strategies (Frings et al., 2006). The amygdala also shows different uses between males and females. In emotionally arousing situations, the right portion of the amygdala in males is activated to improve memory for central details, and in females the left portion of the amygdala works to improve memory for peripheral details (Cahill, 2003). This means that in emotional situations, males may tend to pay attention to the basic facts and females may have a more global view of the event.

The amygdala is involved in helping us produce and interpret emotion. Children were shown pictures of people whose faces were exhibiting fear. As females matured, the portion of their brain that processed this information shifted from the amygdala to the prefrontal section of the frontal lobe, whereas most males continued to use the amygdala for this task (Killgore, Oki, & Yurgelun-Todd, 2001). Remember that the prefrontal lobe helps control impulses and make reasoned decisions. The theory is that young females begin to use language to manage their emotions, whereas young males may simply respond to emotions with emotions.

Table 1.1 contains some information about specific lateral gender differences in the amygdala and the hippocampus.

Table 1.1 Gender Differences in the Amygdala and Hippocampus

	<i>Left Side of Brain (develops first in girls)</i>	<i>Right Side of Brain (develops first in boys)</i>
<i>Hippocampus (memory) (develops faster in girls)</i>	Memory of nouns	Memory of pictures and topography
<i>Amygdala (emotions) (develops faster in boys)</i>	Spelling, reading of words, verbal intellect, and vocabulary	Mathematical calculation and performance

SOURCE: Papanicolaou et al., 2002; Yurgelun-Todd, Killgore, & Cintron, 2003.

This means that females begin processing information in the left side of their brain using language as a framework for memory. Males, on the other hand, begin processing information in the right side of their brain using pictures and emotions to remember events.

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ When presenting information to girls in the classroom, begin with a comprehensive discussion of the material before you introduce the details.
 - For younger students, give each pair of students the same number of colored blocks to look at. Ask them what they notice about the blocks. When the class decides how to sort the blocks (usually using color as a guide), ask them how many they have of each color. If you have enough blocks, make sure that you have different shapes of the same color, which will give the students another way to sort the blocks. Help your students see that there are many different ways to sort the same collection of blocks. Using the card game SET provides a similar task.
 - For older students, begin a unit on multiplication by having students talk about what they already know about the subject and discussing the general use of multiplication in a wide variety of areas. Try to get your students to see common elements in areas using the same type of mathematical operation. Then give direct instruction in the method. This approach works especially well in science where students will have some knowledge about the subject being discussed.
- ✓ Begin all math and science classes with written material and carefully describe every step in a problem. Frequently, those of us who find math and science easy are visual learners and we forget that putting an equation on the board without describing it may not have much meaning for a student who learns best from the written or spoken word.
 - Younger students will want to see the step-by-step directions for a science exercise.
 - Older students will need to read the directions for a lab exercise as homework the night before so that they have time to familiarize themselves with the procedure.
- ✓ If students have weak spatial skills, help them use their verbal skills to compensate. Books such as *The Greedy Triangle* by Marilyn Burns (1994), *Sir Cumference and the Round Table* by Cindy Neuschwander (1997), and *Anno's Mysterious Multiplying Jar* by Masiachiro and Mitsumasa Ann (1983) are all examples of stories that help young students understand the principles of math and figures. There are many similar books, and your librarian or bookseller will be happy to help you find more.

Corpus Callosum

The corpus callosum is the structure that connects the two halves of the cerebrum. The idea has been proposed that if girls use both halves of their brain for language, then the female corpus callosum should be larger to allow the verbal centers on each side of the brain to communicate.

Research is mixed on this topic because there is a tremendous variation in size, shape, and development of this structure. Another factor is that male brains are, on average, bigger than female brains, and it is difficult to say if the differences in size and shape of the corpus callosum are because of sex or individual development (Fine, Semrud-Clikeman, Keith, Stapleton, & Hynd, 2007; Giedd, Blumenthal, Jeffries, Rajapakse, et al., 1999; Morton & Rafto, 2006). An interesting study that looked at the size of the corpus callosum and its relation to reading skills found that as the area of certain sections increased in size, reading ability increased, especially for women (Fine et al.). This last study would seem to confirm the notion that because women use both sides of their brain for language, their corpus callosum will be larger because of the greater number of connections between the two halves. However, this discussion is ongoing because so few studies agree on whether there are gender differences in size, shape, volume, or area of the corpus callosum. Even though there are no definitive answers yet, I include this information primarily because in the future you may hear a discussion of the importance of the corpus callosum to learning.

Sensory Differences

Aside from the gender differences in the way the brain matures and functions, there are also significant gender differences in the way the senses function. All information, regardless of method of presentation or source, enters the brain through one of the senses, so sensory gender differences will create variations in the way children experience what happens in the classroom.

Hearing

From birth, the female ear is more sensitive to sound and can hear quieter sounds and higher-pitched sounds than can the male ear (Cassidy & Ditty, 2001; Corso, 1959). Boys tolerate louder sounds better than girls do (Elliott, 1971; McFadden, 1998), but girls are better than boys are at determining changes in intensity of sound (Velle, 1987). Infant girls are more responsive to auditory stimulation than are their male age-mates (Velle). Girls may find a noisy classroom distracting, but they are better able to discern emotional state from someone's voice.

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ Make sure that your voice works for girls.
 - Very young girls may be startled if you use a loud voice to get students' attention. Flash the lights in the room or develop a hand signal to indicate that students should start paying attention to you.

- In a coed class with older students, girls with very sensitive ears may do better at the back or on the side of the classroom. I have a loud voice, and I recommend to my students with sensitive hearing that the best place for them to sit is in the very front on my left. When I lecture, I turn slightly to my right, so anyone on my left will not get the full force of my voice. On the other hand, if you have a quiet voice, do not assume that all of your students can hear you.
- ✓ Young girls sometimes find it difficult to speak loudly in class when they answer questions. Have the whole class stand up as tall as they can, which will allow them to fully use their diaphragms, and respond in unison to questions or to recite some material that has been memorized. This will help girls learn how to speak a bit louder and, in a group, they will be more willing to do so.

Vision

While girls have better auditory acuity, boys have better visual acuity, and while boys tolerate sound better, girls tolerate light better (McGuinness, 1976; Velle, 1987). However, even though boys may see better at a distance, particularly when the object is moving, girls can remember more items in a picture. When girls look at the same picture after some of the items have been moved, they will be more accurate in finding the moved items than boys (Kimura, 2000).

Girls also show better perceptual speed than boys do. This is the ability to look at similar items and locate the one item that is different, a skill that is useful in proofreading. This ability to find errors is one of the reasons girls generally are more willing to check their work (Kimura, 2000; Majeres, 1999). While research indicates that adult males have better visual memory than females, as children, girls have better visual memory, probably because of the differences in brain maturation (Vuontela et al., 2003). Additionally, several areas in vision have significant gender differences as well.

Color Vision. Most individuals identified with color blindness (whether the more common red-green variety or the rarer blue-yellow variety) are male. It is rare for a female student to have imperfect color vision, but the condition does appear in women. Color blindness is not the lack of color vision but the inability to differentiate between the paired colors of either red and green or blue and yellow. Individuals with red-green color blindness frequently can't see a difference in color between the top and bottom lights on a traffic signal, as they may see red and green as the same color. You can use the colors in class as color-blind students will see them, just don't use red and green to differentiate similar items, such as providing a red bin for homework and a green bin for permission slips.

Females will name more colors and use more elaborate words to identify colors than males will (Green & Gynther, 1995). Whether or not females actually see more colors than males, or whether it is just that males

don't consider slight differences in colors important has not yet been determined. We know that certain cells in the retina, the parvocellular cells, are important for color vision, but there is no research to find if there is a sex difference in the number of these cells (Snowden, 2002).

When drawing pictures, young girls are likely to use more than 10 predominantly warm and bright colors such as red, yellow, pink, and brown, and create pictures with a lot of detail, usually of people placed as if in a posed photograph. Young boys will use fewer than six colors, which may be cooler or darker such as blue, black, and silver, and the pictures may have vehicles or weapons in them designed to be viewed from above or sideways. The impression of girls' pictures is that they are illustrative or decorative, and boys' pictures are realistic or action oriented (Iijima, Arisaka, Minamoto, & Arai, 2001).

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ Girls respond well to the use of color. We will discuss specific uses of color in math and science later, but you will note that girls often like to use colored highlighters and color code their materials.
 - Younger students will quickly learn a color-coding system in a classroom. If you use colored paper to post information, children can learn that yellow sheets contain information for their parents, pink sheets contain information for math class, and the like.
 - Not all girls are neat, and one way to help keep materials organized is to color code everything. My math notebooks were always white and my science ones green. That helped me find them in my bookbag or on my desk. I used colored plastic envelopes to store my papers in, and the color of the envelope matched the color for that class. Using the envelopes does not make me any neater, but it does help keep the material for one class together in my bookbag so that I have fewer places to look for papers.
- ✓ Using the same color to alert students to information will help girls. Teachers have conventionally used red pens to correct papers, and students generally recognize that red marks on a paper indicate mistakes. You don't have to use red, but changing what color you use to correct papers with may create problems for girls. Not all marks made by teachers on papers are to indicate errors, and if you can manage it, try using other colors when you make suggestions or offer praise. "Good work!" will stand out if you write it in green if the corrections are usually marked in red, remembering that color-blind children may see the corrections and the praise as the same color.

Gazing. Not only do boys and girls see differently for acuity and color, but also they choose to look at different things. One-day-old infants were given a choice to look at either a face or a mosaic of a face, and observers agreed that girls looked at the face and boys looked at the mosaic of a face

(Connellan et al., 2000). When one-year-old infants were exposed to videos of moving objects, girls chose to look at faces and boys chose to look at cars (Lutchmaya & Baron-Cohen, 2002). Boys' preference for looking at moving objects at a distance may be responsible for some of the difficulties they have when learning to read and girls, whose eyes see stationary objects close by, may have an advantage when viewing academic work.

When looking at pictures of faces, girls were better than boys at determining what emotion the individual was feeling. Preschool girls were better able than boys were to select a photograph of a child whose face best portrayed the emotion that was described in a story that had been read to the children (Boyatzis, Chazan, & Ting, 1993). In fact, research indicates that all through adolescence, girls are better at nonverbal processing and at determining emotional states of others from facial expressions and body language (McClure, 2000).

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

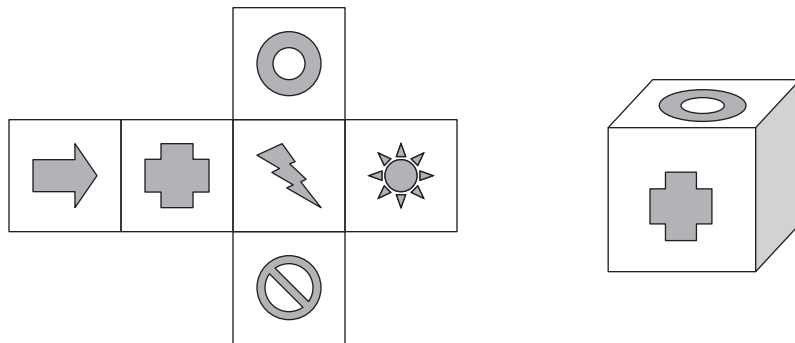
- ✓ Subtle facial expressions are usually picked up by girls. Most girls are able to read facial expressions and body language well, and they use that information to help them understand what you are trying to tell them. However, do not count on that as a means to convey information.
 - With younger students, simply ask children what they think you meant to convey. You may be surprised that not every student gets the same message.
 - With older students, if you are teaching health or life science, you can give a lesson on body language and on facial cues. Your students may also be interested to learn about the facial feedback hypothesis—if you smile, you tend to think more positively, and if you frown, you may think more negatively.
- ✓ When working with girls, place them so that they can see your face. Likewise, do not face the blackboard when you lecture, as girls cannot see your face that way.
 - For younger students, classrooms are frequently arranged in groups with the students facing one other. This means that some students may have their backs to you. Either go to each group to speak to them or have the students turn their chairs around when you are giving directions to the whole class.
 - With older students, I recommend that you use an overhead projector with acetate sheets or use a digital projector to display what you are writing on a tablet-type computer. You can then face your students as you write while the machine projects your notes on a screen.

Spatial Relationships

This topic includes several different skills, some of which may be more problematic for girls and others that show no gender advantage. The reason this information is included is that skills in spatial relations are frequently given as reasons that students do well in STEM courses (Halpern et al., 2007).

- Mental rotation is a skill at which men traditionally excel and involves being able to determine which of several three-dimensional figures are the same as a target figure. What makes the task difficult is that none of the sample figures are in the same orientation as the target (Linn & Petersen, 1985).

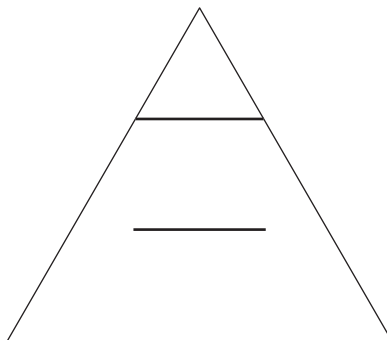
Figure 1.1 Example of a Mental Rotation Task



Which image, seen on the flattened cube on the left, would appear in the blank side of the cube on the right? Which image would be on the bottom of the cube?

- Spatial perception is a skill at which men are somewhat better than women. This skill involves being able to determine the relationship of a distant object to one's own body when there is distracting information. An example of this skill is the ability to determine whether a distant line is horizontal if there is a tilted structure on it, such as in Figure 1.2, Ponzo Illusion (Miller, 2001).

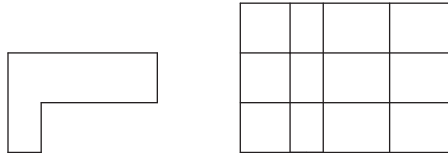
Figure 1.2 Ponzo Illusion



Do the horizontal lines appear to be different in length? Measure the lines to see if you are right.

- Spatial visualization appears to have no gender difference. This skill involves being able to find a simple figure in a complicated one (Linn & Petersen, 1985; Miller, 2001).

Figure 1.3 Example of a Mental Rotation Task



Can you find the simple figure on the left in the more complex figure on the right?

This figure is similar to those on the Embedded Figures Test. Some research indicates that there is no gender difference on this test (Spreen & Strauss, 1998), and other sources report that males are better at finding the hidden figures than females (Jonassen & Grabowski, 1993). While administering this test, I have noticed that men may do a bit better than women, but many women are convinced they can't do it and will say so before beginning the test.

The major issue here is whether or not gender differences in spatial skills affect performance on math and science. Earlier research did not find that spatial skills conveyed an advantage in mathematics but indicated that verbal skills were more highly correlated with math achievement (Friedman, 1995). However, it should be noted that all subjects in the Friedman study were gifted or college-bound students who could be expected to have strong verbal skills. Other studies discovered that performance on a test of mental rotation predicted performance on the SAT-Math (Casey, Nuttall, Pezaris, & Benbow, 1995). More recently, research has uncovered evidence indicating that middle-school girls with poorer spatial-mechanical skills were less likely to do well at the type of math that boys traditionally do extremely well (Casey, Nuttall, & Pezaris, 2001). So do spatial skills make a difference in girls' math performance? Research indicates there may be some influence, teachers I know believe it has a small effect, but my female students are convinced it has a huge influence if they have problems doing well in math, particularly with geometry.

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ One way to help girls who are having problems with spatial rotation is to have models of the figures you are discussing.
 - For younger students, Cuisenaire rods and other similar block systems are wonderful aids to help explain the principles of algebra and geometry.

(Continued)

(Continued)

- Most math departments have models for geometric figures and science departments offer models of parts of the body or biological specimens.
- ✓ Suggest that your students build models for each class.
 - Young children can use bendable straws and tape to construct simple geometric figures both two-dimensional and three-dimensional.
 - Older children can use materials from a craft store to construct models of cells and their organelles. Pipe cleaners, Styrofoam balls or blocks, felt squares, and the like can be used to manufacture the parts of cells or atoms.
 - Another way to build models is to have students become the parts of the model. In the cell model, a different organelle would be assigned to each student who would then become the expert on the function of that organelle. The students would then interact with one another to mimic the actions of the cell.
- ✓ Any exercise that uses maps will help develop spatial skills. Children can make maps of the classroom, the school, their house, the route from where they live to school, the area where the children live, and many other places as well. Understanding how to develop a drawing that is in the same proportions as the original will help develop spatial skills.

PART 2: THE MIND

It can be a straightforward task to substantiate gender differences in sensory function because there are tests for auditory levels, color vision, spatial skills, and the like. The information about differences in brain maturation comes from magnetic-resonance-imaging (MRI) techniques, which provide tangible results. Evidence about how cognitive skills are influenced by the senses is obtained from eye tests, hearing tests, and other similar tests. However, other differences in cognitive function are more difficult to corroborate because the skills are less evident and the information from visualizing techniques is less specific. For example, there is no single empirical test for verbal skill but rather many tests for various aspects of verbal ability, and most of these tests depend on information gained in school. Vocabulary knowledge, spelling ability, understanding analogies, verbal fluency, and reading facility are just a few of the components of verbal skill. Even though there are gender differences in brain maturation in areas that seem to be involved with verbal skills, many other parts of the brain are also involved when an individual is being tested for verbal ability.

It should be noted that there are greater cognitive differences within sexes than there are between sexes (Halpern, 2000), meaning that males and females differ from their own sex more than they differ from the opposite sex. Consequently, there must be factors other than biology involved in creating these differences. Social pressures, cultural beliefs, parental concerns, and educational expectations are just some of the factors that

will affect the development of cognitive gender differences. For example, before 20 months of age, young girls acquire words at a faster rate than young boys (Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991). We have already seen that the language centers on the left side of the brain develop early in girls (Shucard & Shucard, 1990), which may account for girls' early verbal skills. Perhaps the reason girls use language so well as they get older is simply that they have more practice. What starts as a sex difference (age at language acquisition) becomes a salient gender trait (girls talk a great deal) that may appear to have been learned through observing adult models, but which begins as the result of interaction between biological traits and environment (Halpern et al., 2007).

The source of gender differences should not matter to teachers whose only concern will be providing educational opportunities to all students in ways that each student learns best. What teachers need is information about how to recognize differences and how to differentiate approaches to learning based on those differences.

Verbal Skills

We have already seen that the topic of verbal skills is a complicated one, and it may be a bit easier to look at this group of skills by breaking it into three subgroups: (1) input of information such as reading and listening, (2) output of information such as writing and speaking, and (3) utilization of information involving knowledge recall and problem solving. The evidence is strong that girls are better than boys in the first two groups of skills. One consideration for why girls suppose that they are going to have trouble with math is that math appears to require skills in the third group where girls believe they are less competent, such as logic and problem solving.

Input of Information

One way for information to enter the brain is by listening, and we have already noted that females are more sensitive to auditory stimuli and are better able to determine differences in volume than males (Velle, 1987). The research on gender differences in auditory memory indicates that females are slightly better than males at retaining information when the stimulus is heard (Geffen, Moar, Hanlon, Clark, & Geffen, 1990; Trahan & Quintana, 1990). This may be the reason why lectures work well as a method to transmit information for most women. If girls have more sensitive hearing, then it follows that receiving information by listening can be an effective learning technique for them. There is some evidence that girls' auditory as well as their visual working memory develops before that of boys (Vuontela et al., 2003).

Verbal memory, on the other hand, is quite clearly better for girls than for boys. Most females are better at reading comprehension and have

better memory for words than males (Halpern, 2000; Kimura, 2000). It is interesting that when subjects were asked to match words based on their physical characteristics such as length and shape there were no gender differences in speed. On the other hand, when the task involved the sound of words, women were faster than men. These tasks involve reading words out loud, and females have an advantage when the spelling of words is similar, such as sweat and treat, or the words were pseudohomophones, such as brane or selery (Majeres, 1999). The explanation for this difference is that girls have better phonological processing than boys, which means that girls can decipher the sound of words better.

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ Lecture is a teaching style that generally works with girls because they learn well from the spoken word.
 - For young children, make sure that you accompany what you say by showing your students what you are talking about. They need to start to learn to use the written word as well as the spoken word as sources of information.
 - Dictation is an excellent way to find out if your students are hearing what you say. Some students are better at remembering spoken words than others, and it will help all students to practice transcribing oral directions.
- ✓ Do not assume that all girls learn well from lecture, so make sure that you also provide information in written form as well. When a student cannot follow your spoken directions, it may be that the student is not paying attention, but it may also be that the student does not easily process spoken words.
- ✓ Some girls are so good at listening that they may not write anything down. Help these students learn to take some notes to help jog their memories. Suggest that, as they read the textbook, they note information from class discussion that elaborates or supports what is in the book. If students are not allowed to write in books, they may write these notes on sticky notes and place the notes over the paragraph.

Output of Information

Girls have an advantage in understanding and remembering words, and also, they are generally better than boys at producing words. Verbal fluency is measured by counting the total number of words beginning with a certain letter that can be produced in one minute. Females, particularly school-age girls, can produce more words under these conditions than their male age-mates (Kramer, Delis, Kaplan, O'Donnell, & Prifitera, 1997; Spreen & Strauss, 1998). That simply means that girls can get words out faster

when speaking, but there is no difference between females and males in verbal intelligence, understanding the meaning of words (Halpern, 2000).

In writing, girls appear to have better skills than boys. A study pointed out that one reason girls do well on the free-response portion of the U. S. History Advanced Placement exams is that their English composition skills are superior (Breland, Danos, Kahn, Kubota, & Bonner, 1994). Even though females may write more fluidly and with better organization, males are still more likely to earn a living as writers (Halpern, 2000). For example, in 2005, only 18.8% of film writers and 27.2% of television writers were women (Hunt, 2007). It would be pure speculation to give a reason why women are not represented fairly in the writing professions as a whole because girls generally have the edge in writing skills.

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ Give girls the opportunity to write as a way to help them learn the material in the class.
 - If a young girl has trouble solving a particular variety of math problems, have her use words to write down the steps in the process. That may help her see the order of the steps in the problem.
 - One reason for lab reports in science is to help the verbal student process the events that transpired in the laboratory exercise and write down those events in a logical, systematic fashion. The student who has strong verbal skills will benefit from using that strength to organize information that was not collected from a verbal source. If a female student has trouble organizing her thoughts, require that she outline the lab report based on the order of events.
- ✓ Journaling is traditionally required to help students organize their thoughts.
 - For long-term projects, keeping a journal will help all students remember what happened during the progress of the project as well as provide a place to jot down facts for future use. Keeping lab journals is an excellent way for students to process what has happened during a long-term exercise.
 - Math journals can help students work through math problems by giving them a place to write out their difficulties. A sample entry might look like this: "I'm having trouble remembering how to enter a polynomial into my calculator. All of the various parentheses simply make the problem more complicated, but if I don't get them right, the answer is usually wrong. It helps if I write the problem with the parentheses before entering it in the calculator."
- ✓ In science, have students develop questions from classwork or labwork. Learning to rephrase information so that it asks a question rather than answers one helps students use verbal skills to remember information gained from an activity.

Knowledge Recall and Problem Solving

The stereotype for knowledge recall is that boys remember more facts, and that is particularly true if it is in an area that interests them (Ackerman, Bowen, Beier, & Kanfer, 2001; Henrie, Aron, Nelson, & Poole, 1997; Lynn & Irwing, 2002). However, women have better verbal memory, particularly when the task is simple memorization (Martins et al., 2005) or if the task concerns memory for episodes (Halpern, 2000; Lewin, Wolgers, & Herlitz, 2001). That means that women can learn more information intentionally through rote memorization or when the information is made relevant to some event.

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ Point out to your students that while memorizing formulas and other facts may seem to provide a foolproof method for being correct, if they can't remember or make mistakes in recall, they will not get the right answer. Help your students figure out what is the least amount of material needed to derive all the information needed. Learning to solve problems is much better than memorizing all the answers.
- ✓ Learning information by heart is a method many girls depend on, especially in science and math. Although this seems admirable, if the problem is not exactly like the one the student memorized, she may have trouble recognizing it.
 - I have known students to memorize the formulas for determining speed, distance, and rate when these are just different versions of the same formula. Help your students to learn to figure out how to use one formula to find related others rather than letting them memorize each separate formula. The ability to use one formula to find another will be valuable in the years to come.
 - Many girls who have trouble with geometry have passed the course simply by memorizing the process for every type of proof. Help your students see the logical progression of the proof rather than depending on memory.
 - Help them see the pattern in a proof—it always starts with the given information.
 - Teach them how to solve problems backward by starting from the statement that you are trying to prove and moving toward the statement at the beginning.
 - Some of my students had problems with the shorthand developed to save space in proofs, such as SAS for *side, angle, side*, and preferred to write out the whole name of the theorem because seeing the words helped them frame the proof.

If the information requires visuospatial processing, such as graphs, charts, formulas, or geometric figures, it has been thought that men are better able to remember that information simply through visualization of the information (Lewin et al., 2001). One study suggested that more women were object

visualizers, remembering static pictures, and more men were spatial visualizers, remembering information by manipulating or transforming the images (Harshman & Paivio, 1987). A later study did support the two types of visualizers but did not find the same gender differentiation (Kozhevnikov, Kosslyn, & Shephard, 2005). This study determined that object visualizers solve problems holistically by looking at the entire problem, whereas spatial visualizers solve problems by analyzing the various elements in the problem. The point was made that both types of visualizers perform equally well on the quantitative section of the SAT and can solve science problems equally well, albeit from a different perspective. According to the latest information in this area, there may not be any gender differences in the style of visualization.

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ In math and science classes, present information for both types of visualizers by helping them find patterns in the problems. Object visualizers will benefit when the lesson gives set solutions to a problem type. Spatial visualizers will benefit when the lesson encourages the students to break the problem into different steps that can then be approached from different perspectives.
 - It is important to start this process very early. Have very young students use geoboards to help them visualize patterns and shapes.
 - Use tessellations to show that patterns can emerge by coloring the designs in repetitive ways.
 - Older students can use logic puzzles, chess, and other games to help them see how to use the parts of a problem to come to a solution.
- ✓ Pair students up and have one student describe something to the other who then has to draw it. Both students learn about visualization because the describer has to translate an object into words that will make sense to the student who is drawing. The student who draws has to translate words into pictures on the page.
- ✓ Prepare girls for standardized tests by giving them sample items requiring visualization. Analyze the different types of items and, as a class, develop different approaches for each type of question.
 - All students can learn to categorize problems by finding key words in the problem, which gives some direction to the method that will work best to solve the problem. For example, if the problem asks for *the total* number of items, addition is required to arrive at the answer.

The other issues in this area are problem-solving approaches and logic skills. The diversity between girls and boys in this area makes a huge difference in the way that they answer problems, but whether these differences are innate or learned is not clear. This is an area where teachers would like to know if these differences are acquired or built into the way brains

function. If students learn problem-solving strategies, they can be taught to use specific approaches. If the approaches that students use are part of the way their brains operate, then the teacher must help students find different methods using their own inborn strategies as a framework.

The stereotype is that girls and boys do not always use the same strategies in mathematical problem solving. A study of first graders found that girls were very concerned about getting the right answer, and to do so they would use methods such as counting on their fingers to insure that they were correct. Boys in this study were more likely simply to retrieve information even though they did not always arrive at the correct answer. What is interesting is that the number of correct responses was about the same for both girls and boys (Carr & Jessup, 1997). Another study with similar results revealed that girls in Grades 1 through 3 were more likely to solve problems using concrete strategies such as using tallies, and boys in the same classes were more likely to solve problems using more abstract solution approaches involving concepts (Fennema, Carpenter, Jacobs, Franke, & Levi, 1998).

By sixth grade, girls were less sure of their ability to solve problems and were more likely than boys to ascribe their mistakes to a lack of proficiency in math. However, the girls in this study, even though they were not convinced of their math ability, were more likely than the boys to continue to work on a problem, whereas the boys were more likely to give up (Vermeer, Boekaerts, & Seegers, 2000).

The gender differences in problem-solving strategies continue through high school, and a study of students who performed well on standardized tests revealed some of those differences when those students were asked to solve items from the SAT-M. The items were classified as conventional when the method of solving the problem was clear using an algorithm or as unconventional when the method of solving the problem might require estimation, insight, or some creative use of more conventional methods but was not an approach that had been taught in class. On these problems, female students were more likely to use conventional strategies, and male students were more likely to use unconventional strategies (Gallagher & De Lisi, 1994). This confirmed an earlier study that proposed that female students were more likely to use strategies they had been taught in class (Kimball, 1989).

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ It is tempting to teach students one way to solve problems. This takes less time and most students will do well. The problem arises when the problem on the standardized test does not look exactly like the ones covered in class. When that happens, girls may have trouble.
- Give groups of students different problems to solve. Then have each group come to the front of the room and show their classmates how to solve the problem. That will allow you to cover more material, and when students come up with novel methods, you will have the chance to help the class learn new approaches.

- If a student asks how to solve a problem, don't tell her immediately. Ask her what she thinks is the way to solve it. Frequently, girls are just looking for affirmation that they are on the correct path and, if you tell them how to do it, they may not learn to develop their own methods.
- ✓ Before you include questions on your own tests that can be solved in unconventional ways, give the class similar items for homework or as a class exercise. Let students work together to develop novel solutions. Yes, you need to prepare your students for the state-standard exams, but knowing how to use information in an innovative way will solidify understanding much more than just learning to identify what problems require certain solution approaches. If items on the standard exams do not look exactly like the ones studied in class, knowing a variety of solution paths will increase your students' chances of solving the problems.

The conclusion to be drawn from these studies is that when doing math problems, female students are more likely to work hard, to be very concerned that they use the right procedure, to use strategies that they have been taught in class, and to be less sure of their ability to be successful in math. This certainly describes many of my female students who worked hard, but if they could not match a problem with a solution they were familiar with, they would state that they did not know how to solve the problem. When I prodded them to come up with new approaches, the girls would point out that they had learned a certain method and that was how they were going to solve the problem. The older the student, the more resistant she was to coming up with a different way of solving the problem. The chapter on math will give many ideas and strategies to help girls overcome this mindset.

Analytic Styles

Another skill related to problem solving is the approach that is used to analyze information. One theory is that the male brain is wired to predict behavior by analyzing systems and understanding the principles that control them. In this model, the female brain is wired to predict behavior by empathizing with others and understanding them (Baron-Cohen, 2003). The empathizer must be connected in some way to others to work with them, whereas the systemizer needs to see others in a detached way to understand them. This theory is one explanation of why women are likely to follow the directions of superiors and men will try to figure out what superiors want from them before they act.

This model might explain why males perform better on standardized tests and females do better on teacher-made tests, especially in high school math (Kimball, 1989). Girls are more likely to pay close attention to what the teacher finds important and prepare for that material on the test.

Boys, on the other hand, are frequently astounded at what they find on a teacher-made test and will remark that the teacher never told them what material they would be responsible for knowing. On standardized tests, boys can use their systemizing skills to analyze a problem and figure out how to solve it while the girls spend time trying to relate the problem to ones they have seen in class. My female students would return after taking the SAT-M and remark that they probably did badly because they didn't recognize any questions on the test from work we had done in class, and then when they found out their score, they were astounded at how well they had done.

SUGGESTIONS FOR APPLYING THE THEORY TO YOUR CLASSROOM

- ✓ Make sure that you prepare your students for standardized tests by helping them learn general problem-solving techniques for all sorts of problems. The important part of these strategies is to get students to work independently and to realize that there is a myriad of possible solutions.
 - This works well when the approach starts when students are very young. Give groups of students several objects, such as a soccer ball, a piece of paper, a length of rope, and a chair, and challenge them to get each member of the group from one side of a room to another without touching the floor.
 - Older students can be given a theoretical problem to solve, such as figuring out how a family of four can live on a particular income.
- ✓ Remember that not all students approach problem solving in the same way. Girls can get confused if you present alternative approaches, thinking that they have to learn all of the ways that you demonstrate. Make it clear to your students that if an alternative problem-solving method is confusing they don't need to try to learn that method as long as they are successful with another strategy.
- ✓ Approach all problems in the classroom as avenues to teach or model problem solving. Be purposeful about this by remarking that the problem exists and that the class can solve the problem on their own. Problems can range from how to decide who will be the "person of the day" in an elementary class to how to study for an exam with an older class.

While girls may not do as well as boys on the SAT-M, on other standardized tests, such as the National Assessment of Educational Progress (NAEP), the difference between girls and boys is either not significant or, in some cases, girls are doing better. In 2005, 12th-grade boys only scored two points higher than 12th-grade girls on math. However, in the same year, girls' scores in reading averaged 13 points higher than those of boys.

These results indicate that it is not necessarily the standardized nature of a test that is the reason girls don't do as well as boys in math (National Center for Educational Statistics [NCES], 2007b).

Recent information has linked the gender gap in math to the gender gap index of the World Economic Forum. In gender-equal countries, girls scored as well as or better than boys in math (Guiso, Monte, Sapienza, & Zingales, 2008). Certainly, in math some of the differences between girls and boys are because of social inequities, and the more girls obtain social parity, the better their math scores become.

BRAIN AND COGNITIVE DIFFERENCES

Those in the scientific fields are beginning to understand that the brains of females and males do not function identically and that those differences result in gender-specific ways of thinking (Halpern et al., 2007). At the same time, we are very aware of the influence that society has on what we believe we can do, which can give us confidence to persevere or convince us we should not even try. Teachers who understand the basics of cognitive gender differences will be better able to frame lessons for all of their students.

ANSWERS TO QUIZ

1. A—Girls can hear whispers very well (Cassidy & Ditty, 2001; Corso, 1959; McFadden, 1998).
2. B—Boys are more comfortable when the room is colder, even though it may be hard to get adolescent girls to put on a sweater when they get cold (Beshir & Ramsey, 1981).
3. C—Boys and girls have equal activity levels. This is true as long as you are talking about children younger than 24 months. After that, boys seem to be more active, but even then, the level of activity varies a great deal and depends on the situation and on the expectation of activity levels (Maccoby, 1998).
4. B—Boys see moving objects better, particularly if the moving object is a car (Lutchmaya & Baron-Cohen, 2002)!
5. A—Girls have more connections between neurons in the brain. The suggestion is made that the female brain tends to consider facts in context rather than as individual bits of information (de Courten-Myers, 1999).
6. A—Girls' left side of their brain matures sooner than boys'. It is the left side of the brain where verbal processing begins and the right side of the brain that begins the development of spatial skills (Shucard & Shucard, 1990).

(Continued)