This limited capacity explains why we have to memorize a song or a poem in stages. We start with the first group of lines by repeating them frequently (a process called *rehearsal*). Then we memorize the next lines and repeat them with the first group, and so on. It is possible to increase the number of items within the functional capacity of working memory through this process, called *chunking*. In arithmetic, chunking occurs when the young child's mind quickly recognizes that both 3 + 1 + 1 and 3 + 2 equal 5.

The implication of these findings is that teachers should consider these limits when deciding on the amount of information they plan to present in a lesson. In other words, less is more.

**Time Limits of Working Memory.** Working memory is temporary memory and can deal with items for only a limited time (see Table 3.1). For preadolescents, that time is likely to be 5 to 10 minutes, and for adolescents and adults, 10 to 20 minutes. These are average times, and it is important to understand what the numbers mean. An adolescent (or adult) normally can process an item in working memory intently for 10 to 20 minutes before fatigue or boredom with that item occurs and the individual's focus drifts. For focus to continue, there must be some *change* in the way the individual is dealing with the item. As an example, the person may switch from listening to an explanation of a concept to physically applying it or talking to someone else about it or making connections to other learnings. If something else is not done with the item, it is likely to fade from working memory.

*Answer to Question 4. False: Working memory is short-term memory and can deal with items for only a limited time.*

Of course, some items can remain in working memory for hours or even days. Sometimes, we have an item that remains unresolved—a question whose answer we seek or a troublesome family or work decision that must be made. These items can remain in working memory, continually commanding some attention and, if of sufficient importance, interfering with our accurate processing of other information. Eventually, we solve the problem, and it clears out of working memory.

*Working memory has capacity limits and time limits that teachers should keep in mind when planning lessons. Less is more! Shorter is better!*

The implication here is that teachers should consider these working memory time limits when deciding on the flow of their lessons. In other words, shorter is better.

## Impact of Technology on Attention and Memory

Research studies are now revealing that the widespread use of technology is having both positive and negative effects on our students' attention and memory systems. Because young brains are still developing, their frequent exposure to technology is actually wiring their brains differently from the brains of children in previous generations. As these so-called "digital natives" interact with their environment, they are learning how to scan for information efficiently and quickly. Technology allows them to be more creative and to access multiple sources of information, practically simultaneously. But all this comes at a cost.

Learning requires attention. Without it, all other aspects of learning, such as reasoning, memory, problem solving, and creativity, are at risk.

How children develop attention is largely determined by their environment. Modern technology has thrust children into a world where the demands for their attention have increased dramatically. Distraction has replaced consistent attention, and, as we noted earlier, the capacity of working memory appears to be shrinking. Their brains are becoming accustomed to, and are rewarded for, constantly switching tasks, at the expense of sustainable attention. This constant switching from one task to another has a penalty. When students switch their attention, the brain has to reorient itself to the new task, further taxing neural resources. And because of working memory's limited capacity, some of the information from the first task is lost as new information from the second task moves in. Furthermore, the switching causes cognitive overload, a condition where the flow of information exceeds the brain's ability to process and store it. Consequently, the students cannot gain a deep understanding of the new learning or translate it into conceptual knowledge.

### *Is It Better to Take Notes on Paper or on a Laptop?*

High school and college students are often of the belief that taking notes on a laptop enhances their academic performance. After all, laptops allow students to access the Internet, collaborate with other students locally and internationally, engage in demonstrations and other activities, and, of course, take more notes. Because they have grown up with keyboards and technology, many students today can type faster than they can write. Consequently, students who use laptops in the classroom are likely to record more notes on a laptop than they would if they wrote them out in longhand on paper. This would seem to indicate that taking notes on a laptop allows for greater learning and a better review of that learning at a later date—say, during a test. Right? Well, not so fast!

A recent research study that included three different experiments found that college students who took notes on a laptop did not learn as much as those who wrote their notes on paper (Mueller & Oppenheimer, 2014). Students who wrote out their notes had a greater conceptual understanding of the material and were more successful in integrating and applying it than were those who took laptop notes, even though the laptop group took more notes. What happened here? Researchers suggest that because writing by hand is slower than typing, these students' brains had to listen, process, and then jot down a summary of the new learning. These cerebral processes apparently enhanced understanding and retention. Those students who typed their notes essentially recorded a transcription of the teacher's presentation, with little processing of the new material. Ironically, the more verbatim the student's transcript was, the lower that student's retention of the lesson content. Even when a group of laptop students were instructed to think about the lesson's information and type the notes in their own words, they exhibited the same degree of verbatim transcription, and they did no better in summarizing than the laptop students who did not get this instruction. This research reminds us that technology may be faster, but it does not necessarily help students learn the course content better.

***Answer to Question 5. False:*** *Students who take notes in longhand remember more and have a deeper understanding of new material compared with those who take notes on a laptop.*