Have Technology and Multitasking Rewired How Students Learn?

How does the mind work—and especially how does it learn? Teachers' instructional decisions are based on a mix of theories learned in teacher education, trial and error, craft knowledge, and gut instinct. Such knowledge often serves us well, but is there anything sturdier to rely on?

Cognitive science is an interdisciplinary field of researchers from psychology, neuroscience, linguistics, philosophy, computer science, and anthropology who seek to understand the mind. In this regular American Educator *column, we consider findings from this field that are strong and clear enough to merit classroom application.*

By Daniel T. Willingham

Question: It seems like students today have a love affair with technology. They are much more up-to-date on the latest gadgets, and they seem to have a sixth sense about how to use them. Is it true that growing up with cutting-edge technology has left them thinking differently than students of past generations? And what do the data say about bringing this technology into the classroom? Does it help students learn?

Answer: Today's students are indeed immersed in technology. According to a recent study, the average American between the ages of 8 and 18 spends more than 7.5 hours per day using a phone, computer, television, or other electronic device.[1] The press weighs in with stories suggesting that changes in technology are so profound that today's teens think of those in their mid-20s as

Daniel T. Willingham is a professor of cognitive psychology at the University of Virginia. His most recent book, Why Don't Students Like School?, *is designed to help teachers apply research on the mind to the classroom setting. For his articles on education, go to **www.danielwillingham.com**. Readers can pose specific questions to "Ask the Cognitive Scientist," American Educator, 555 New Jersey Ave. N.W., Washington, DC 20001, or to **amered@aft.org**. Future columns will try to address readers' questions.*

ILLUSTRATIONS BY JAMES YANG

"old fogies."[2] Technology has certainly changed how students access and integrate information, so it seems plausible that technology has also changed the way students think. But laboratory research indicates that today's students don't think in fundamentally different ways than students did a generation ago.

Should technology change the way you teach? On this point, there is less solid research because new technologies are, well, new. The existing research does tell us something rather obvious: new technologies do not represent a silver bullet. Just using a new gadget does not guarantee student learning. Laboratory research also indicates something more subtle: new technologies may be effective or not depending on the material and on characteristics of the student.

Has Technology Changed the Way Students Think?

I commonly hear two suggested ways that technology has changed today's students. The first is that without the rapid changes and the multimedia experiences technology can provide, students will be bored. The second suggested change is that students have developed the ability to multitask—that is, to perform more than one task at the same time. There is a bit of truth to the first of these, but not in the way that most people think. There is no truth to the second.

Engagement

Don't students find technology engaging? A complete answer to this question must have two parts. First, we might suggest that the question itself doesn't make sense. How engaging a technology is for the user depends on how it's used. It also depends on the content. It doesn't make any sense to say "Kids are interested in cell phones," because their engagement will depend on what they do with the cell phone. A teenager who is only allowed to use her phone to call her mother will be dramatically less interested in her cell phone than one who has unlimited text messaging. Is a presentation more interesting if the speaker uses PowerPoint than if the speaker does not? Potentially, but we have all seen a speaker who used PowerPoint only to create bulleted lists, which he or she then read aloud, a practice more or less certain to bore everyone. In contrast, many students are quite engaged by the *Twilight* series of novels despite the lack of technological flair.

Engagement or interest is a mental state, and the environment that will lead to that mental state need not have a technological component. In a previous article,* I suggested that a good bet for engaging students in academic content is to pose solvable mental problems. I am using the word "problems" in the broadest sense—the problems need not be overtly presented as puzzles to be solved. For example, a story presents a series of mental challenges as the listener pieces together the characters' motives and perhaps anticipates what might happen next. But the problem does have to be both challenging (i.e., not too easy) and solvable (i.e., not too hard). So while a young child may be entranced by Eric Carle's *Brown Bear, Brown Bear, What Do You See?* but not the least bit interested in Toni Morrison's *Beloved*, the opposite would likely be true for a teenager. In order for technology (or any instructional tool) to increase student engagement in academic content, it has to aid in presenting problems as both challenging and solvable. And many technologies can do just that. For example, students in a physics class may grasp the idea of sensitivity to initial conditions more easily with graphing software that allows them to make small changes in input data and then immediately see large changes in the resulting graph. Technologies like hyperlinks—the clickable words that take us around the Web—help students to explore information sources on their own. But there is nothing inherently interesting about the technology (at least once the newness wears off); students are not interested in all software or all hyperlinks. It's the content and what the user might do with it that makes it interesting or not.

In order for technology to increase student engagement in academic content, it has to aid in presenting problems as both challenging and solvable.

However, many new technologies *do* have a feature that makes them inherently interesting, irrespective of how they are used or the content they convey. That feature is providing rapid changes in what the user sees or experiences. Every teacher knows that a loud noise outside will make students turn toward the windows. This phenomenon is easily observed in the laboratory as well.[3] But not just any new sight or sound will do—it has to be unknown. We turn our attention to *learn* something. If I know that my dog is in the room, I won't look up from my book when I hear a jingling sound. But I will look up if I think she's outside. We turn our attention to new things because we want more information about them. That's why when your e-mail program pings to alert you to new mail, you feel compelled to investigate, to find out what the e-mail is about. Many new technologies have this property; new sights and sounds come to us in a continual stream, and we are engaged by this flow of new information.

I've presented two conflicting ideas: one suggesting that technology is inherently interesting, and the other suggesting that it all depends on how it is used and the content it conveys. Which is correct? These possibilities are not mutually exclusive. There is a "wow" factor that is real—be it a new technology or a new experience provided by an old technology (like a new text message delivered by your old cell phone)—but for the interest to be

*See "Why Don't Students *Like* School?" in the Spring 2009 issue of *American Educator*, available at www.aft.org/newspubs/periodicals/ae/issues.cfm.

sustained and to transfer to the subject matter, the technology must be used wisely. This interpretation is supported by data on students' reactions to interactive whiteboards. A number of studies have surveyed students (and teachers), after some weeks or months of using an interactive whiteboard, as to whether they liked it and whether it made them more interested in the subject matter.[4] These surveys indicated that students were very enthusiastic about the new technology. But another study[5] took a different approach. These researchers didn't ask what students thought about the interactive whiteboard per se; they just asked how much they liked their math class. Half of the students had been in a class with an interactive whiteboard, and half had not. The whiteboard had a positive effect on student interest in math class, but not nearly as robust as one would expect based on the other research. In sum, students find the interactive whiteboard really cool, so if you ask them about it, they respond enthusiastically. But that feeling transfers only minimally to the subject matter. That doesn't mean that the interactive whiteboard *couldn't* be used to make math more interesting. It means that the presence of an interactive whiteboard alone doesn't buy the teacher that much. The teacher must know what to do with it.

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Multitasking

What about multitasking? I've just said that many new technologies offer a rapid stream of new information to explore. Perhaps today's students have adapted to these technologies in ways that have changed their brains. Perhaps they find it difficult to focus on one thing for a long period of time, and multitasking engages them because it allows them to do several things at once. Perhaps they are better than previous generations at doing several things at once—for example, completing math problems while listening to music and also carrying on an instant messaging conversation with a friend.

Survey data indicate that younger people do multitask quite often; over half of high school students report that they multitask "most of the time," and about 25 percent report watching television or chatting with friends while they do their homework.[6] Young people report multitasking for more hours per day than older people,[7] and laboratory tests show that younger people are better at multitasking than older people.[8]

In fact, all of us perform tasks best when we do only one at a time. So, when laboratory tests find that younger people are better at multitasking than older people, what that really means is that younger people have less degradation of the speed and accuracy of each task, compared with when each task is done separately.

Young people's advantage in multitasking is not associated with them practicing it more, or enjoying it more, than older people. It is associated with young people's greater working-memory capacity.[9] Working memory is the mental "space" in which thinking occurs. For example, if you multiply 85 and 33 in your head, you manipulate these numbers in working memory to calculate the answer. If you tried to multiply 83,021 and 39,751 in your head, you would probably get confused. You have a limited amount of "room" in your working memory, and you would run out. It turns out that people with more room in working memory are better at multitasking. For reasons that are not well understood, young people generally have more working-memory capacity than older adults do, and so are better at multitasking.[10]

I mentioned briefly that young people's practice with multitasking does not account for the advantage they have over older people. The reality is actually somewhat surprising: college students who report being chronic multitaskers tend to be *worse* at standard cognitive control abilities—like rapidly switching attention between two tasks—that are important to successful multitasking.[11] That doesn't necessarily mean that practicing multitasking has made them worse. It may mean that people who are not very good at mental control *choose* to multitask more often. In fact, lack of mental control may mean that they are more distractible, and that's why they choose to multitask frequently. (Research on multitasking is becoming more common, so we should understand it better in the coming years.)

So, there is *not* evidence that the current generation of students "must" multitask. Is multitasking a good idea? Most of the time, no. One of the most stubborn, persistent phenomena of the mind is that when you do two things at once, you don't do either one as well as when you do them one at a time.[12] Our perception is that we can do two things simultaneously without cost: we may not be able to hold a conversation while we compose a memo, but many students have told me with confidence that they can hold a conversation with me while they text a friend. Actually, even simple tasks show a cost in the speed and accuracy with which we perform them when doubled up with another, equally simple task.[13]

In fact, most of the time when we believe we're multitasking, we're actually switching between two tasks. Switching from one task to another is hard because different tasks follow different rules and call for different types of responses.[14] It takes a moment or two to mentally recalibrate to these different circumstances. For example, suppose a student carries on an instant messaging conversation with a friend while she writes an English paper. The conversation and the paper each have a different history and logical progression. There are also conventions of writing particular to each: the paper requires complete sentences and that facts be footnoted, whereas instant messaging encourages abbreviations such as "lol." It's not that students (or adults) can't switch between two different tasks, but there is always a cost to speed and accuracy.

This generalization—you can't do two things as effectively as one—applies to television watching as well, but it may not apply to listening to music. Having the TV playing in the background while doing homework reduces the quality of the homework.[15] For background music, however, the results are more complex. Some studies show that music poses a distraction,[16] and others do not;[17] some indicate that vocal music distracts but nonvocal does not.[18] Still other research indicates that introverted people (those who are less outgoing) are more negatively affected by background music than extroverts (those who are more sociable).[19] This surprising finding might be due to different baseline levels of physiological activity for introverts and extroverts.

What's the bottom line in this complex literature? Multitasking is never a good idea if you really need to get something done. Listening to music while working may be the exception for some students working on certain types of tasks. Some teachers allow students to listen to their iPods while they work at particular tasks and others don't. The research literature is not clear enough to recommend to either group that they consider changing that policy.*

Teachers need professional development to create lessons that exploit the potential advantages of technology; crafting such lessons is not straightforward.

How Might Technology Influence Classroom Practice?

Just because new technologies are not altering how students think and are not necessary for students to be engaged, that doesn't mean that technology can't be useful in the classroom. What do we know about how technology can aid student learning?

Initially, it might seem that the advantages offered by new technologies are obvious. An interactive whiteboard allows a whole class to see a computer screen and the teacher (or a student) to control the computer easily. Student response systems (clickers) allow students to respond to teacher-posed questions and quickly see the tabulated results. The subtle part is figuring out the most effective classroom applications.

Can research provide any guidelines as to which classroom applications are most effective? As you might expect, these technologies are so new that there has been little research on most of them, except for interactive whiteboards and multimedia instruction. The studies on these point to two conclusions. First, the mere presence of technology in the classroom does not necessarily mean that students learn more. Second—and, perhaps, a corollary of the first conclusion—using these technologies effectively is not as obvious as it might seem at first.

Britain has made an enormous investment in interactive whiteboards,[20] and by 2007, 100 percent of primary schools and 98 percent of secondary schools had at least one interactive whiteboard.[21] British researchers have assessed the impact of this initiative, most often in teaching mathematics.

As mentioned in the previous section, early research used survey methodologies to simply ask students and teachers whether they thought interactive whiteboards were useful. The responses from both groups were overwhelmingly positive, and both groups agreed that interactive whiteboards seemed to help students focus their attention.[22] But other data indicated that the presence of interactive whiteboards did not help students learn mathematics any better.[23] These results have led researchers to a quite logical conclusion: the mere presence of interactive whiteboards in a classroom does not necessarily improve—or even change—teaching all that much.[24] Teachers need time and professional development to create lessons that exploit the potential advantages of the technology,[25] and it must be recognized that crafting such lessons is not necessarily straightforward.[26]

Although researchers are beginning to conclude that the effective use of interactive whiteboards might be more complex than was first guessed, research on multimedia technology is much further along, and it supports the same general conclusion—using technology effectively may not be as obvious as it first appears. Multimedia instruction simply refers to a lesson that contains words (printed and/or spoken) and pictures (illustrations, photos, animation, and/or video).[27] It might seem obvious that pictures are bound to supplement words and thereby enhance learning. That's often true, but not always.

Recent reviews[28] emphasize the role of working memory—the mental space in which thinking happens—in how multimedia lessons are interpreted and remembered by students. Multimedia learning means that the student must keep both text and graphics in mind simultaneously, and coordinate the two. One obvious implication is that if the text and graphics conflict, the multimedia lesson will simply confuse students. Further, if the text and graphics that go together are separated in time or in space, there is a greater burden on the student to remember them accurately and mentally put them together, and a greater likelihood that the student will not do so successfully.[29]

Recognizing the importance of working memory leads to more subtle predictions as well, predictions that are rooted in differences among students. Working memory is limited in size—each of us only has so much mental space to work with. But this size limitation varies somewhat from person to person.

*For a video by Daniel T. Willingham that summarizes the research on multitasking, see **www.youtube.com/watch?v=34OZ-dsNkBw**.

So a multimedia lesson that is effective for a student with a large working-memory capacity might be overwhelming for a student with a smaller capacity. That predicted finding has been observed in a study of a multimedia lesson in cell biology, delivered on a computer.[30] In one condition of the experiment, subjects could see cellular structures only in cross-section (that is, a two-dimensional picture of a "slice" of a three-dimensional structure). In the other condition, subjects saw the two-dimensional cross-section and a three-dimensional model of the cell that they could rotate by dragging it with the mouse cursor. The results showed that students with a large working-memory capacity benefited from the chance to see and rotate the three-dimensional model; they scored better on a content test administered immediately after the lesson. But students with a small working-memory capacity not only didn't benefit from the three-dimensional model, they actually learned *less* than comparable students (i.e., who also had a small working-memory capacity) who saw only the two-dimensional model. These students were apparently overwhelmed by trying to coordinate the three-dimensional images with the principles they were reading about.

Other findings also highlight the importance of working memory for multimedia learning. For example, it's well known that extensive background knowledge allows one to circumvent the limitation of working memory. To take an obvious example, if I ask you to hold six letters in mind for one minute, it will be much easier to do with B-R-A-K-E-S than with X-P-W-M-Q-R. Although both are a string of six letters, the first forms a word, so you can treat it like a single unit. It's like holding one thing in working memory, not six. Naturally, this saving of space in working memory only works if you *know* the word "brakes." The same phenomenon is observed in many other domains. The chess expert looking at a board does not see 16 white pieces—she sees several clusters of pieces, each cluster defined by the relationship of the pieces to one another and to opposing pieces. Whether it's chess pieces or letters in a word, the compacting of many things into one thing in working memory is based on prior knowledge.†

If prior knowledge allows one to circumvent the size limitation of working memory, then we might predict that people who know something about a topic will experience multimedia learning about that topic differently than those who do not. There are data supporting that prediction. For example, reading comprehension is sometimes compromised[31] in a hypertext environment—that is, text like that found on the Web, where the reader can click on links to see a word definition or a related figure. Deciding whether to click a hypertext link, and then, if clicked, reading the material or studying the figure, disrupts the flow of reading the main text and makes it harder to thread together the ideas. The extent to which hyperlinks disrupt reading comprehension depends on the working memory and prior knowledge of the reader. Those with a large working-memory capacity or with some background knowledge about the subject of the text find hyperlinked text less disruptive.[32]

Two conclusions are salient from this literature. First, the mere presence of technology in a classroom is no guarantee that students will learn more. New technologies are tools like any other, and they can be used in ways that are helpful or not. Second, the ways that new technologies can be usefully applied are not always obvious. Many of the most popular technologies are so new that the research literature on them is thin. There is not a list of best practices for their use.‡ Drawing on what we have learned from the multimedia literature, teachers should carefully monitor students to see if a new technology-based component in a lesson is enhancing comprehension or becoming overwhelming.

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What Does All This Mean for Teaching?

1. *Encourage your students to avoid multitasking when doing an important task.* The literature is clear on this point. Engaging in any mentally challenging task should be done on its own—not while also watching television or carrying on a conversation. Music may be an exception for some tasks and some students.

Students are likely to believe that they are good at multitasking, so they may need some quiet time in class to see just how efficient they can be when multitasking is not permitted. To most students, updating their Facebook page while text messaging and watching TV may be fun and seem efficient, but adding homework into that mix presents serious problems. As I discussed in a previous column,§ we remember what we think about, so dividing attention between homework and socializing and/or TV is very likely to decrease students' ability to learn academic content and skills.

2. *If a new piece of technology is placed in your classroom with the expectation that you will use it, take advantage of online*

†For more on this, see "How Knowledge Helps," which I wrote for the Spring 2006 issue of *American Educator*, available at www.aft.org/newspubs/periodicals/ae/issues.cfm.

‡The exception is multimedia lessons; see Roxana Moreno, "Learning in High-Tech and Multimedia Environments," *Current Directions in Psychological Science* 15, no. 2 (2006): 63–67.

§See "What Will Improve a Student's Memory?" in the Winter 2008–2009 issue of *American Educator*, available at www.aft.org/newspubs/periodicals/ae/issues.cfm.

teacher communities. As noted above, there is not a research-based list of best practices for the use of new technologies. The best ideas for how to teach with interactive whiteboards, clickers, social networking software, and other new technologies will come from teachers. Happily, the teachers who are enthusiastic early adopters of technology are also the ones who are likely to share their ideas with their colleagues via the Internet. There's no need to reinvent the wheel. Get online and find out how others are using technology. Two good places to start are **www.tammyworcester.com** and **www.freetech4teachers.com**.

3. *Think about what the technology can and can't do*. If your district plops an interactive whiteboard in your room, you may think "Okay, here it is. How can I use it?" Another (and probably more productive) way to look at technology is to turn this idea on its head. Instead of thinking "How can I use this tool?" think "I want to do X. Is there a tool that will help me do it?" That requires considering what different technologies can do.

Videos are better than photographs for showing processes that evolve in time, but photographs are better than videos for studying the details of a scene. Text messaging offers asynchronous, easily accessed communication between two people. Twitter offers this sort of communication among many people, but users are limited to 140 characters. Clickers allow simultaneous student response that is anonymous to other students, but that the teacher can track over time. When you encounter a new technology, try to think in abstract terms about what the technology permits that was not possible in the past. It's also worth considering what, if anything, the technology prevents or makes inconvenient. For example, compared with a chalkboard, an overhead projector allows a teacher to (1) prepare materials in advance, (2) present a lot of information simultaneously, and (3) present photocopied diagrams or figures. These are clear advantages. However, there are also disadvantages. For instance, James Stigler and James Hiebert noted that American teachers mostly use overhead projectors when teaching mathematics, but Japanese teachers use chalkboards.[33] Why? Because Japanese teachers prefer to maintain a running history of the lesson. They don't erase a problem or an explanation after putting it on the board. It remains, and the teacher will likely refer to it later in the lesson, to refresh students' memories or contrast it with a new concept. That's inconvenient at best with an overhead projector.

4. *There's nothing wrong with engagement*. I noted that students are enthusiastic about interactive whiteboards, but the enthusiasm doesn't seem to transfer to the content of the class. It would be better, of course, for students to become engaged with the content itself, but if the technology gives students a little energy, that's a start. A college professor I know sends assignments to his students via text messages. Another professor sniffed at this idea, noting that he could just as well hand out the assignments on slips of paper. What's important is to be clear-eyed about what's being accomplished. In this instance, the texted assignment may give students a moment of fun.* ☐

*It's also worth noting that this professor had ascertained that his students all had cell phones, and that these text messages would not cost them anything. For many teachers, the best bet may be to focus on using the technology provided by the school.

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Renaissance

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