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Commentary

The Digital Expansion of the Mind Gone Wrong in Education

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As Marsh and Rajaram (2019) make clear, researchers are still in the early stages of enumerating and exploring the implications of Internet usage for memory and cognition. That uncertainty has not, however, discouraged policymakers and pundits with an interest in K-12 education. They have not only taken for granted that the impact of the Internet on memory and cognition is in some ways predictable, they have confidently taken the next step of drawing implications for schooling from those putative effects. Here I will describe three such implications, and I will argue that the suggested education reforms are founded on a misunderstanding of the cognitive processes involved and of the likely impact of Internet use on those processes.

Implication 1: Reduced Emphasis on Memorization in Schooling

Most educators would list "teaching students to think critically" as an important goal of schooling. Research over the last 40 years has shown the importance of domain knowledge to critical thinking in reading (Shapiro, 2004), mathematics (Rittle-Johnson, Star, & Durkin, 2009), science (Carnine & Carnine, 2004), and history (Shreiner, 2014). Nevertheless, surveys have consistently shown that there is not uniform agreement among teachers as to the importance of student knowledge. For example, in a 2000 survey just 51% of teachers agreed with the statement "How much students learn depends on how much background knowledge they have—that is why teaching facts is so necessary" (Ravitz, Becker, & Wong, 2000, p. 10). A 2007 survey of teachers included an item suggesting that "accuracy and fluency in factual knowledge and basic skills form the foundation for conceptual understanding and critical thinking," and only 42% of teachers agreed (Snider & Roehl, 2007, p. 881).

The division among teachers apparent in these responses aligns with long-standing epistemological divisions in education theory (for a review of this debate, see Tobias & Duffy, 2009). Some theorists hold that factual knowledge is crucial to understanding, and also that knowledge can be transmitted from one person to another in a fairly straightforward manner. This view is clearly compatible with education that emphasizes knowledge delivered via teacher talk. The constructivist view, in contrast, suggests that understanding comes about only when an individual constructs meaning him or herself—that is, puts together the parts of a complex idea to make it meaningful. Hence meaning cannot be directly transmitted, and the value of trying to teach knowledge per se is unclear.

This debate took on new urgency around 2010, as technology became pervasive: 97% of classrooms had computers available to students for instruction by 2008 (Gray, Thomas, & Lewis, 2010) and by 2018 95% of students had ready access to a smart phone (Anderson & Jiang, 2018). If the value of teaching knowledge directly was unclear before, access to the Internet seemed to render student knowledge irrelevant. Why ask students to memorize what they could so easily look up? Marissa Mayer, then vice president for search products at Google, claimed that "the Internet has relegated memorization of rote facts to mental exercise or enjoyment" (Mayer, 2010). In 2016, Jonathan Rochelle, the director of Google's education apps group, said he couldn't answer his children when they asked why they needed to memorize the quadratic equation. "I don't know why they can't ask Google for the right answer if the answer is right there" (Singer, 2017).

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This thinking draws on Marsh and Rajaram's (2019) Properties 1, 5, and 7. You can find anything on the Internet, this access is now widespread for students, and the access is quick. Memorization is taxing for students and has the potential to undermine motivation. Why ask students to do it if they don't need to? The answer is that you actually can't always find what you hope to.

Users of Internet search engines are familiar with one type of access problem: a search returns thousands or even millions of web pages. Researchers have found that even college students attending a selective university use a feeble strategy to cope with this overload: they explore only the sites on the first page of results, thus surrendering to Google the job of evaluating the appropriateness of the findings to the user's purpose (Wineburg, 2018).

We might imagine this finding simply means that we need to teach students to conduct more sophisticated searches, but the truth is that Internet searches are inherently limited because they are decontextualized. To appreciate why that's important, consider the results of human sematic memory search. For example, suppose you read "Trisha spilled her coffee." Different aspects of meaning of this event are accessed from semantic memory depending on whether the next sentence is "Dan jumped up to get her more," or "Dan jumped up to get a rag," or "Dan jumped up, vowing never to put brandy in Trisha's coffee again" (Willingham, 2017). The reader need not even consciously consider irrelevant aspects of meaning of the verb "spill." But a reader who tries to use Google to make the connection between Trisha's spilled coffee and Dan's desire for a rag has a real problem. Searching "coffee" and "rag" lead to web pages about music (there's a song titled *Hot Coffee Rag*), home furnishings (coffee-colored rag rug), and a food and beverage company in Thailand.

Searching "coffee" alone is no better, for reasons first articulated by George Miller and Patricia Gildea in the 1980s, when considering the looking up of words in a dictionary (Miller & Gildea, 1987). The meaning of words depends on context. The writers of dictionaries cannot, of course, anticipate the context each reader will encounter, and so dictionaries strive to write definitions that are context-free. The result is that definitions are readily open to misinterpretation. In one of their examples, a child read that the word "meticulous" means "very careful," and so wrote "I was meticulous about falling off the cliff." Knowing a little bit about the word or the context in which it's used helps, and that's what the "just Google it" mindset is missing; people who think you can look everything up don't realize how much background knowledge they bring to a task like reading.

The same people overestimate the speed advantage imparted by the Internet. We think of an Internet search as speedy, and there's no doubt that opening a new browser tab and executing a search is much faster than attempting to locate the right book and then finding the desired information therein. But searching semantic memory is still faster than Google. Pausing to look up the meaning of a word disrupts the flow of reading, which is likely the reason that readers have little appetite for this work. Their tolerance for unfamiliar words varies depending on the particular text, but on average readers report that once they know fewer than 95 to 98 percent of the words in a text, reading is no longer comfortable (Hu & Nation, 2000; Schmitt, Jiang, & Grabe, 2011). In sum, there is no doubt that the Internet is a powerful research tool, but it's not clear that it's so powerful that educators should substantially change their expectations as to what students ought to have in semantic memory (i.e., facts they ought to learn).

Implication 2: The Flipped Classroom

A "flipped classroom" is meant to reverse the usual set of activities students complete at home and in class. The typical instructional model has students learning new content in class, usually by listening to a lecture. At home, they complete problems that provide practice on the new concepts they have learned, or they put those concepts to use as they work on papers or projects.

In a flipped classroom, students are meant to learn new content at home through video lectures and readings. The hope is that they will find learning easier by video than by classroom lecture because they can stop the video as often as they like to take notes or think, and they can review parts they find confusing. In class, students complete problem sets, have discussions, or work on projects. While there's little need for a live instructor to be present when students are learning new content via lecture (the thinking goes) students need guidance and feedback when they are actually putting knowledge to use. Therefore, that work ought to be done in class, when the instructor is present to help.

Flipping a classroom depends on student access to broadband Internet. About two-thirds of Americans have broadband Internet at home (Pew Research Center, 2018), so implementations of the flipped classroom in K-12 schooling is still relatively uncommon. Most implementations have been in higher education settings where broadband access can be assured. Have they been successful?

Flipped classrooms are difficult to evaluate because most research reports are case studies of a single course, and it's obvious that much depends on the quality of the implementation. How good are the videos? How effective is the instructor in leading interactive classroom activities?

Even with that limitation, a recent review of the available research yields some insights (Akçayır & Akçayır, 2018). Few studies (about 15%) report a positive impact on student engagement or motivation. About half of the studies report that students earn higher grades in the flipped classroom, a figure that seems encouraging, but ought to be interpreted in light of possible publication bias. Given that the logic of the flipped classroom is to make it easy for students to learn at home, it is telling that just 8% of studies in this review reported that students come to class better prepared.

When the flipped classroom idea gained traction around 2010, more than one college instructor joked "I've been using the flipped model for years—I just didn't know it." The point is that before videos, instructors counted on texts for students to learn new content, which students would then discuss in class. The videos were supposed to make this preparation easier, but their potential impact may have been overestimated. A live instructor may be more compelling than one on video, and there are surely fewer distractions in a lecture hall than at home (or a library, or a coffee shop), where students might feel no compunction about watching instructional videos while texting friends, listening to music, and so on. Then too, social contagion might help keep students on-task during a traditional lecture; the instructor's responsiveness and attention make it easier for students to stay with a lecture (Frenzel, Becker-Kurz, Pekrun, Goetz, & Lüdtke, 2018).

Another challenge in running a flipped classroom is the difficulty of conducting the classroom activities. The main responsibility of professors is easier in a traditional classroom (lecturing) than in a flipped classroom (supervising activities). Discussions, projects, and problem-solving sessions all have *unpredictability* in common. The instructor cannot know the direction the class will take, and that obviously makes it difficult to prepare; different content knowledge will be relevant depending on the direction the class takes, and so the instructor often feels that he or she must know *everything* to conduct this sort of class activity. Further, the instructor must make in-the-moment decisions about how to guide student thinking; for example, if a student is working a problem and needs help, the instructor has just moments to decide how to respond in a way that neither tells the student too little nor too much. In contrast, the lecturer tightly controls what happens in the class, and can plan in advance what he or she will need to know. Even under the best circumstances—motivated students, well-produced videos—flipped classrooms may deliver on their promise only for more experienced instructors and those with very deep knowledge of the content.

Implication 3: Personalized Learning

The third implication educators have drawn from the broad availability of the Internet is the possibility of personalized learning. Personalized learning is an extension of an older solution to a persistent problem: there are many more students than teachers. Instruction must therefore be one-to-many, but students come to school with different levels of preparation and require different amounts of practice to master schoolwork, so a single lesson plan is unlikely to be effective for all.

A solution to this problem was offered nearly a century ago by Pressey (1926) who suggested that each student might spend some time each day working at a teaching machine, which would be capable of presenting problems to students, recording and evaluating answers, and, most important, using student performance to determine what happened next. Students who mastered material quickly could move on, and those who struggled could work more problems or see another explanation. B. F. Skinner published extensively on this idea in the 1950's and 1960s and worked with a manufacturer to produce teaching machines and programs in math and other subjects (Skinner, 1965). Teaching machines were never broadly adopted in schools, however, partly because teachers were wary of a possible replacement, and partly due to doubts in the broader public that children could really learn from a machine, or if they could, whether they should (Benjamin, 1988).

The idea got a breath of new life in the 1980s, when mainframe computers (and a computer lab with a roomful of dummy terminals) became affordable for some school districts. Collecting simple responses, evaluating them, and engaging conditional logic to determine what happens next are challenging on purely mechanical devices, but computers make these tasks simple. And indeed, those aspects of the problem were not the main obstacle to success in this second wave of interest in machine-based instruction. In 2003, Alfred Bork, a key proponent of computer-based learning in the 1980s wrote a retrospective article that evaluated why a revolution in instruction had not taken place (Bork, 2003).

His answer boiled down to the quality of instructional materials. It's easy to get a computer to count incorrect answers to fraction division problems and, when a threshold is passed, to present another explanation of the principle. The hard part is writing a second high-quality explanation of fraction division. It's also hard to write questions that are clear and that evaluate student performance reliably and validly.

If the main motivation of computer-based instruction is to allow students not just to work at their own pace but to experience *different* instruction based on their performance or their interest, then that requires the preparation of much more content. Each choice point where students might be sent to different types of work or assessment implies an exponential increase in the need for content, and the digital revolution has not made the writing of that content any easier.

Despite Bork's pessimism, the computer-based learning industry is thriving. Computer costs have continued to decline and by 2012 the student: computer ratio in US K-12 schools averaged 1.8:1 (OECD, 2015). Some of this technology is used for whole-class teaching, but the more common model is, as Pressey envisioned, a student working alone or with one other student at a personal computer that's meant to provide individualized instruction. Research reviews allow two conclusions regarding effectiveness. First, the effect size for learning outcomes is modest, around $d = .35$. Second, there is a fair amount of variability around this mean, with a significant number of teaching software packages actually showing negative effects (Hattie, 2009; Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011).

The modest average effect size is particularly concerning when we consider the possibility of publication bias, and that the comparison condition in these studies is typically business-as-usual classroom practice, confounding the effect of the software treatment with possible motivational effects. These concerns are especially plausible given Hattie's report that the average effect size reported in education meta-analyses is $d = .40$ (Hattie, 2009)

These dispiriting results have not slowed enthusiasm for a new wave of technology-assisted instruction. Between 2010 and 2015 Rupert Murdoch's News Corporation poured an estimated 1 billion dollars into Amplify Education, a curriculum and instructional materials publisher built around personalized learning. The Gates Foundation and the Chan-Zuckerberg Initiative have both announced major initiatives to fund research in personalized learning (Herold, 2017).

These investments cannot be written off as a naïve neglect of past work—there are new developments. One is new machine-learning algorithms (as developed and improved on social media platforms) that might be better able to anticipate student interests and abilities, and so better deliver content that students find motivating and at the right level of difficulty. Another is a database of student performance that is better organized and more complete, thus providing improved fodder for the machine-learning algorithms.

It's too early to tell what will become of these latest attempts, but it's notable that the focus has not been on overcoming the key obstacle—creating an enormous library of high quality instructional materials and a map that shows sensible ways students could be guided through the library. It is telling that, although he remains a believer in the possibility of personalized learning, Larry Berger, CEO of Amplify Corporation, said in 2018 "The map doesn't exist and we have, collectively, built only 5% of the library" (Hess, 2018).

Conclusion

I've listed three ways that educators anticipated that broad access to the Internet might revolutionize schooling: obviate the need for memorization, flip the classroom instruction model, and personalize learning through computer-based instruction. None has lived up to its promise. Is there a moral to be drawn from these stories of failure?

The most important lesson is also the most obvious: student learning is a complex system, and predicting the consequences of change to one part of that system is at best uncertain. The predictions educators made were reassuringly logical. Students once needed to memorize the Pythagorean theorem (and much else) because it was inconvenient to look it up. Now it's easy to look things up. Students had no choice but to attend lectures because they lacked the means to watch filmed lectures at home. Now it's easy to watch videos at home. Students once needed to follow the same lesson plan as their peers because teachers could not deliver a separate lesson to each student. Now it's easy for a computer to do that.

The logic was specious for different reasons. Sometimes we thought technology was a suitable replacement for humans, but that turned out not to be true: humans need speedy and contextualized search that Google cannot provide, and humans prefer live lectures to video. In the final case (personalized learning), developers focused so closely on what the technology *does* that they lost sight of the subject-matter content that technology was there to deliver.

What's remarkable is the volume of time and money invested in these ideas without anyone recognizing the inherent problems sooner. We now have the benefit of hindsight, of course, but shame on us if we do not learn from these experiences. The future will include more arguments about the consequences for learning. When those arguments appeal to common sense and do not include pilot data, they should be viewed with extreme suspicion.

Author Contributions

Daniel T. Willingham is the only author and did everything for this work.

Conflict of Interest Statement

The author declares that he has no conflict of interest.

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