

Why Johnny Can't Add Without a Calculator

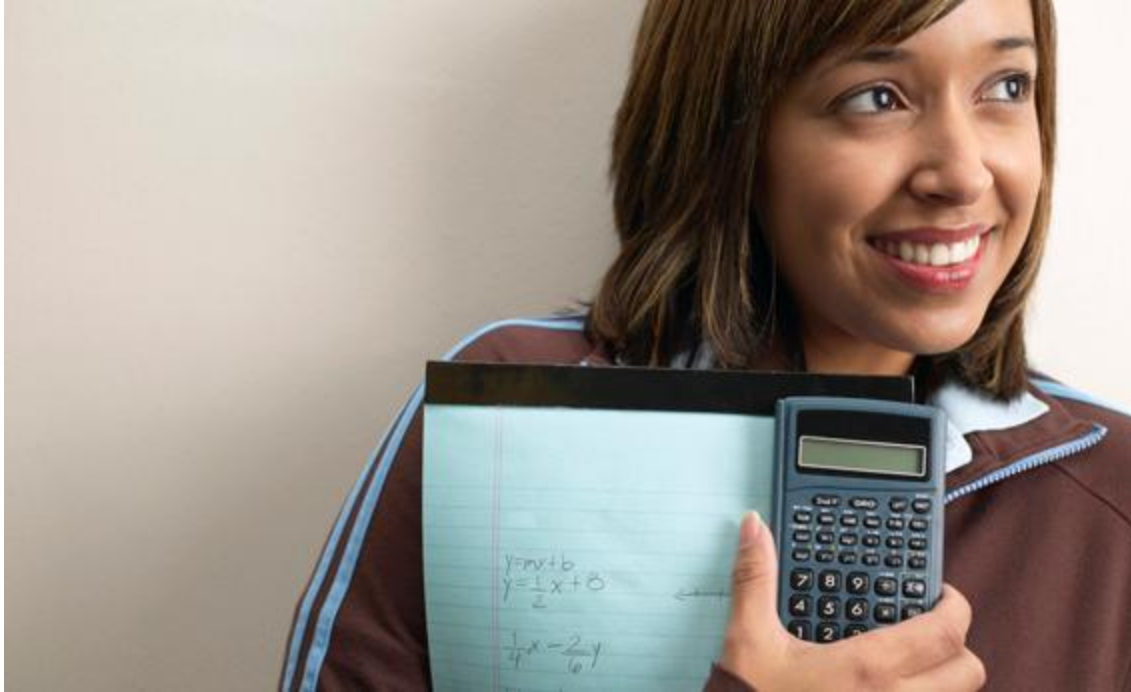
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Why Johnny Can't Add Without a Calculator

Technology is doing to math education what industrial agriculture did to food: making it efficient, monotonous, and low-quality.



If you learn how to multiply 37 by 41 using a calculator, you only understand the black box. You'll never learn how to build a better calculator that way. Photograph by Thinkstock.

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When Longfellow Middle School in Falls Church, Va., recently renovated its classrooms, Vern Williams, who might be the best math teacher in the country, had to fight to keep his blackboard. The school was putting in new “interactive whiteboards” in every room, part of a broader effort to increase the use of technology in education. That might

sound like a welcome change. But this effort, part of a nationwide trend, is undermining American education, particularly in mathematics and the sciences. It is beginning to do to our educational system what the transformation to industrial agriculture has done to our food system over the past half century: efficiently produce a deluge of cheap, empty calories.

I went to see Williams because he was famous when I was in middle school 20 years ago, at a different school in the same county. Longfellow's teams have been state champions for 24 of the last 29 years in MathCounts, a competition for middle schoolers. Williams was the only actual teacher on a 17-member National Mathematics Advisory Panel that reported to President Bush in 2008.

Williams doesn't just prefer his old chalkboard to the high-tech version. His kids learn from textbooks that are decades old—not because they can't afford new ones, but because Williams and a handful of his like-minded colleagues know the old ones are better. The school's parent-teacher association buys them from used bookstores because the county won't pay for them (despite the plentiful money for technology). His preferred algebra book, he says, is “in-your-face algebra. They give amazing outstanding examples. They teach the lessons.”

The modern textbooks, he says, contain hundreds of extraneous, confusing, and often outright wrong examples, instead of presenting mathematical ideas in a coherent way. The examples bloat the books to thousands of pages and disrupt the logical flow of ideas. (For instance, the standard geometry book for Fairfax County, which is used in schools around the country, tries to explain what a mathematical point is by analogy to pixels on TV screens, which are not in fact point-like.) Teachers at other schools in the county have told him that they would rather use the old books, too, but their principals would kill them. Other teachers have told me the same about new technologies—they, like Williams, think the technologies are ineffectual, but lack his courage to oppose them.

According to an October 2011 report, 89 percent of high school math teachers think their students are ready for college-level mathematics. But only 26 percent of post-secondary teachers think the students are ready once they get there.

This shortfall in mathematical preparation for college-bound students has existed for a long time, but it is being exacerbated by the increased use of technology. College-level math classes almost never use graphing calculators, while high-school classes invariably do. College professors want their students to understand abstract concepts; technology advocates claim their products help teach students such abstractions, but in practice they simply don't.

Take the Promethean, one of the two interactive whiteboards the school uses. When I asked a Longfellow science teacher what she could do with the Promethean she couldn't do on the blackboard, the first thing she showed me was a music video featuring a Rube Goldberg machine. She did not intend this ironically.

The second thing she showed me was a drawing of an electric circuit in which wires connect a light bulb to a battery. When the circuit was closed, the bulb lit up. This drawing goes to the heart of the technological disconnect. Her students like it when the bulb lights up, she says, because it reminds them of a video game. But this shortcut is dangerous. Learning how to visualize—as required when an electric circuit is drawn on a blackboard—is vital for developing the ability to think abstractly. You also have to make students manipulate real circuits with real batteries, with real wires that connect them and sometimes break. Showing them a toy circuit in computer software is an unhappy middle ground between these two useful teaching exercises: You neither learn how to trouble-shoot in the real world, nor do you think clearly about how electrons work.

Math and science can be hard to learn—and that's OK. The proper job of a teacher is not to make it easy, but to guide students through the difficulty by getting them to practice and persevere. “Some of the best basketball players on Earth will stand at that foul line and shoot foul shots for hours and be bored out of their minds,” says Williams. Math students, too, need to practice foul shots: adding fractions, factoring polynomials. And whether or not the students are bright, “once they buy into the idea that hard work leads to cool results,” Williams says, you can work with them.

Educational researchers often present a false dichotomy between fluency and conceptual reasoning. But as in basketball, where shooting foul shots helps you learn how to take a fancier shot, computational fluency is the path to conceptual understanding. There is no way around it.

The fight between those who seek a way around hard work (a “royal road to geometry,” in Euclid's famous phrase), and those who realize that earned fluency is the only road to understanding goes back millennia and became particularly acrimonious in America in the last half-century in the so-called math wars. On one side are education researchers like Constance Kamii, at the University of Alabama, who argues that teaching children to add and subtract is harmful. This camp says it has insights into the way children learn that warrant departure from traditional ways of teaching math. On the other side is the consensus of working scientists and mathematicians as well as teachers like Williams, who notes that it took very smart adults thousands of years to develop modern mathematics, so it makes sense to teach it to students rather than get them to “discover” it themselves.

What is new to this fight is the totalizing power of technology. A 2007 congressionally mandated study by the National Center for Educational Evaluation and Regional Assistance found that 16 of the best reading and mathematics learning software packages—selected by experts from 160 submissions—did not have a measurable effect on test scores. But despite this finding, the onslaught of technology in education has continued. The state of Maine was the first to buy laptops for all of its students from grades seven to 12, spending tens of millions of dollars to do so, starting with middle schoolers in 2002 and expanding to high schools in 2009.

The nation is not far behind. Though no well-implemented study has ever found technology to be effective, many poorly designed studies have—and that questionable body of research is influencing decision-makers. Researchers with a financial stake in the success of computer software are free to design studies that are biased in favor of their products. (I'm sure this bias is, often as not, unintentional.) What is presented as peer-reviewed research is fundamentally marketing literature: studies done by people selling the software they are evaluating.

For instance, a meta-analysis of the effectiveness of graphing calculators from Empirical Education Inc. reports a

“strong effect of the technology on algebra achievement.” But the meta-analysis includes results from a paper in which “no significant differences were found between the graphing-approach and traditional classes either on a final examination of traditional algebra skills or on an assessment of mathematics aptitude.” In that same paper, calculators were marginally helpful on a tailor-designed test. The meta-analysis included the results of the specially made test, but not the negative results from the traditional exam.

Take this gem from researchers at SRI International. They say that standardized tests don’t capture the “conceptual depth” students develop by using their software, so the “research team decided to build its own assessments”—and, of course, they did relatively well on the assessments they designed for themselves. Another example: A recent study by the Education Development Center compared students who took an online algebra 1 class with students who took nonalgebra eighth-grade math.* The online students did better than those who didn’t study algebra at all (not exactly surprising). But the online students weren’t compared with those who took a regular algebra class.

Despite the lack of empirical evidence, the National Council of Teachers of Mathematics takes the beneficial effects of technology as dogma. There is a simple shell game that goes on: Although there is no evidence technology has been useful in teaching kids math in the past, anyone can come up with a new product and claim that this time it is effective.

I tried using one such product, Cognitive Tutor from Carnegie Learning, which claims to be “intelligent mathematics software that adapts to meet the needs of ALL students.” One problem asked me to calculate the width of a doorframe, given the frame’s height and a diagonal measurement of the door. After 30 seconds’ work with pen and paper, I submitted my answer: 93.7cm. But Cognitive Tutor wouldn’t accept it. It wanted me to go through an elaborate and cumbersome series of steps to get its answer: 93.723. This isn’t teaching math—it’s teaching how to use a particular software package. The supposed “real-world applications” don’t even reflect the real world. Show me a tape measure that allows you to measure to one-hundredth of a millimeter.

Though serious empirical research fails to show any beneficial effects of technology, it also doesn’t demonstrate any harm. The emphasis on technology is in part damaging because of its opportunity cost, both in effort on the part of policymakers and in terms of money. It also distracts from the real problem: teachers who don’t understand enough about math or science. This has been a problem for a long time.

A report earlier this year from Michigan State University showed that K through eight teachers with no math specialization (the vast majority—more than 90 percent of K through six teachers and more than two-thirds of sixth- to eighth-grade teachers) got only half the questions right on a base-line test meant to see whether they knew the material they were supposed to be teaching.* The good news is that most teachers are aware of their own limitations: Only about 10 percent of the nonmath specialization K through eight teachers said they were “confident to teach all topics” in math.

Hung-Hsi Wu, a math professor at UC-Berkeley (and another member of Bush’s math panel), has been running three-week classes for elementary and middle school teachers every summer for the last dozen years. His “students” must wrestle with deep mathematical questions that both pertain directly to simple math and are poorly understood by most teachers. Why does $(-2) \times (-3) = 6$? The answer isn’t straightforward, and Wu takes several pages to give it. If you don’t understand it, though, you don’t really understand multiplication. But Wu has only been teaching about 25-30 teachers a summer—there is money for new technology but little for comprehensive teacher training. Meanwhile, the new technology makes it easier than ever for teachers to avoid learning their subject. Promethean, the “interactive whiteboard” company, advertises as a selling point the fact that teachers can share lesson plans online. But drawing up a lesson plan is itself educative: A teacher who plans his own lecture is forced toward mastery of the material, but one who downloads a PowerPoint presentation doesn’t have to know anything beyond how to download the presentation. It is a mirage of efficiency: empty calories.

The real shortfall in math and science education can be solved not by software or gadgets but by better teachers. Programs like Wu’s can make more teachers more like Williams. That’s where efforts should be focused, not on imagined technological solutions, which obscure more than they reveal.

In this, the new Common Core standards for math, which were adopted with lightening speed by 45 states and Washington, D.C., fall short. They fetishize “data analysis” without giving students a sufficient grounding to

meaningfully analyze data. Though not as wishy-washy as they might have been, they are of a piece with the runaway adaption of technology: The new is given preference over the rigorous.

Computer technology, while great for many things, is just not much good for teaching, yet. Paradoxically, using technology can inhibit understanding how it works. If you learn how to multiply 37 by 41 using a calculator, you only understand the black box. You'll never learn how to build a better calculator that way. Maybe one day software will be smart enough to be useful, but that day won't be any time soon, for two reasons. The first is that education, especially of children, is as much an emotional process as an imparting of knowledge—there is no technological substitute for a teacher who cares. The second is that education is poorly structured. Technology is bad at dealing with poorly structured concepts. One question leads to another leads to another, and the rigid structure of computer software has no way of dealing with this. Software is especially bad for smart kids, who are held back by its inflexibility.

John Dewey, the father of American education reform, defined miseducative experiences as those that have “the effect of arresting or distorting the growth of further experience.” “Growth,” he wrote, “depends upon the presence of difficulty to be overcome by the exercise of intelligence.” The widespread use of computer technology is inimical to the exercise of intelligence. I fear this is no more than shouting into the wind, but resist it while you can, because once it gets locked in—as our food system is, to monocultures and antibiotics in factory farms—it will be even tougher to get away from.

Also in Slate's special issue on science education: Fred Kaplan explains why another “Sputnik moment” would be impossible; Philip Plait explains why he became the “Bad Astronomer”; Paul Plotz describes how almost blowing up his parents' basement made him a scientist; Tom Kalil says that the Obama administration is using the Make movement to encourage science education; and Dana Goldstein explains why you should make your daughter play video games. Also, share your ideas for fixing science education in the Hive. This article arises from Future Tense, a joint partnership of Slate, the New America Foundation, and Arizona State University.

Correction, June 29, 2012: This article originally misidentified the Education Development Center as the Educational Development Center.

Correction, June 25, 2012: This article originally misidentified the university that carried out a study of teachers' knowledge of math. It was Michigan State University, not the University of Michigan. (Return to corrected sentence.)

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