K–12 Calculator Woes

In the third grade my daughter complained that she wasn't learning to read. She switched schools, was classified as Learning Disabled, and with special instruction quickly caught up. The problem was that her first teacher used a visual word recognition approach to reading, but my daughter has a strong verbal orientation. The method did not connect with her strongest learning channel and her visual channel could not compensate. The LD teacher recognized this and changed to a phonics approach.

My daughter was not alone. So many children had trouble that verbal methods are now widely used and companies make money offering phonics instruction to students in visual programs.

The concern here is with serious learning deficits associated with calculator use in K–12 math. Calculators may not be making contact with important learning channels. Are they the latest analog of visual reading?

For brevity, connections are presented as "deductions" (this about calculators causes that in learning). However the deficits described are direct observations from many hundreds of hours of one-on-one work with students in elementary university courses.[1] The connections are after-the-fact speculations. If the explanations are off-base, the problems remain and need some other explanation.

Disconnect from mathematical structure. Calculators lead students to think in terms of algorithms rather than expressions. Adding a bunch of numbers is "enter 12, press +, enter 24, press +,…", and they do not see this either figuratively or literally as a single expression "12+24+…". Algorithms are less flexible than expressions: harder to manipulate, generalize, or abstract; and structural commonalities are hidden by implementation differences.[2] The algorithmic mindset has to be overcome before students can progress much beyond primitive numerical calculation.

Disconnect from visual and symbolic thinking. Calculator keystroke sequences are strongly kinetic. But this sort of kinetic learning is disconnected from other channels: touch typists, for instance, often have trouble visually locating keys. Many students can do impressive multi-step numerical calculations but are unable to either write or verbally describe the expressions they are evaluating. Their expertise is not transferred to domains where it can be generalized.

Even among high achievers calculators leave an imprint in things like parenthesis errors. The expression for an average such as $(a + b + c)/3$ requires parentheses. The keystroke sequence does not: the sum is encapsulated by being evaluated before the division is done. Traditional programs also encourage parenthesis problems,[3] but they seem more common among calculator-oriented students.

Lack of kinetic reinforcement. It is ironic that calculators might be too kinetic in one way and not enough in another, but this seems to be the case with graphing. In some K–12 curricula, graphing is now almost entirely visual: students push keys to see a picture on their graphing calculators and are tested by hand math actually connected with ways our brains learn, and the way calculators are used to bypass drudgery has weakened these connections and undercut learning.

If the explanations offered are correct, then there are several further conclusions. First, the learning connections in traditional courses are largely accidental, and a more conscious approach should significantly improve learning. Second, calculators are not actually evil, but we must be much more sophisticated in how such things are designed and used.[4] But most of all, learning must now be the focus in education. Not technology, not teaching, not learning in traditional classrooms, but unfamiliar interactions between odd and variable features of human brains and a complex new environment.

—Frank Quinn
Virginia Polytechnic Institute and State University
quinn@math.vt.edu

Author's Note: What do you think? Enter opinions and comments at https://survey.vt.edu/survey/entry.jsp?id=1236216488429.

[1] *At the Math Emporium at Virginia Tech,* http://www.emporium.vt.edu.

[2] *For further analysis see "Beneficial high-stakes math tests: An example" at* http://www.math.vt.edu/people/quinn/education.

[3] *See the Teaching Note on Parentheses at* http://amstechnicalcareers.wikidot.org.

[4] *See "Student computing in math: Interface design" at the site in footnote 2 for an attempt.*