K–12 CALCULATOR WOES

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Introduction

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 speculations are off–base the problems remain and need some other explanation.

1. 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 $12 + 24 + \ldots$. Algorithms are much less flexible than expressions: harder to manipulate, generalize or abstract, and structural commonalities are hidden by implementation differences[2]. The algorithm mindset has to be overcome before students can progress much beyond primitive numerical calculation.

2. Disconnect from Visual and Symbolic Thinking

Calculatorkeystroke sequences are strongly kinetic. But this sort of kinetic learning is disconnected from other channels: touch typists, for instance, often have trouble locating keys. Many students can do impressive multi–step numerical calculations but are unable to either write or verbally describe the expressions they

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

[2]For further analysis of this problem see *Beneficial high-stakes math tests: an example* at www.math.vt.edu/people/quinn/education.

are evaluating. Their calculator 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.

3. 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 selecting from several pictures. They never pick up a pencil and draw a curve. Many students seem unable to internalize qualitative geometric information from purely visual input. Even some of our advance–placement students are now unable to draw or verbally describe the qualitative shape of an exponential or quadratic function.

That purely–visual instruction might have this effect should not be a surprise. Many people know they can improve comprehension of written material by copying it by hand. Kinetic reenforcement may be even more important for qualitative geometry than for text.

3.1. **Lack of Verbal Reinforcement.**

People with strong verbal orientations often have to be able to read an expression out loud before they can understand it.

My daughter went back to school in her early thirties and had to take statistics. At the beginning this was a disaster, but then I taught her how to parse and read the expressions out loud. The material became easy and she finished near the top of the class.

Now that I know what to look for, and how to look for it, it seems to me that many students would be helped by verbal reinforcement. Unfortunately this is rare in any approach to math: teachers talk more than listen and rarely make students read out loud, especially when they don't want to expose their ignorance. I cannot tell if calculators contribute to this problem but they certainly aren't part of the solution.

4. Summary

We have clever new technology but the same old brains. It turns out that some of the dreary things involved in by–hand math actually connected with ways our brains learn, and the ways 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, some learning benefits of traditional courses are largely accidental and a more conscious approach should significantly improve learning in these as well. Second, calculators are not actually evil, but we must be much more sophisticated in how

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

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.

[4]See *Student computing in math: interface design* at the site in footnote (2) for an attempt at such a design.