Healing Math Learners

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This essay is about the stagnant condition of mathematics education in the United States. In 1957 Admiral Hyman Rickover, father of the nuclear navy, called for improved math and science learning in response to the launch of Sputnik by the U.S.S.R. I was in elementary school then, and have watched math teaching remain in turmoil. In five decades since Sputnik we have lived through old math, new math, math reform, math standards, and math wars. Given the current political climate, national defense may provoke another educational "call to arms" in response to a perceived worldwide threat. International competition in the global economy wasn't a sufficient wake up call in the previous decade.

But we have a moral obligation to address the growing inequity in math learning between students in communities of wealth and communities of poverty, between suburban and urban students, and between white and Asian students and other students of color. Whatever the provocation, educators must change the way we have taught math for two generations for the majority of learners to actually learn math and attain quantitative literacy (Ellis, 2001).

Mathematics teaching and learning today is still narrowly focused on skills, is rarely integrated with science or other subjects, and does not connect theoretical understanding with real world applications. Mathematics instruction now excludes many learners. About a third of our students succeed in learning math to the level of algebra, and less than 30 percent of high school graduates have studied advanced math (National Science Board, 2006). Most of the others, including many teachers, have been wounded by their experiences trying to learn math. They believe that learning math is difficult and subtly communicate this attitude to their students. Many parents were also wounded and a fair number convey the impression to their children that learning math really doesn't matter very much in life. "We don't use algebra in our daily lives anyway, so why learn it?" This is an American phenomenon. Students in other countries are more successful in learning math through calculus and often complete advanced math or science degrees in this country.

For the last fifteen years I have been working with students in urban schools and coaching their math teachers. Together we are asking the question, "Why are some students learning algebra while others are not?" After a decade of supporting math education as a teacher educator, classroom coach, and university researcher, I am reporting my observations. Many math students were seriously wounded by their early math teaching and don't obtain the most basic levels of education required to become quantitatively literate. If we don't do something different, yet another generation may be lost.

Synopsis of Conditions in Math Learning
In this section, I offer six observations about the current condition of math teaching and learning.

1. **Only one third of students learn enough math to enter science and technology oriented careers.** We teach math as a pen on overhead, marker on board, or paper on pencil procedure for individuals rather than a team-based process of making meaning for groups of students. About a third of the students get most of it, about a third get some of it, and about a third get little of it. Less than a third of students in urban schools are learning enough math to complete STEM (Science, Technology, Engineering, Mathematics) majors in college although only a third of these successful students actually enroll in those majors. Another third of the students understand enough to move to the next grade level and generally avoid advanced courses in science or math. The remaining third are lost to STEM careers or to school. "Of 659,000 minority high school graduates in 2003, only 26,000 had the requisite preparation in science and mathematics to qualify for admission to study engineering or technology at the college level" (Slaughter, 2005).

2. **Only students who learn the way we traditionally teach succeed in math.** Pencil and paper manipulation of algorithms has changed little since the advent of common schools a century and a half ago. Students who can look at examples in textbooks and than replicate patterns in their imagination are making sense of math the way schools now teach it. Students who think best through communication with others now struggle with math instruction, as do those who think best with their bodies and feelings since few patterns are taught this way.

We have put aside math discourse and math models in favor of textbooks, examples, and practice problems or worksheets. Some teachers believe only a few students are mentally qualified to learn math rather than expecting most students to learn math through calculus as 95% do in Japan. We expect that almost two-thirds of our students will enter non-technical fields that involve only reading, writing, and relating so they "don't need to learn" much math. The seduction of consumer marketing, lottery fantasies, and inattention to and retirement planning are evidence enough that a lack of numeracy does matter (Ellis, 2001).

3. **What schools teach and students learn are algorithms and properties. We teach algorithms and properties in a vacuum of conceptual understanding about such fundamentals as place value, number relationships, and basic operations, particularly practical applications in science or social studies.** The current culture of testing facts, figures, and formulas does not emphasize these fundamentals. Elementary schools have few science classes and middle schools do not integrate math into science since making the equations and calculations is beyond many students' functional math level. A respected veteran eighth grade science teacher reports that most of his students in an urban school cannot:

- Easily weigh 5 grams of salt on a balance beam scale in a paper cup that weights 9 grams.

- Calculate how much 50 milliliters of water weighs if one milliliter weighs one gram.
- Given a ruler with inches on one side and centimeters on the other, calculate how many centimeters are in an inch.

Each of these examples demonstrates that student lack conceptual understanding and practical applications for the operations of addition, subtraction, multiplication, and division.

4. **Teachers teach what they know and teach math the way they were taught. Most elementary math teachers have little preparation beyond college algebra and a two-credit teacher education course in math methods or about twenty-four classroom hours. Middle school math teachers frequently have a major in a field other than math.**
Despite the advent of an increasingly technological world, few math classrooms use computer technology, multi-media data display, or wireless communication. Most schools and math classes look like they did fifty years ago with the possible exception of overheads or whiteboards replacing chalkboards and graphing calculators replacing slide rules and tables. One of the most difficult dilemmas is use of calculators to do simple computations. Many teachers advocate calculators and encourage students to do so. Others discourage calculator use and ask students to rely on mental math skills to estimate or make accurate computations. In general, the more students can do without calculators the better their math skills are. (I encourage students to use place value and number relationships to ground mental calculations in meaning rather than procedures.)

5. **Students are being wounded by current elementary math teaching. These are not self-inflicted injuries but rather wounds that result from poor curriculum, poor instruction, and poor assessment in arithmetic.** Many students come from elementary school wounded by their math teaching. Most of these students have given up and are lost by the sixth grade before they leave high school in frustration. Few of those who drop out or are incarcerated have more than rudimentary arithmetic skills and no understanding of algebra. As a mathematics education community, we must reach into the elementary schools to support the teachers, create a healthy math learning culture and staunch the wounds. This can only be done by first healing the math wounds of current elementary teachers and improving the quality of preparation (Kenschaft, 2005).

6. **Teachers in middle school try to triage these math wounds. Like interns in hospital emergency rooms, middle school teachers "triage" or sort students into three categories – non-urgent, emergent/urgent, and untreatable.** Visit many urban middle schools and you will find three levels of math classes: college preparatory classes for those students who are on track and do their homework; grade level classes where students take the same math curriculum but for twice as long, either over two years rather than one or in double period classes; remedial or "academy" classes where students have a regular class and a second class to revisit concepts they should have learned previously. Effective middle school math teachers report that most of the wounded students need to experience some success in mathematics to begin healing their math wounds. Many

students are so deeply wounded they no longer care if they experience success and behave accordingly.

What Will Heal Math Learners?
Current grants from the National Science Foundation and many private foundations are putting funds into secondary math reform rather than math learning by elementary teachers. **However, the need for healing math wounds in middle school will continue until the math education community assumes responsibility for the professional development of elementary teachers. This must not be a trivial in-service effort to familiarize them with textbooks, standards, and curriculum objectives as legislation now requires**. Elementary teachers must improve their understanding of mathematics and study the way students think and learn math.

This learning by elementary teaches will require elementary math coaches, professional learning communities, and commitment to curriculum reform focused on practical applications of operations with understanding. Until that happens as a matter of course, elementary teachers will learn with and from one another and gain confidence in their own conceptual understanding of math, but at a slower rate and at the expense of their students. Steen (2003) observes the lack of progress in improving math performance as an indicator "of widespread underestimation of the depth of understanding and intensity of effort required to teach mathematics effectively. A lack of respect for the complexity of the problem encourages quick fixes (smaller classes, higher standards, more tests, higher teacher salaries) that do not yield greater disciplinary understanding or pedagogical skill" (p. 3). With appropriate support, elementary teachers can move beyond the formal algorithm and testing approach to teaching math and focus on the informal diagnosis and assessment of math learning that leads to individual and conceptual understanding of math operations.

Teachers Can Heal Math Wounds Through Diagnosis and Treatment
The current educational system has almost snuffed out the art of individual diagnosis and treatment that is the foundation of healing. Schools approach teaching quite narrowly as a function of explanation, practice, and testing primarily through textbooks, workbooks, and worksheets completed in class or as homework.
Evaluation is based on standards, achievement testing, and high stakes exit exams in most public schools. Evaluating the condition of patients does not heal their wounds. Diagnosing the extent and nature of individual wounds and treating each patient accordingly is a long-term and expensive process but produces reliable results. The most effective math teachers know this and work with students at lunchtime and after school to improve their understanding of math concepts.

Curriculum Reform Must Focus on How Students are Thinking and Learning Math
The math education research community is ponderous and moving very slowly in the direction of healing. Studies are so tightly focused on single problems or specific skill sets that the big picture is very diffuse and cloudy-- like an impressionist painting that only looks real from a distance. We need to mount a serious effort to determine how children think about and learn mathematics as they make meaning individually and

collectively. Programs such as Cognitively Guided Instruction and Developing Mathematical Ideas have been successfully engaging elementary math teachers in healing math wounds and conceptually understanding math for two decades or more.
We must support mathematics learning throughout the educational enterprise. All teachers deserve full support so they can engage in more powerful levels of math learning for themselves and their students. Efforts in the East Bay Area around UC Berkeley such as Diversity in Math Education, Leading for Excellence and Equity in Math and Science, and Pre-Engineering Partnerships academic acceleration academies are demonstrating that secondary teachers can heal math wounds more effectively.

Classroom math coaching and professional learning communities are at the core of full support for professional development of elementary and secondary teachers. As teachers learn to understand and teach math conceptually, then pre-school children will learn patterns and counting, elementary students will learn place value and operations, middle school students will learn algebra and geometry, and high school students will learn calculus. Then the majority of students, not only the privileged few, will succeed in understanding mathematics.

Educational Policy Must Include Numeracy as Well as Literacy
Education and legislative policy makers must realize that the future of our ecology, technology and economy depend upon a highly educated workforce that can solve complex problems, relate with one another, and communicate with colleagues throughout the world. Math literacy must be elevated to the status of language literacy by showing each other and our children real world applications and working with adult learners in math the way we enroll newcomers in English classes. This approach would require policies that make math literacy a foundation of learning the way oral and written communication are.

Parents and teachers would be supported to study math as adult learners. Many parents themselves do not know algebra, so they can't assist their children with homework or convey the attitude that math has been important in their lives or careers. For our educational system to succeed in making mathematics truly accessible, parents must also have access to adult education in math so they can heal their wounds as well.

Concluding Comments
We risk losing another generation of urban youth to the street culture where they fight, injure, and waste each other at an enormous psychic, spiritual, and financial cost to our cities, indeed, to our whole society. When only the upper and middle class youth have access to high quality education, we all suffer the consequences. Further, math will continue to be the gatekeeper preventing a majority of public school students from equal access to an adequate, much less higher, education.
Despite some rising test scores, American math education is wounding far to many students. Far more fail than succeed, and most developed countries of the world do a more effective job of teaching their youth. Mathematics learning can only be improved if we start to help elementary students conceptually understand number relationships and applied operations. Their teachers need full support to heal themselves and their students.

New metaphors of math learning are being embraced in the academy and can influence all levels of education. Visions of math learning would contain creative and useful diagnostics so students and teachers could more powerfully create specific learning opportunities. Healing math wounds requires a curricular, community, and cultural commitment to math education. We face a complex problem that requires a simple solution-- change the way we have been teaching math for 150 years and fund our entire educational system appropriately!

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