Why School Mathematics in the 21st Century is Different

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I have been a mathematics teacher, supervisor, consultant and leader for over 40 years. I have seen dramatic changes in societal expectations, workplace demands and available technology, which all have a direct impact on K-12 mathematics - an impact that is far greater than for most other disciplines. Yet, for most of this time, few schools have recognized these differences in mathematics and therefore treated mathematics as equivalent to all other school disciplines. I argue here that this equivalence is false and ignores many factors that should lead us to consider much greater differentiation among school disciplines.

First, despite all my credentials as a certified math geek and booster, I believe that the language arts – reading with understanding, writing clearly and coherently, and listening and speaking effectively – continue to be the most important of all disciplines. We cannot teach mathematics or social studies or science if students cannot read with understanding and listen effectively, and we cannot assess these other disciplines if students cannot write or speak effectively. This overarching importance of the language arts tends to play out in most schools, very appropriately, with greater allocations of time, more professional development, and greater support personnel.

However, when it comes to changes in the teaching of language arts over the past 40 years, very little has needed to be significantly changed in terms of curriculum, instruction, assessment or mindsets about the discipline. Then, as now, expectations are that schools will ensure that *all* students will learn to read and write. Teachers now use a Maya Angelou poem instead of a Shakespearean sonnet to meet demands for greater multi-culturalism and one fiction book is replaced by a non-fiction work each year to marginally shift the focus to more non-fiction. Superficially, man against man has become person against person, and man again nature has morphed into person against nature – not significant changes. In all of these 40 years, genre, theme, plot, and author's intent have not shifted one bit as the focus of literature and teaching resources used 40 and 20 years ago remain as useful today as then. The ways that teachers were taught language arts in elementary school, high school and college, on the one hand, and the way that they are expected to teach today, on the other hand, are barely distinguishable.

Then consider history. Once again, only minimal changes have been expected from social studies teachers as well. The causes of the great wars or the impact of kings and emperors or an understanding of the great civilizations and their contributions remains essentially unchanged. In fact, videos of history teaching in 1960 vs. 2020 would reveal that the most significant change is the technology used for presentation as teachers have moved from film strip projectors to 35mm projectors to op scan devices to today's reality of YouTube and online video libraries to bring the same content to life. Again, not significant changes.

Then there is mathematics. First and foremost is how mathematics has been transformed from a discipline that in 1960, and even 1980, was systematically designed to sort students out. It was never intended to work for *all students.* In fact, for much of the history of schooling,

mathematics was the great filter that ensured that some succeeded, many stayed average and some failed, ensuring that the existing workplace pipelines were appropriately filled. Only since around 1990 have we fully recognized that societal, workplace and technological changes require a totally new conception of mathematics: that is mathematics must work for all students if societal and economic needs are to be met. How does a society make good decisions when decision-makers and citizens don't understand probability or risk? How do employers fill vacancies when machines do the mindless work and workers need to be quantitively literate? How does a society protect its very existence when HIV-Aids, population growth, Ebola viruses, etc. all require visceral understanding of exponential growth? These are only a few of the reasons why, unlike language arts and social studies, mathematics curriculum and instruction are under assault to change and change in substantive ways.

Second is what we now know about the modes of instruction that support these changes. While language arts and social studies classes have always included large and small group instruction and important opportunities to communicate and argue, mathematics has overwhelmingly been taught by lecture to passive students sitting compliantly and quietly in rows. This may have been effective for sorting students, but it is clear that this is *not* an effective way to empower all students. Implementing such changes are particularly difficult when so many teachers of mathematics are being asking to teach in distinctly different ways from how they were taught.

Third, there is the lingering focus on calculus as the K-12 capstone of mathematics, mostly done by memorizing procedures and formulas and completed using primarily pencil and paper. Before the world went digital, there were no alternatives. Today, most calculus is done by machine and what is non-negotiable is the ability to model with mathematics, currently a seriously subordinated piece of the curriculum. And then there is data, big data, algorithms for dealing with big data and statistics. Many believe this is the slice of mathematics that is far more important, and more essential for a much large proportion of students, than calculus and all the pre-calculus components of the curriculum. This, too, is another large and challenging change for K-12 mathematics.

And finally, there is the ongoing struggle over what mathematics is essential in a world of calculators and computers and what mathematics is increasingly obsolete. This question and wrestling with its answers is a major challenge that only mathematics teachers face and need time and guidance to resolve. Fifty years ago, students were taught the square root algorithm that no one remembers, and no one uses anymore. But we still teach and assess multi-digit long division, memorized formulas and theorems, trig identities and a slew of symbol manipulation with polynomials, radicals and rational expressions, and synthetic division. Why? Determining what is truly obsolete and inappropriate in a curriculum that is already overstuffed, and nearly impossible to cover, is the starting point of difficult discussions that mathematics teachers alone need to have.

That is why in 2019, among the disciplines, mathematics poses unique challenges and requires time for these difficult discussions, sensible guidance about implications of making changes, and effective and impactful collaborative structures and professional development that differ in substantive ways from what is provided or expected in other disciplines.