Computers and Calculators are Everywhere — Does that Mean that Math Education Needs to Change?

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In the U.S. in the 1990s there was a big push to get computers into the schools as quickly as possible. In 1995 Bill Gates, the founder of Microsoft, wrote the book *The Road Ahead*, in which he argued that computer technology would bring great benefits to education. A few years later U.S. Vice-President Al Gore visited a public primary school so that he could be photographed as he helped bring electronic equipment into the school in order to connect it to the Internet. The National Council of Teachers of Mathematics agreed that greater reliance on computers and calculators was the way to go, perhaps because they thought — wrongly, as it turned out — that the introduction of computers would make teachers' work easier.

In 1996 I published an article in *The Mathematical Intelligencer* that argued the case against calculators and computers in primary and secondary math classes. My article was well received by mathematicians, most of whom seemed to share my skepticism about the computer hype. But outside the mathematical world people paid attention to Bill Gates — whose company has taken in many billions of USD in revenue from its sales to schools — and to Al Gore, not to me or to other mathematicians.

A quarter century later, at least in the U.S., it's easy to see that the skeptics were right. It is widely recognized that a big problem with American youth is that they spend far too much time staring at screens

— television screens, computer screens, and cellphone screens. Many schools have banned the use of smartphones, and some have generally moved away from computer use.

To many experts in early child development and in mathematical pedagogy it was clear from the beginning that increased reliance on calculators and computers was *not* the way to improve education. According to Douglas Sloan of Columbia Teachers College, “For the healthy development of growing children especially, the importance of an environment rich in sensory experience -- color, sound, smell, movement, texture, a direct acquantance with nature, and so forth -- cannot be too strongly emphasized.... At what points and in what ways will the computer in education only further impoverish and stunt the sensory experience so necessary to the health and full rationality of the human individual and society?... What is the effect of the flat, two-dimensional, visual, and externally supplied image, and of the lifeless though florid colors of the viewing screen, on the development of the young child's own inner capacity to bring to birth living, mobile, creative images of his[/her] own?”

Some also questioned the effect of computers on teacher-student interaction. Larry Cuban, who is known for writing a detailed study of the history of attempts since 1920 to introduce technology into American schools, wrote: “In a culture in love with swift change and big profit margins, yet reluctant to contain powerful social mechanisms that strongly influence children (e.g., television), no other public institution [besides schools] offers these basic but taken-for-granted occasions for continuous, measured intellectual and emotional growth of children.... The complex relationships between teachers and students become uncertain in the face of microcomputers... [I]ntroducing to each classroom enough computers to tutor and drill children can dry up that emotional life, resulting in withered and uncertain relationships."

When considering the use of calculators in math class, we need to ask: Do the students learn to punch buttons, or do they learn mathematics? During the 1990s and early 2000s I taught a class in our teacher-preparation program that included weekly visits to a public middle school to present math enrichment topics to children who were about 12 years old. On one occasion we had the children play a math game that involves dividing by 7 and rounding off to the nearest integer. When they had to find 60/7, they punched it correctly into their calculators, which displayed 8.5714… But most of them could not read or interpret the answer. They did not understand the significance of the decimal point, and so they could not answer the question.

On another occasion I was preparing the children for a visit to the university, where they would be given a free lunch, but would have to pay for any total cost above 8 USD. I reminded them that the total would include the tax, which would be almost exactly 10%, and so the actual cost of their food should be lower than 8 USD. I asked them to estimate their maximum food cost before tax if they didn't want to pay anything. I was shocked that not a single student had any idea of how to solve the problem. First of all, they had no conceptual understanding of what 10% tax means and how to compute it. Second, they had no knowledge or experience in mental estimation. I would have been happy with an answer giving just a rough estimate of 7 USD, although 7.25 USD (a clear choice once one does the mental calculation that 7.20 USD would result in a total cost of 7.92 USD and 7.30 USD would result in a total cost of 8.03 USD) would have been better.

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In order to have a conceptual understanding of the formulas for the circumference and area of a circle, students need to understand that π is a very special, irrational number — it is *not* 3.14 — and that there's a logical reason why the same very special number occurs in both formulas. The reason comes from a concept that is fundamental in calculus: You can get closer and closer to the exact area of a circle by dividing the circle into a large number of narrow concentric strips, each of whose areas is very close to the product of its outer circumference and its width, and letting the number of strips increase toward infinity.

Because of the importance of conceptual understanding, in the calculus final exams at my university we ask for exact (not decimal) answers. For example, $\sin(60°) = \frac{1}{2}\sqrt{3}$, *not* 0.866; the circumference of a circle is $2\pi r$, *not* 6.283r.

It has long been clear to careful observers that calculators and computers were not helping American students learn mathematics. Then in 2020 came the most dramatic and widely acknowledged demonstration of the ill effects of replacing traditional teaching methods with educational technology. The complete failure of remote instruction during the Covid-19 pandemic should finally put an end to any hope that the problems of math education in the U.S. will have a technological solution.

But in writing for a Vietnamese readership I want to be cautious. In the U.S. the widespread use of computers in the schools has occurred against a backdrop of decreasing public support for the schools, declining respect for teachers, and major increases in outside obstacles to children's ability to learn. Alarming numbers of American children now suffer from health problems, lack of physical activity, Attention Deficit Disorder, drug abuse, mental illnesses, chronic absenteeism, and almost universal addiction to cellphones and social media. Most countries do not have these problems, at least not to the same extent.

So I won't argue that it would necessarily be wrong to change the math curriculum by relying more on calculators and computers, and deemphasizing arithmetic and algebraic computations. Rather, I'll list some precautions that should be taken before introducing any major changes.

- Core concepts of computation should not be dropped. At a young age students should have an intuitive understanding of the decimal system, including multiplicaton and division, and should readily be able to hand-multiply 3- and 4-digit numbers, divide a 2-digit number into a 4-digit number, understand the role of powers of 10, and have some appreciation that what they're seeing is the place-value system — one of the great achievements in the early history of mathematics — in action. A little later they should be comfortable using scientific notation and should be able to work with the metric system — for example, estimating in their head how long it will take to travel a given distance in km at a given speed in km/hr. They should also be able to estimate mentally the total cost of a trip to a produce market where they buy various amounts of different products at different prices per kg.

- The amount of time students are expected to study math in class and out of class should not be reduced. A class in programming or computer use or other non-mathematical subjects should never be classified as a math class.

- Before any change is introduced, teachers must be thoroughly trained in how best to teach using the new materials. A good job of teacher training is likely to take a few years.

- Vietnamese mathematicians should take part in the development and evaluation of proposals for changes. Before a major change is made, it should have broad support from the Vietnamese Mathematical Society, the Vietnam Institute for Advanced Study in Mathematics, and the Hanoi Mathematical Institute. Mathematicians should be invited to review new textbooks and other teaching material.

- When unnecessary arithmetic and algebraic computations are dropped from the curriculum, a good choice of material to replace them would be “word problems,” that is, problems that require the student to translate from a “story” posing a question to an equivalent mathematical formulation. For example, given the radius of a bicycle wheel and the number of revolutions per second that it’s being pedaled, compute the bicycle’s speed. Or at a more advanced level: given the initial amount of water and pollutant in a lake and the rate at which polluted water with a given concentration of pollutant is entering the lake (and the well-mixed water is leaving the lake at the same rate), derive a formula for the amount of pollutant in the water at time t.