1. What's wrong with math education and how do we fix it?

The short answer is that students spend around 80% of their time in math class doing hand calculations and 20% learning mathematical thinking. The fix is to improve the balance to more thinking and less calculating. For a fuller explanation of what this would mean, read the transcript of Conrad Wolfram's TED Talk.

2. If, in a computer-based math world, students only spend 20% of the time calculating, what do they do with the other 80%?

Students should be able to set up a problem, ask the right questions, turn it into math, specify the calculation, and interpret as well as validate the results. Take the 80% of the time spent doing hand calculation and turn it into time learning concepts and creative skills. Let computers do the calculating.

3. Computers are already widely used in the classroom. How is this different?

Unfortunately, while computers have been widely introduced into classrooms, the math curriculum has mostly not changed to take them into account. The result is that computers have largely been utilized for "computer-assisted math"—as a replacement for teachers in the forms of multimedia presentations of hand calculating methods, practice sessions, and student evaluations. We believe that instead of having computers teach students to compute, computers should be used for computing and students should learn concepts, applications, and interpretation and validation skills from teachers.

Computer-based math allows students to learn through making use of computers to do computation. The power of the computer allows them to work on harder problems and large sets of real data. They can be better connected with how math is used in the real world as well as understand better when to apply which methods in new situations. Computer-assisted math is when the computer is used in learning, but not as a tool; instead it is doing or assisting the teacher's role. It teaches concepts to students through explaining or visualizing the procedures, but leaves students to do the actual computation by hand.

4. Will computer-based math improve standardized test results?

Maybe. Maybe not. However, standardized tests are often focused on students reproducing calculating procedures rather than understanding and applying math. Computerbasedmath.org believes that we should focus students on the understanding and application and delegate the procedural calculating steps to computers. As such we will be campaigning for changes to standardized testing to match the needs of real-world math, rather than focusing on improving test scores that evaluate outdated skills.

5. Are there lesson plans and other resources for teachers already designed for this approach?

We are developing prototype materials to seed further development for use in classrooms. If you want to try the materials when they are available, or want to help in developing additional courseware materials, sign up here.

An aim of our summit in 2011 was to plan for the development and deployment of pilots for the classroom. Hundreds of volunteers have offered to develop course material for computer-based math, and material will become available in the coming months. Many universities have applied similar ideas to undergraduate education, but most school-level use of computers has tended to focus on using computers to reinforce the traditional approach of having students learn manual procedures. At computerbasedmath.org we plan to change that.

6. Are you really suggesting students should use algorithms they're not familiar with when calculating by hand?

Often, yes. There are cases where algorithms give insight into the concepts and applications. However, in many cases the algorithms give no real insight, often because they are optimized for hand-computing efficiency, or worse because they only work for solving simplified school-level examples. Even where the algorithms do give understanding, once seen, little extra is achieved by spending large amounts of time becoming skilled at their application. By using computers, more examples can be seen, and larger examples can be tried, to allow students to gain greater intuition about their application and result.

7. How will students know whether computers have given the right answer if they don't know how to do computations for themselves?

Validation of results is a vital skill, but the traditional approach of expecting students to check their results by hand and just "try hard not to make a mistake" is not practical for real-world math problems. If, for example, you are working with formulas with many thousands of terms, hand checking is unlikely to give any reliable information. Instead, approaches such as comparing with alternative techniques, checking against known values, or simplified models are more important. In our current educational system, little time is provided for teaching these skills, as it is all being consumed practicing the hand-calculating procedures.

8. Surely students shouldn't be allowed to have the computers do the work until they have got the basics straight by hand?

That depends on what is meant by basics. Certainly the application of tools without understanding the concepts would be a problem. But the hand application of computation procedures is not necessarily useful in gaining that insight. Worse still, assuming that doing the procedures leads to understanding of ideas often causes the curriculum to be ordered in terms of computational rather than conceptual complexity. Computer-based math could allow many conceptual "basics" to be grounded much sooner. For example, ideas such as limits in calculus could be conceptually accessible much sooner than they are currently introduced.

9. If students rely on computers, how will they manage when computers are not available?

Firstly, at computerbasedmath.org we do believe it is worthwhile learning hand calculating when it's practically useful, for example, day-to-day numeracy—particularly estimating—for which more time needs to be made available. However, there are very few situations when involved mathematical modeling is required when practicality prohibits the use of a computer. And in most professional environments, access to a computer is as convenient as access to pencil and paper.

10. What skills does computerbasedmath.org bring to this problem that qualifies it to initiate change in math education?

The computer-based math paradigm is focused on teaching students to understand and relate to math the way professionals in the real world use math. The computerbasedmath.org founding team's experience in making mathematical software has put them in a unique position of dealing with both academic and industrial math practitioners as well as schools and educational policy makers. They recruit mathematicians and are engaged in math research. This has allowed them the perspective to identify the problems and needs of all these people.

Being at the epicenter of math and its uses has brought to them numerous relationships with educators who support our work and will help to guide it.

11. Some teachers are not qualified to teach with a computer. Many are surprisingly behind on technology. How do we change that?

There will be significant challenges in training teachers in new skills, although those will have as much to do with the teaching of new methodologies and validation skills as with the IT skills. Teachers will certainly need to commit to learning enough about computer-based math software to use it effectively in their classrooms. An aim of computerbasedmath.org is to make the appropriate teaching and training available to support teachers through this process.

12. How will schools be able to maintain the computer infrastructure for a computer-based math course?

The initial plan for computer-based math materials will not create any additional IT burden beyond having desktop computers available. Longer term plans will also introduce web hosted versions to avoid the need for local software installation, and mobile device support will allow students to use their own equipment.

13. How can we know if students understand something when they can ask the computer to do it for them?

Knowing what to ask a computer to do, in an open-ended task, is an important skill and will be most challenging for students who do not understand what they are trying to do. Doing computations by hand does not necessarily mean that students have any insight into what the task means or why they are performing the calculation, but introduces the additional confusion about whether their failure is a lack of understanding or a lack of procedural application.

14. How does computer-based math relate to teaching programming?

Programming is an important skill for computer-based math. It allows students to learn to describe and formulate mathematical procedure. It forces clear thinking and quickly exposes lack of understanding. It is also how mathematical tasks are often performed outside of education. However, computerbasedmath.org does not support "educational programming languages" where programming concepts are over-simplified to the detriment of utility. Students should use real tools and apply them to real problems.

15. What will be left of the subject if you strip out all this computation?

As well as being able to spend more time learning key problem-solving skills such conceptualizing and formalizing a problem and interpreting and validating results, the removal of pointless procedure practicing will make room for new math topics for which there is currently no room in the curriculum. Currently school math students have no knowledge of graph theory, Fourier transforms, optimization methods, and many other topics that are potentially accessible to them, if only there was time.

16. Won't this result in fewer people who can advance the creation of new algorithms?

The general skills needed to advance mathematical theory are developed by computer-based math. Where specific specialist knowledge of procedures is needed, that can be learned later—such knowledge is rarely related to the very simple school procedures taught now. More importantly, by engaging more people in math in the first place and keeping more in mathematical education to the higher levels, there will be more people who are in a position to choose to specialize in specific math research fields.