Faculty viewpoint

Chazelle: The greatest computer science revolution is yet to come

At the annual meeting of the American Association for the Advancement of Science in February, professor of computer science Bernard Chazelle issued a call to arms for his profession, challenging his colleagues to evangelize the importance of studying computer science. The following is adapted from a longer essay by Chazelle that appears in the April issue of Math Horizons *titled "Could Your iPod Be Holding the Greatest Mystery in Modern Science?"*

Photo by Denise Applewhite

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Computer science is full of mysteries, none more vexing than this one:

The top 36 computer science departments in the United States saw enrollments plummet 20 percent in the last five years. Why are students running away from the field at the very moment that the computer science revolution is just unfolding?

Most people think of computer science, if they think of it all, as being something useful—the way that, say, people think of plumbing as being useful. And it is, obviously. But it is much more than that. Computer science is not just about gaming, not just about the Internet; it offers an original window through which to view the world. Computing promises to be the most disruptive scientific paradigm since quantum mechanics. It will transform science and society in profound ways.

Computer science is the true "New Math"—the modern conceptual template for the natural sciences of the 21st century. Classical math gave sciences formulae and differential equations; computer science gives them algorithms. What exactly is an algorithm? Much more than a mathematical formula, it is a self-referential narrative consisting of commands, loops, and conditionals (if X, do Y). Think of Google as a clever algorithm. Or you can even think of an economy, an ecological system, or a social network as an algorithm in action. To make a literary analogy, the mathematics of natural sciences is an anthology of one-liners: formulae and equations that are pithy, insightful, deep, brilliant. Modern physics illustrates how much a few math formulae can do. The algorithms of computer science are more akin to long, messy, infuriatingly complex novels. That is exactly what makes it unique and appealing – computer algorithms can capture nuances of complex reality in a way that standard mathematics cannot.

I'll be the first to admit that, as the recent breakthroughs on Fermat's Last Theorem and the Poincaré Conjecture indicate, the field of mathematics has rarely been more fertile with new ideas. No field of inquiry matches math in intellectual depth and vitality. Having said that, today's math follows in a long, continuous tradition: If a math giant from the past—someone like (Friedrich) Gauss—were to come back to Earth, he would have a lot of catching up to do but he would find that math is done much the same way that it was done during his life.

Computer science, by contrast, is a radically new way of thinking, a new way of looking at all sorts of problems. Classical mathematics can't come near to describing the complexity of large systems (human, biological, or otherwise) in the way that computer science can (or will). The quantitative sciences of the 21st century such as proteomics and neurobiology, I predict, will place algorithms rather than formulae at their core. In a few decades we will have algorithms that will be considered as fundamental as, say, calculus is today.

The power of algorithms is already revealed by the fact that computer science has become integral to all the sciences. Modern biology, for example, is very quantitative and increasingly an "information science," so a computer science background is imperative. At Princeton, we're retooling the COS curriculum to reflect such connections and the fact that the field is not so much about operating computers as it is about thinking in new ways. For example, I've been part of the pioneering "integrated" course developed by David Botstein and colleagues in computer science, chemistry and physics. The course simultaneously incorporates physics, biology, chemistry, mathematics and computer science. In one lecture, I discussed "Zero Knowledge"— how you and I can convince each other of new facts without revealing anything about them. Some students told me afterwards this completely shattered their intuitive notion of "knowledge." Mathematics has long been the lingua franca, the Esperanto, of science. But I would argue that science now has two Esperantos: math and computer science.

So given that computer science—in my obviously biased estimation—is perhaps the most exciting field of study one could choose, why are students heading to law school? In part, the dot-com bust scared them. Computer science departments have lost students all across the country. That's why we saw Bill Gates in recent months gallivanting across North American campuses, trying to turn kids on to the field. But also I think that computer science lacks a great popularizer. More than 25 years ago the book "Göedel, Escher, Bach: An Eternal Golden Braid," by Douglas Hofstadter, got a whole generation of people excited about the future of the field. But today computer science doesn't have anyone the way that, for example, physics has Stephen Hawking or biology has Richard Dawkins—someone who in a sustained way explains to the broader public the beauty and wonder and potential of the field.

I am sometimes asked why students should major in computer science—aren't all the programming jobs being outsourced to India anyway? Can you actually get a job if you study computer science? Yes, absolutely, and I am not talking about minimum-wage programming jobs. First, as I said, all the other sciences require the kind of thinking that computer scientists offer. Second, for those of an entrepreneurial bent, the Internet is paramount; if you don't understand computer science you are lost. I don't think it is just coincidence that two of the biggest Internet visionaries—Jeff Bezos of Amazon and Eric Schmidt of Google—are products of the computer science and electrical engineering departments at Princeton. Third, and (since I am a theorist) most exciting, are careers in theoretical computer science. The field would exist even if there were no computers. Computer science is not bound by the laws of physics; it is inspired by them but, like mathematics, it is ruled and guided by its inner, autonomous logic.

A few short years before Einstein turned our world upside down with his theory of relativity, the great Lord Kelvin declared, "There is nothing new to be discovered in physics now." Not his lordship's finest hour. I think that computer science bears an uncanny resemblance to pre-Einstein physics. Moore's Law—Gordon Moore's prediction that computing power would increase exponentially because the number of transistors on a microchip would double every 18 months or so—put computing on the map. But count on algorithms to unleash computing's true potential. I predict that there will be an Einstein of computer science. The revolution is yet to come.