Computing Will Transform Education
Ken Koedinger

Fifty years from now, people will be teaching computers to teach other people. Not only will university instructors and school teachers be training and mentoring computers on their expertise so that those computers can tutor and mentor other students at scale, but industry managers, executives, and knowledge workers will also be "showing" computers how to pass on their expertise to new employees. Computers will learn how to teach by "observing" people teach other people. For example, machine learning algorithms and natural language processing will be applied to peer and instructor feedback to develop and improve automated feedback.

Computer science will be a regular part of elementary school instruction. Ubiquitous computing devices, not just ebooks, but eglasses, emicroscopes, elabs, eworlds, etc., will play a major role in schools. They will *not* replace human teachers, but instead be a completely integrated part of a flexible and mobile classroom. While computers will help students practice and master fundamental doing, reasoning, designing, convincing, and learning skills, human teachers will be supporting the students to pursue self-directed collaborative projects. Fourth-graders will create successful online start-up businesses and charities — the lemonade stands of the future. People will still be better at teaching people skills, but will have more time to focus on teaching people skills given the support from the computer.

Why and how will these predictions come about? Improvements in education are fundamental to solving many of our most challenging issues in the world today, including hunger, poverty, terrorism, and war. But can dramatic improvements be made in education? Science and technology have led to major improvements in many areas of human endeavor. Consider how transportation has progressed from horse drawn carriages to jet airplanes. Or how computing advances, epitomized by Moore's law, have produced so many amazing inventions such as this iPhone on which I am dictating this text. Education, however, has been slow to improve on the basis of science and technology. To be sure, we are seeing growth in scores on intelligence tests and on the U.S. National Assessment of Educational Progress, but the growth is small. As interactive educational technologies, such as intelligent tutoring systems, simulations, and educational games, have seen increased use in schools and in training, evidence is emerging that they can dramatically increase educational outcomes, such as cutting in half the time it takes to learn college-level introductory statistics or doubling achievement in algebra over a school year. At the same time, online resources, such as Wikipedia and MOOCs, are giving direct, low cost access to knowledge and education to vastly more people. The technology-enhanced revolution in education, promised for so long and now being championed through the CMU's Simon Initiative, is finally coming.

How will we overcome the inertia that grips educational practice today to reach the ambitious future outcomes outlined above? We need learning science and technology to advance more quickly and feed on itself in a way that produces exponential growth. How might that work? The more educational technologies are in place, the more those technologies can contribute to advancing our understanding of learning and how to improve it. In other words, increasing educational technology use will support more extensive, more efficient, and more reliable exploration of which learning technologies work best under what circumstances. Further, as schools and colleges improve student-

learning outcomes, particularly in STEAM (science, technology, engineering, arts, and mathematics) fields, the greater supply of professionals who can use science, technology, and design to improve education. We are now at an elbow point in the growth curve whereby these two positive feedback loops can operate effectively and synergistically. One loop uses effective educational technology to produce improvements in learning science that, in turn, produce better educational technology. The other loop uses improved student learning outcomes to produce more professionals to further improve education.

Why now? There are three critical factors. First, it is only recently that we have installed a critical mass of educational technologies in schools, homes, and companies that can collect data that in turn can fuel science and practical improvement. Second, the sciences of learning, coming from a diverse set of disciplines including computer science, psychology, education, neuroscience, and economics, have recently advanced to a stage whereby they can productively use the vast amount of data being collected and turn these data into improved educational practice. Educational technologies in wide use are beginning to move the needle. Third, we are now seeing increasing public interest in improving education and in making schools and colleges more accountable to producing the best for our students. Such interest reflects a fundamental human desire to make life better, and education is a key piece, perhaps *the* key piece, in life's puzzle. Where there's a will, there's a way! Advances in computing devoted to education will fuel corresponding advances in learning science, which will fuel advances in educational practice. Teachers will still teach, but they will be dramatically more effective by using advanced computing appropriately.

Find Out More

Some existing demonstrations of educational technology producing large gains in learning outcomes (e.g., doubling achievement) and in learning efficiency (e.g., halving the time to achieve as good or better outcomes) at the high school (e.g., algebra) and college (e.g., introductory statistics) levels:

Pane, J. F., Griffin, B. A., McCaffrey, D. F., Karam, R. (2013). Effectiveness of Cognitive Tutor Algebra I at Scale. *Educational Evaluation and Policy Analysis*, *36*(2): 127-144.

Lovett, M., Meyer, O., Thille, C. (2008). The Open Learning Initiative: Measuring the effectiveness of the OLI learning course in accelerating student learning. *Journal of Interactive Media in Education*. http://jime.open.ac.uk/2008/14/.

Some learning science and technology challenges and opportunities:

Koedinger, K.R., Brunskill, E., Baker, R.S.J.d., McLaughlin, E.A., Stamper, J. (2013). New potentials for data-driven intelligent tutoring system development and optimization. *AI Magazine, 34*(3).

Koedinger, K.R., Booth, J. L., & Klahr, D. (2013). Instructional Complexity and the Science to Constrain It. *Science, 342*(6161), 935-937.

Singer, S.R. & Bonvillian, W.B. (2013). Two Revolutions in Learning. *Science 22*, Vol. 339 no. 6126, p. 1359.

Some relevant web resources:

CMU's Simon Initiative: http://www.cmu.edu/simon/

LearnLab, the Pittsburgh Science of Learning Center: http://learnlab.org

LearnSphere, a data infrastructure to improve learning: http://learnsphere.org