Learning results from what the student does and thinks and only from what the student does and thinks.

—Herbert A. Simon (1916-2001),
Richard King Mellon University Professor of Computer Science and Psychology,
Carnegie Mellon University; 1978 Nobel Laureate in Economic Sciences

On December 5, 2011, I was one of ten university presidents invited to the White House to meet with President Barack Obama and Secretary of Education Arne Duncan to discuss a critical issue: how to reduce costs and improve the productivity of U.S. higher education. The other presidents there represented some of the nation’s largest public university systems (Maryland, New York, and Texas among them).

I was there because Carnegie Mellon is the leader in creating technology for education.
ne university leader after another told the President about their system’s experience with Carnegie Mellon’s learning technology and its promise for helping universities to improve learning and to contain costs.

The technology that has the world of higher education so excited is Carnegie Mellon’s Open Learning Initiative (OLI). The history of OLI is quintessential Carnegie Mellon, and the future of this technology is very promising. That’s reason enough to write about it, but OLI is also at the heart of the university’s commitment to a research-based understanding of human learning and deployment of technologies that incorporate this understanding—what we call “learning science and engineering.”

The Science of Learning and Higher Education Productivity

My last Presidential Perspectives focused on Carnegie Mellon’s research initiative in “Brain, Mind, and Learning,” where I promised to write in more detail about CMU’s OLI. All of this research is interconnected, and OLI is an example of our faculty’s tremendous momentum in neuroscientific work and its applications.

One of the oldest of these research streams is the “science of learning,” a field created and developed at Carnegie Mellon in an enduring interdisciplinary collaboration among cognitive scientists and computer scientists. CMU Professors Herbert Simon and Allen Newell began working on these problems in the 1950s, and the work has been carried on brilliantly by their colleague John Anderson, the Richard King Mellon professor of psychology, and now by Anderson’s student Ken Koedinger, professor of psychology and human-computer interaction and co-director of the joint University of Pittsburgh-CMU Pittsburgh Science of Learning Center, along with many of their students and colleagues in psychology and human-computer interaction. This work is a great example of Carnegie Mellon scientists driven to collaborate to answer important questions—how human beings learn and how teachers can use technology to enhance learning.

This learning science tells us that the “sage on the stage” courses, which probably characterized virtually all students’ academic work, and is characteristic of offerings at most universities, are less-than-ideal settings for grasping new concepts and skills. Learning happens when students are actively engaged in the material; when they are goal-directed and get immediate, targeted feedback on their work; and when they learn to monitor their own progress. None of this happens in a typical large lecture class. The only person continually active during a lecture is the instructor; students may be taking notes, but they also may be texting or daydreaming.

Learners need active involvement with the material. They need what learning scientists call “scaffolding”—structured explanations, detailed examples, problem-solving frameworks, progressive hints, and frequent directed practice. The ideal way to do this is with well-prepared instructors who are teaching individual students, and monitoring each student’s progress with frequent and rigorous assessment. Even in the best of economic times, however, that is far too expensive. In the current fiscal climate, we are moving in the opposite direction; faculty at America’s cash-strapped public universities and community colleges have seen teaching loads soar.

As more and more people around the world seek access to higher education, and as governments—in America at least—continue to disinvest in public education, universities need to deliver instruction faster and more effectively, and at a price middle-class Americans can afford. We need a method that combines the accessibility and low-cost of the Internet with the high quality of individualized instruction provided by a great teacher.

Higher Ed’s Productivity Dilemma

CMU Provost and Executive Vice President (and professor of economics) Mark Kamlet often refers to an influential paper written by economists William Baumol and William Bowen in 1967 that argued that the costs of labor-intensive activities, such as music performance or classroom teaching, would rise faster than costs in general (i.e., the rate of inflation). Baumol and Bowen noted that while labor-saving automation and process improvements have big effects on productivity in manufacturing and some services, areas like the arts and schooling show little in the way of productivity improvement. Activities such as listening to a horn quintet or learning chemistry depend on human attention, which cannot be replaced or extended very easily.

Manufacturers have used technological methods to produce many more widgets per hour of human labor, but it still takes universities the same number of hours to teach introductory chemistry today as it did in 1950. During those six decades, faculty salaries have risen to keep pace with rising wages in the broader economy. Baumol and Bowen posited that because of this flat productivity, costs of higher education would persistently rise faster than the rate of inflation—and they have been proven right. Although there are many reasons for the rising costs of college in America, this is surely an important one. Without a complete revolution in our approach to teaching, Baumol and Bowen predicted, this productivity problem will persist.

Technology has the potential to improve this, but so far many results have been disappointing. Just putting course content online is not enough. Universities adding free lectures to their Web sites should be commended for expanding access to ideas. But even for a highly motivated learner, it is tough to work through an entire course this way—witness the high dropout rates at online universities. The novice or
struggling learner has practically no hope of completing a course without more support.

**CMU’s Open Learning Initiative**

William Bowen, who also served as president of Princeton and then president of the Andrew W. Mellon Foundation, had been especially skeptical about the power of technology to improve productivity in higher education. But in 2011 he changed his mind: in the foreword to the book *Unlocking the Gates*, he wrote that “the work at Carnegie Mellon [i.e., OLI] has caused me to rethink my position” on the potential impact of online courses.

> *The key message (from the White House) was a challenge to us to question all our strongly held assumptions … but I do think technology can help us educate more students faster and better.*

—Jared L. Cohon  

Carnegie Mellon’s OLI may indeed be the beginning of an answer to the productivity problem. CMU’s OLI courses are Web-based learning environments whose course design reflects a detailed, science-based understanding of how students learn. But OLI adds another layer of innovation by incorporating the potential for data-driven continuous improvement into the course design itself. OLI’s outstanding and creative co-directors Candace Thille (CMU OLI’s director and principal investigator) and Joel Smith (CMU’s vice provost for computing services) have helped OLI become something truly revolutionary, enabling faculty to think about instruction in very different ways than in the past.

Three elements make OLI distinctive and powerful:

> **First, course creation moves from a solo performance to a team sport.** OLI classes begin with interdisciplinary course-design teams of faculty content experts, human-computer interaction experts, learning scientists, designers, and software engineers. These teams design learning environments, with course content, practice exercises, and review. They create intelligent tutoring modules, virtual laboratories, simulations, and very frequent opportunities for assessment and feedback.

> **Second, the system collects data on each episode of learning.** Just as Amazon, Google and Netflix discover our book or movie preferences by tracking our online actions, so can our OLI monitor the mouseclicks and keystrokes of users, generating data that shows at the most detailed level what learners are responding to (or not) in the learning environment.

> **Third, this rich trove of data provides immediate feedback to all of the participants.** Everyone involved gets feedback—students, instructors, course designers, and learning scientists. Students can see at once how they are doing (instead of waiting a week for tests to be returned). Instructors can check a dashboard (designed by Dr. Marsha Lovett of the Eberly Center for Educational Excellence at CMU) to see where their students are struggling, or where they need more explanation or practice. Course-design teams monitor what works and what doesn’t. Then they make improvements, try another explanation, add a video, or expand the practice exercises. Student performance also is available for studies by learning scientists, fostering a cycle of experimentation built right into the course itself—with the aim of always getting better.

CMU started OLI in 2002, and by the mid-2000’s, we had solid evidence that students in our OLI courses had mastered complex subjects just as thoroughly as students in regular lecture classes. CMU OLI courses are expensive to develop, but once developed they are relatively inexpensive to run. Today there are CMU OLI courses in French, logic, statistics, engineering statics, chemistry, computer science, and other fields. They are freely available to individual learners and at low cost to colleges and universities who want to use them for degree credit. CMU’s required “Computing at Carnegie Mellon” course is now a CMU online OLI course—teaching this course more effectively, less expensively, and more flexibly than ever.

**Make It Faster**

It is when CMU’s OLI is used in a classroom with an instructor, however, that we are seeing the most impressive results. OLI online modules become the textbook, workbook, and assessment system, all in one.

In 2007, the William and Flora Hewlett Foundation encouraged us to push the model further, to make learning happen faster without sacrificing quality. That spring, Dr. Lovett of the Eberly Center paired a group of CMU students taking OLI statistics with a control group taking the same course the traditional way. Students in the CMU OLI group completed an online module on their own in advance of each class session, and the instructor got a report on what students grasped and where they were struggling. The instructor never gave a formal lecture, but rather spent class time focusing on where those particular students needed help. The OLI group had regular meetings with the instructor for eight weeks, while the traditionally taught class met for 15 weeks.

The result: OLI learners demonstrated learning outcomes equal to or better than the traditional class, in half the time. Six months later, CMU OLI students had retained the material just as well as the traditional class. The professor, Oded Meyer, reported that it was one of the best teaching experiences of his career.
Let me repeat: CMU’s OLI students mastered the course just as well but in half the time. That kind of astonishing result has been repeated elsewhere. This is what gets the attention of university presidents, and now, as I learned, it has the attention of the President of the United States.

**Strengthening American Competitiveness**

President Obama and President Bush before him both recognized that improving student success and college completion in higher education, including community colleges, is crucial to U.S. competitiveness in the future. Many more people need access to post-high school education to thrive in the technology-based global economy.

CMU’s OLI just may be the kind of disruptive technology to achieve this goal. OLI staff members at CMU are now testing OLI courses at a range of universities and community colleges, including those whose presidents were at the White House in December. We are also part of a collaboration with grantees of the Department of Labor who are creating job-training programs. This is just the beginning.

**A CMU Success Story**

OLI’s success has CMU written all over it. Our OLI aligns with every dimension of our research culture: It grew from interdisciplinary (and inter-university) collaboration; it aims for practical impact on a serious problem; it links information technology to another content domain (cognitive psychology); and data-driven continuous improvement is designed into the model itself.

The most important point about CMU’s OLI is that the team-based, scientific design of courses combined with rich feedback makes for a much better experience for students and their instructors. OLI has the potential to bring sustained educational achievement for many who have never been able to grasp this level of academic achievement before, and at a cost that middle-class American families can afford.

This technology also will allow faculty members to think differently about the range of offerings and experiences in higher education. The CMU OLI model will surely expand options. A student might take one class in OLI “anytime, anywhere” mode while taking another course delivered in the traditional way. One could imagine OLI courses allowing students to complete a four-year degree program in three years. Or in their junior and senior year they could incorporate diverse experiences, such as more hands-on research activities, and community internships. Senior faculty could devote their time to mentoring or teaching capstone courses. These are just some of the possibilities.

CMU’s OLI is important—a “game-changer”—but it is only one part of our continuing commitment to learning science. Professor Anderson is refining his learning models using new tools in neuroscience, including fMRI imaging. Professor Koedinger and his colleagues are continuing to work on K-12 tutoring systems, expanding assessment tools, and integrating gaming interfaces—especially needed in motivating disaffected learners. All of this, along with more sophisticated machine learning ideas, will help us continue to engineer refinements to the next generation of educational technologies.

None of this would have happened, and our future programs would be impossible, without the support of some far-seeing partners in the philanthropic community, most notably the William and Flora Hewlett Foundation, the Bill & Melinda Gates Foundation, the Lumina Foundation, the Walter S. Johnson Foundation, the Spencer Foundation, and the Kresge Foundation. We are also grateful to the National Science Foundation for its support of the Pittsburgh Science of Learning Center. CMU’s OLI is a shared success story, and we are very grateful for these partnerships.

I hope that the university’s success with OLI will inspire innovations in learning science all over the nation, converting the solo task of the lonely lecturer to the collaborative team sport of effective instruction. We are studying ways to join with other leading universities and community colleges to implement OLI on a much bigger scale. Maybe we will see a new educational technology industry grow to bring these innovations quickly and affordably to those who need them most.

Try it out yourself, for free, at www.cmu.edu/oli. Let me know what you think.