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REPORT

Unleashing the Potential of Technology in Education

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Introduction

We are at the dawn of an era in which educators have the potential to harness technology to produce a step change in student achievement. Although visionaries have been promising for years that technology would transform primary and secondary education—and despite the billions of dollars spent networking schools and equipping them with computers and other devices—the actual impact on student outcomes to date has been disappointing. Even where educators have succeeded in introducing devices and software into the classroom, they've often failed to leverage that new technology to improve student performance. Yet when technology is strategically introduced into every step of the educational value chain, it does, in fact, have the potential to enhance every aspect of instruction and learning.

To fully realize this promise—and dramatically improve student outcomes in primary and secondary education—technology must be deployed in support of what is known as a *closed-loop instructional system.* Such a system is a deeply aligned set of educational objectives, standards, curricula, assessments, interventions, and professional development. Within this system, technology can enable continuous improvement at every level.

Already, technology is reshaping higher education in the U.S., where an explosion in online learning has enabled millions of adults to pursue degrees or certificates across a myriad of fields. This growth has been seen across for-profit, state, and private institutions that are seeking new revenue and growth opportunities. The building blocks are also present at the primary and secondary levels, where we have seen a proliferation of interactive whiteboards, computers, and other technologies in classrooms—and where today's tech-savvy students are often armed with personal laptops, smartphones, and other devices. In recent years, an abundance of innovative digital *content* has also emerged, propelled by a new generation of education companies. Furthermore, the cost of technology continues to drop precipitously, expanding access to significantly more students across all levels—many in lower-income groups that historically have been excluded.

But the simple fact that these new educational tools exist and have advanced so significantly does not guarantee a revolution in student outcomes—neither does it mean that schools will adopt these novel technologies in a meaningful way. To truly reap the full benefits that technology has to offer, the stakeholders in education must overcome a full range of barriers—from the lack of an appropriate information and communications technology (ICT) infrastructure to the much more human challenge of changing entrenched practices in education.

This report delineates how the technology of today and tomorrow can serve as a catalyst for change in primary and secondary education. It explores how those in education—from teachers to education leaders and policymakers—can harness the benefits of new technology to dramatically improve student performance and educational outcomes. This analysis has grown out of dozens of education projects that The Boston Consulting Group has conducted over the past ten years while working with clients ranging from national, state, and local governments around the world to school districts, charter school operators, universities, and for-profit higher-education companies. All illuminated the immense challenges that educators face—and the pressing need for innovative solutions.

A New Era in Educational Technology

Why Now?

Education pundits have long promised that technology would transform today's outmoded schools, most of which were designed to prepare young people for the industrial age rather than a knowledge economy. More than a decade ago, during the height of the dot-com boom, high-tech executives and other enthusiasts were predicting that the revolution was just around the corner. "We've just begun to use these [digital] tools to transform education," Apple CEO Steve Jobs told *BusinessWeek* in 2000 in a story exploring the future of educational technology. Certainly, technology has succeeded in reshaping many other sectors of the economy—from banking to travel—beyond recognition. Even the staid book-publishing industry is being transformed, as the proliferation of devices such as Amazon's Kindle and Apple's iPad drives sales of e-books. So why has education been left out of this revolution?

Unmet Promises

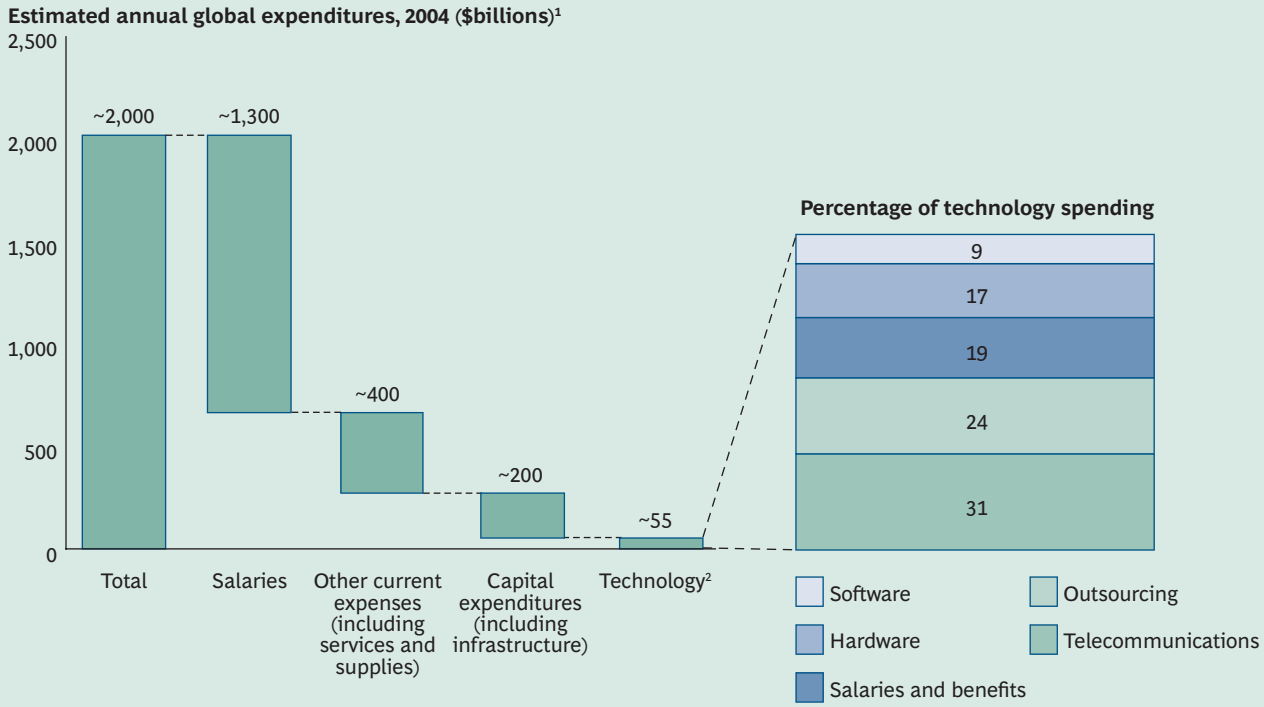
As Tom Vander Ark, former executive director of education for the Bill & Melinda Gates Foundation, recently observed, "Education remains one of the few sectors that information and communications technologies have not transformed."

One explanation for this failure is that technology spending still accounts for only a tiny fraction of overall education spending around the world, lagging far behind expenditures on salaries and other current expenses. (See Exhibit 1.) Such spending has been far lower in education than in industries in which technology has had more impact. Gartner estimates that in 2010 in the U.S., primary- and secondary-education systems spent $9.2 billion on IT, just 1.6 percent of their total spending. Comparable labor- and knowledge-intensive industries, such as professional services and health care spend 4 to 6 percent of their operating expenses on technology. As a result of their low spending, many schools struggle with broken computers, faulty network connections, and other issues that impede the effective use of technology. If U.S. education systems invested in technology at a level similar to that of comparable industries, the total investment would equal $25 billion to $30 billion annually—three times the current spending on technology.

An even more critical factor hindering the impact of technology is the way in which it has been used in education. Computers and related offerings have typically been seen as machines that can automate and support existing practices rather than as tools to transform learning, teaching, and even schools themselves. As Harvard Business School Professor Clayton Christensen and his coauthors observed in *Disrupting Class: How Disruptive Innovation Will Change the Way the World Learns,* "[T]he way schools have employed computers has been perfectly predictable, perfectly logical—and perfectly wrong."

For example, the U.S. government program known as E-rate promotes spending on hardware and technology by reimbursing providers for discounts on services to eligible schools and libraries. While this program has ensured that many schools are now wired, it has not provided the support needed to help them use the technology effectively. We've placed computers and interactive whiteboards in the classroom and plugged them into the Internet, but we have done little to leverage this new technology to restructure the school day, the classroom, the curriculum, or the ways in which students engage with teachers—all critical components to successful outcomes

Exhibit 1. Only 3 Percent of Annual Global Spending for Education Goes to Technology



Sources: UNESCO, *Global Education Digest,* 2007 and 2009 (Table 13); World Bank; Gartner, *IT Spending by Industry Market, Worldwide, 2007–2013, 3Q09 Update* (October 16, 2009); BCG analysis.
[1]Expenditures are broken down on the basis of the 2007 weighted-average proportion of primary, secondary, and postsecondary spending according to the International Standard Classification of Education (UNESCO).
[2]Includes public and private expenditures (all other categories include only public expenditures).

in education. The chief opportunity for innovation does not center on simply automating existing practices but rather on redesigning educational processes to tap the full benefits that technology has to offer.

Training teachers to use instructional technology and digital resources effectively is critical. But this training has in many cases been inadequate. Much professional development and training has focused more on operating the technology than on exploring and explaining how it might transform education. As a result, many instructors are uncomfortable using the tools in their classrooms, and they all too often revert to traditional teaching techniques.

Similarly, implementing a digital-friendly curriculum is key—but many individual school systems lack sufficient resources to devote to in-house curriculum development. A number of providers, such as K12 and Connections Academy, have developed high-quality digital curricula, lesson plans, instructional tools, assessments, and teacher training. School systems can take advantage of these resources at greatly reduced costs rather than "going it alone." But so far, most have failed to do so.

As a result, in the majority of primary and secondary classrooms, the textbook still dictates what students learn and how they are taught. Two decades into the twenty-first century, such an approach deprives students of an extraordinary wealth of digital content that can awaken their curiosity, deepen their engagement with a subject, and ultimately greatly expand the knowledge they acquire. Digital resources can also free up teachers to assume very different roles in the classroom, allowing them to spend far more time coaching and mentoring students and far less time lecturing or disseminating facts.

By now, stories of how technology has failed to live up to its potential have become part of the culture at many educational institutions. But despite technology's troubled history in the classroom, we're convinced that the dynamic that governs educational technology is at a precipice of dramatic change.

Key Forces Driving Change Today

A confluence of four forces, in particular, is helping to finally ignite the technology revolution in education.

The number of companies focused on deploying technology in education is proliferating. Perhaps the biggest driver of change is the sheer number of companies dedicated to helping educators use technology effectively. Most of today's companies—including those that are thriving—did not even exist five years ago. To be sure, some of these companies are still small, but together they demonstrate the reality that technology can transform the classroom.

At a new career and technical high school in Las Vegas, for instance, students carry iPods that have been preloaded with apps customized to their course schedule. Students in health science have an anatomy app, for example, while students learning Spanish carry a digital Spanish-English dictionary.

Nationwide, individual parents, students, and teachers are also getting into the game by developing education apps, such as those introduced by DreamBox Learning and Reasoning Mind. As this activity accelerates, students will soon have access to thousands of customized learning apps.

Technological innovation is progressing at an accelerated rate. Another force is the breathtaking pace at which educational technology is improving. There's been an explosion in the amount of high-quality content that is readily accessible online. The benefits of all this digital content have been compounded by the emerging capability to remotely connect students with dynamic teachers and tutors. In combination, these developments address one of the key barriers to high-quality education in disadvantaged communities.

Simultaneously, enormous advances have been made in the infrastructure for technology, including the growth of cloud computing. And the proliferation of mobile devices makes it much easier for students to access digital content anytime and anywhere. By 2014, global shipments of smartphones, netbooks, e-readers, and tablets are expected to top 800 million units—four times the number in 2009. (See Exhibit 2.) With the prices of these devices falling, it is becoming easier for educational institutions, local education agencies, states, and nations to join the technology revolution.

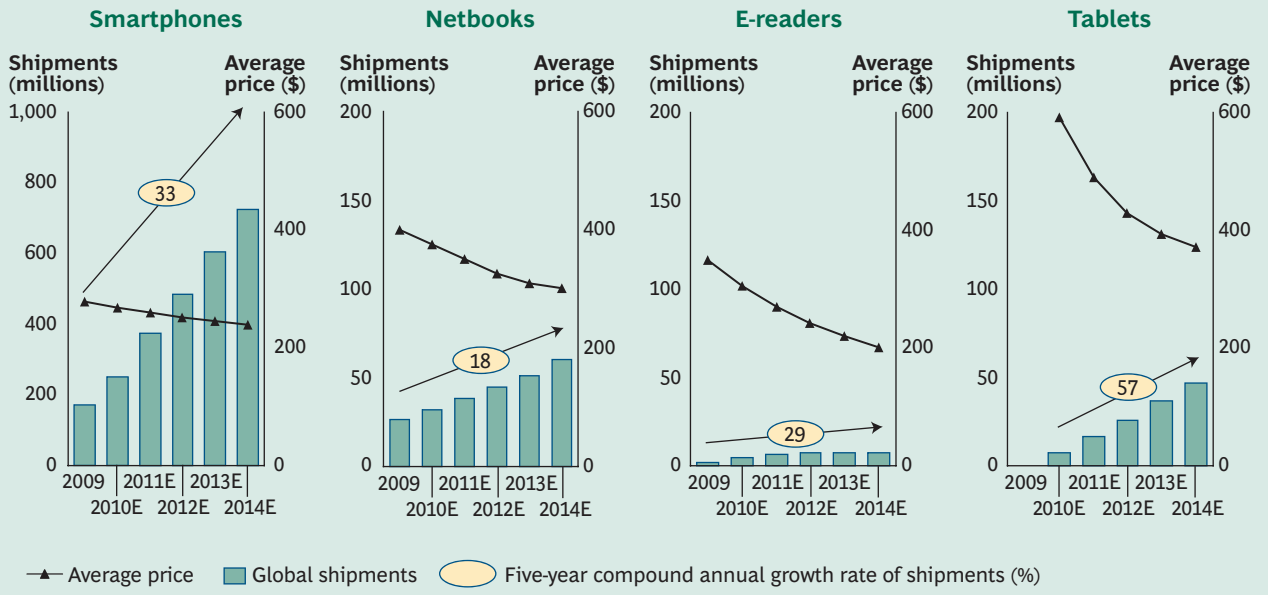
The proliferation of mobile devices makes it easier for students to access digital content anytime and anywhere.

Public scrutiny of the cost of and return on investment in public education is escalating. Since the mid-1970s, education spending per pupil in the U.S. has more than doubled, while many achievement metrics—such as the math proficiency of 17-year-olds—remain remarkably unchanged. Add to that the recent economic crisis, which has placed many school systems, states, and nations in dire fiscal straits, and it is no surprise that the cost and value of education have taken center stage. The trend of recent decades is simply not sustainable. Significant demand awaits new models in education that demonstrate the ability to produce comparable or improved outcomes at a lower cost—and several technology-enabled models are showing significant promise.

For instance, one study estimates that the Florida Virtual School, the first and largest state-run online school, has saved Florida $38 million over the past four years. In California, the Riverside Unified School District is piloting a program under which students either use their own devices (such as an iPod Touch) or are given a device to access digital content. Riverside estimates that this approach could yield a cost savings of 30 percent over traditional textbooks, while also appealing to many students.

And Rocketship Education, a charter school network outside San Francisco with ambitious plans for national growth, is asking its students to spend 25 percent of each day in a "learning lab" working on customized, computer-delivered material; during this time, the students are supervised by employees who earn lower wages than teachers do. Rocketship believes that this model not only supports learning but also is replicable and sustainable without requiring philanthropy to supplement public funding.

Exhibit 2. Prices of Devices Are Falling Significantly—and Availability Is Swelling



Sources: Smartphones: Gartner, *Forecast: Mobile Devices, Worldwide, 2003–2014, 1Q10 Update;* Netbooks: IDC, *Worldwide Mininotebook 2009–2013 Forecast and Analysis,* July 2009; E-readers (includes connected e-readers only): IDC, *Worldwide Connected eReader, Portable Media Player, and Portable Navigation Device 2010–2014 Forecast,* June 2010; Tablets: IDC, *Worldwide and U.S. Media Tablet 2010–2014 Forecast,* May 2010; BCG analysis.

Technology increasingly penetrates a greater proportion of children's lives. The classroom that does not embrace technology is becoming progressively out of touch with the way even the youngest children interact and learn at home and outside of school hours. One technology study commissioned by the Joan Ganz Cooney Center at Sesame Workshop interviewed more than 100 children between the ages of 4 and 7 (about half of whom were from low-income families) and found that about two-thirds had used an iPhone before; 64 percent said that it was "easy" or "very easy" to use; and 53 percent did not need an adult to help them play with the iPod Touch during the observation period of the study. Educators must acknowledge that students need to learn how to apply their skills in a technology-rich setting. Not only will this approach prepare students for the world into which they will be graduating, it also reflects the world in which they already live.

No More Tradeoffs: Richness, Reach, *and* Results

The four forces outlined above challenge the antiquated system of education, which is severely limited by physical constraints. Historically, a student's access to teachers, courses, and content depended largely on where he or she lived. As a result, students in less advantaged neighborhoods or countries have lacked access to the high-quality teachers and courses that inspire their more affluent counterparts. At the same time, most schools have been structured in ways that severely limit the teachers' capacity to meet the differing abilities, interests, and learning styles of individual students.

But new advances in technology now offer hope that we can eliminate these constraints and, in the process, greatly improve opportunities for individual students. In short, the tradeoffs that have historically existed between richness and reach as they relate to student achievement are being made obsolete by technology. These tradeoffs have long limited teachers to choosing between focused one-on-one instruction and the broader "lecture hall" teaching of many students. Technology can eliminate this forced choice by giving teachers both access to many more students via remote connections and the ability to interact with all those students on a more individualized level via online assessments, adaptive learning, and communications. (See the book *Blown to Bits: How the New*

Economics of Information Transforms Strategy by BCG's Philip Evans and Thomas Wurster, for a detailed discussion of richness and reach.)

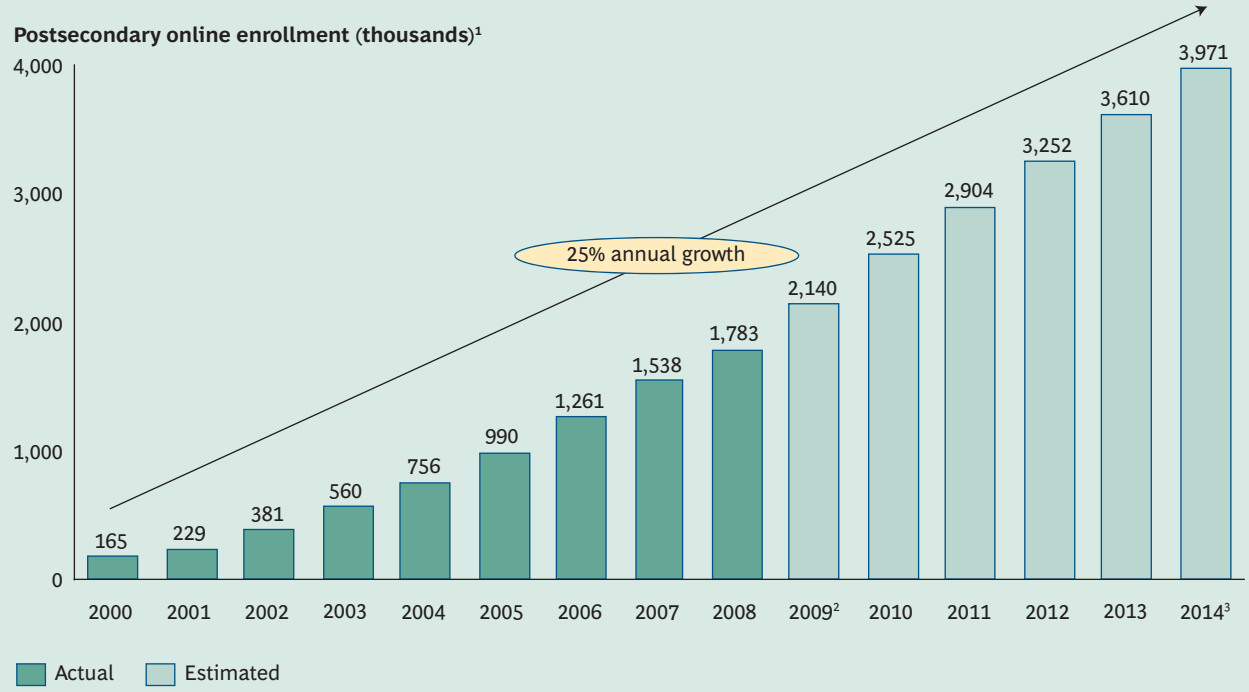
Assessing the landscape in education, we are finally at a point where we can see several key trends taking shape that expand both richness and reach.

Education Anytime, Anywhere, and for Anyone. Location has long governed students' access to education. But thanks to the explosion in online learning—and technology's ability to connect teachers to students in remote locations—this barrier is rapidly eroding. In Tamil Nadu in rural India, the Gramjyoti Rural Broadband Project, launched by the Swedish telecommunications company Ericsson, is using wireless broadband to transmit lessons delivered by specialist teachers. The sessions are interactive and cost far less than it does to recruit a teacher to move to that remote area. Similarly, the MIT OpenCourseWare site, sponsored by the Massachusetts Institute of Technology, provides free access to more than 1,300 of the university's courses and has drawn more than 70 million visitors since 2000—most of whom access the site from outside the U.S. And there are many other equally extraordinary examples.

Since 2000, annual enrollment in U.S. postsecondary online courses has grown more than tenfold, from 165,000 students in 2000 to an estimated 2.5 million in 2010. (See Exhibit 3.) By 2014, it is expected to reach nearly 4 million. Most of this growth has come from so-called nontraditional students: adults aged 25 and older. Nearly one-quarter of these older students pursued their postsecondary education online in 2009; by 2014, that proportion could climb to 35 to 40 percent.

Although much of the early growth in the sector was driven by for-profit providers such as the University of Phoenix and Kaplan Higher Education, traditional not-for-profit universities are increasingly introducing online

Exhibit 3. U.S. Enrollment in Postsecondary Online Courses Has Grown More Than Tenfold Through 2010



Sources: Eduventures, *Online Higher Education Market Update 2009;* BCG analysis.
[1]At degree-granting schools.
[2]The 2009 data represent ~11 percent of total postsecondary enrollment and ~24 percent of adult (aged 25 and older) postsecondary enrollment.
[3]The estimated data for 2014 represent ~20 percent of total postsecondary enrollment and ~35 to 40 percent of adult postsecondary enrollment.

programs in an effort to boost growth and serve a wider array of students. UMassOnline, the online division of the University of Massachusetts, now offers more than 100 degree and certificate programs online and serves more than 45,000 students.

Enrollment in online courses is also taking off at the primary and secondary levels, rising from just 45,000 in 2000 to 1 million in 2007. Online learning often gives students access to courses not offered in their high school. Apex Learning, for example, was founded in the late 1990s by Paul Allen, cofounder of Microsoft, in part to give students more choice in Advanced Placement (AP) courses. Today, Apex offers not only 15 AP courses (far more than the typical high school) but also a full high-school curriculum of approximately 100 digital courses. Over the years, it has served some 1 million students from nearly 5,000 school districts across all 50 states.

Technology is enabling teachers to customize what they offer on the basis of individual student needs.

And more than half the states in the U.S. now have virtual high schools. These programs create new opportunities for home-schooled students and those who were poorly served before—including physically challenged students and those in small or underfunded schools. Florida Virtual School now offers more than 100 courses to students in all 67 Florida counties—as well as to students in every other state and more than 40 other countries.

A Great Teacher for Every Student. There is increasing agreement that the quality of the teacher is a vitally important factor in educational outcomes. Studies suggest that providing students with a high-quality teacher three years in row will produce huge gains on standardized tests and help to significantly close racial and income-based achievement gaps. The problem, however, is that many of the best teachers work in affluent schools, often leaving low-income students with less effective instructors. In the U.S. and many other developed countries, there are also serious shortages of teachers in the science, technology, engineering, and math (STEM) disciplines. And many developing countries face more fundamental shortages of trained teachers in all disciplines. In countries such as Nepal and Chad, the ratio of trained teachers to students is just under 1 to 100, compared with an average ratio of 1 to 15 in developed countries.

With technology, all students—irrespective of where they live—can now have access to the world's best teachers. Academic Earth, for example, offers lectures from top-rated professors at Yale, Stanford, MIT, and Princeton. Academic Earth's mission is "giving everyone on earth access to a world-class education." In Australia, CLIVE International—CLIVE stands for Continuous Learning in a Virtual Environment—is using technology to address a severe shortage of native English-language teachers in Asia, where the demand for English instruction is enormous. CLIVE uses videoconferencing, webcams, and other technology to enable teachers in Australia to lecture and communicate with students in Asia. This is far less expensive than the traditional solution of hiring English teachers from as far away as the U.S. and Canada.

A Customized, Adaptive Learning Experience. For centuries, personalization has been the gold standard in education. It's why wealthy families hire tutors for their children, it's also why the universities of Oxford and Cambridge still use a tutorial system. But for the vast majority of the world's educators, personalizing instruction has been an enormous challenge. Now, technology is enabling teachers to customize what they offer on the basis of individual student needs, skills, and interests.

Consider Reasoning Mind, which creates an engaging online community to individualize math instruction for students in grades 2 through 7. This is a far cry from the old "drill and kill" software programs that did little to raise math scores. Reasoning Mind, which is being used in several schools in Houston and Dallas, employs an international curriculum far more rigorous than the typical U.S. curriculum. An evaluation by The Academy of Medicine, Engineering and Science of Texas found that "Reasoning Mind students perform 10 [to] 20 percent better than their peers on TAKS [the Texas Assessment of Knowledge and Skills achievement tests] and other math achievement tests, and 76 percent of students say they like math more than before they participated in the program."

Meanwhile, in New York City, School of One—a pilot program being tried in three of the city's public schools—is demonstrating how technology can help teachers personalize instruction. School of One uses a learning algorithm

that takes into account individual students' performance to develop a daily "playlist" for each student and teacher. The menu includes teacher-led instruction, one-on-one meetings, independent learning, and virtual tutoring. Though this program is still being piloted, Arthur Levine, president emeritus of Teachers College at Columbia University, recently commented, "New York City's School of One may turn out to be the single most important experiment conducted in education so far. It is the future."

Timely, Relevant, and Compelling Content. For generations, the content provided in classes has been largely limited to textbook materials. Because it takes an average of three years to produce, a new textbook can be out-of-date from day one. By contrast, technology offers educators exponential increases in the timeliness and richness of the learning materials that they can share with students.

Take, for example, the Commonwealth of Virginia, which was told that a new physics textbook would take five years and a multimillion-dollar investment to produce. Instead, the state turned to CK-12 Foundation, a nonprofit publisher, which used freelance authors and a combination of paid content and materials harvested from the public domain to create a new textbook in just three-and-a-half months—for a fraction of the original projected cost.

Similarly, despite the increasing importance of science, many students attend schools that have outdated and inadequate science labs. But now "virtual labs" are emerging that expose students to world-class science. Brigham Young University and Pearson Education have teamed up to create Y Science Laboratories—offering virtual labs in chemistry, physical science, physics, and earth science to middle and high schools, as well as to colleges. These labs put students in a virtual environment where they make the same kinds of choices—and experience the same consequences—that they would in an actual lab. The labs were created by video game designers using photographs and videos to create remarkably realistic simulations.

Enabling the Closed-Loop Instructional System

If educators, institutions, and policymakers are to realize the full potential of technology, they need to take a holistic approach and incorporate it into what is called a *closed-loop instructional system.* (See Exhibit 4.)

The closed-loop approach in education is hardly new: the best educational institutions have always taken a comprehensive, holistic approach to educating their students. They start by setting clear objectives. They then put in place a curriculum designed to meet those objectives, and they hire instructors who can teach the curriculum in a compelling fashion. Because student aptitudes and learning styles vary enormously, these institutions use frequent assessments to spot problems and then intervene to help struggling students get on track. Finally, they carefully monitor student outcomes and use these data to modify and improve the closed loop for future students. *What makes technology such a powerful lever is that it can help educators do all of this better, faster, and usually at a significantly lower cost.*

Taking the Right Steps

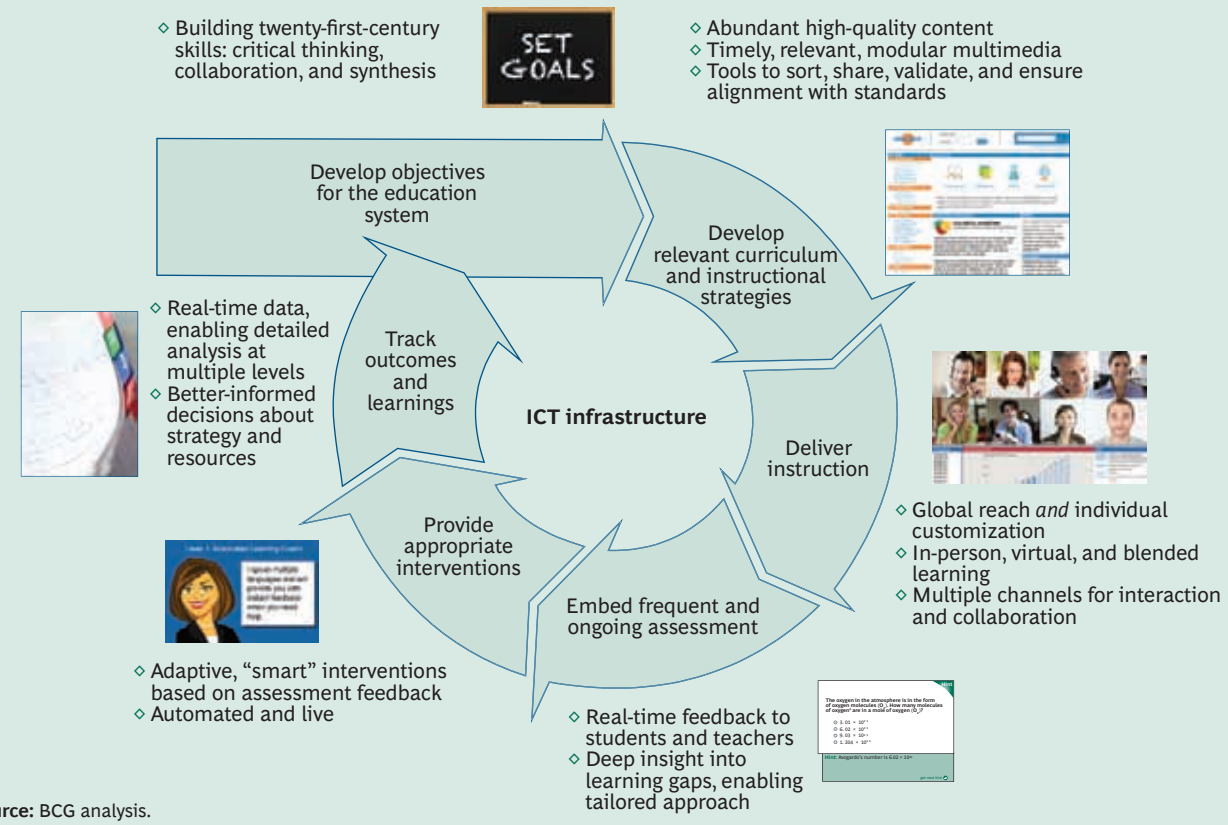
Here we outline how educators can use technology to enable each of the six core elements in a holistic, closed-loop instructional system.

Establish educational objectives focused on twenty-first-century skills. The first step in creating a closed-loop system is to carefully establish objectives. These should set clear expectations for what students will learn and the abilities and skills they need to master by the time they graduate. Take Oxford University's famed "Greats" program of study, which in the nineteenth century was viewed as ideal preparation for those who would eventually run the British Empire. Greats students were required to complete rigorous courses in Greek and Latin, history, philosophy, and literature.

Today, there's growing agreement among educators and business leaders that graduates should be equipped with twenty-first-century skills. Among the most important are thinking critically, collaborating, and creating knowledge or new insights from mountains of information. While education was once designed largely to impart content, twenty-first-century instruction focuses more on developing competencies. And because these competencies will be required of workers from China to California, the objectives of national education systems are likely to look increasingly similar in the years ahead.

In the U.S., higher-education institutions are increasingly using sophisticated technology to teach twenty-first-century skills. The University of Phoenix, for example, is using a virtual simulation developed by Toolwire to help students in its Axia College IT program develop problem-solving and critical-thinking skills. In the simulation, students act as IT professionals in a virtual company, and over the course of the semester they must work through IT problems similar to those they would face in the workplace. Technology ensures that they gain lifelike experience in a highly condensed and tailored setting while they confront problems they might not witness in a multiweek internship or other "real-world" experience. Similarly, in a University of Texas course on instructional technology, students are assigned a project to design a school district's annual technology plan. As part of the assignment, they must work with an IT professional in a school district. The students also use Skype to videoconference and collaborate with chief information officers in

Exhibit 4. Technology Enables a Closed-Loop Instructional System to Deliver Better Student Outcomes



Source: BCG analysis.
Note: ICT is information and communications technology.

school districts across the country. It is only a matter of time before similar instructional technology is available for use at the middle- and high-school levels.

Develop relevant curriculum offerings by using open-source content. The next step is to develop a curriculum that will enable teachers to realize these objectives. Technology has now expanded curriculum resources beyond the highest hopes of teachers from just one generation ago. Rather than relying on a single textbook, today's teachers can mine resources developed by the world's greatest universities. The challenge is how to navigate through this abundance to find and validate material that meets the standards students will be held to—and then to adapt this material to those students' needs.

Fortunately, there is a growing number of companies and other organizations whose mission is to help educators harvest and use open-source content. Curriki, a nonprofit created by Sun Microsystems cofounder Scott McNealy, is dedicated to the development and free distribution of "world-class educational materials" for grades K–12. It already provides more than 40,000 lessons, videos, and other educational resources that have been used by educators from Silicon Valley to Morocco.

Another company, BetterLesson, was launched in 2008 to provide access to highly rated curricula. It allows teachers to upload lesson plans for free and to collaborate with other teachers by sharing best practices and insights. KIPP, the best-known U.S. operator of charter schools, is using BetterLesson to help improve the effectiveness of its teachers.

Some educational systems are developing comprehensive intranets that help all the stakeholders in education make

better use of online content. On the sites, students and teachers can have their own online working space, as well as the ability to chat with other students and teachers about their goals and progress. Teachers can plan and develop learning sequences by drawing on a large content repository and the resources of their colleagues from other schools. The Ultranet created by the Australian state of Victoria is a good example of this trend. (For more about Victoria's Ultranet and other examples from around the world, see the sidebar "Educational Technology on a Large Scale: Lessons and Best Practices.")

Deliver instruction virtually. Technology helps create extremely interactive and collaborative learning environments. Students in the U.S. who are studying Spanish, for instance, can use videoconferencing to communicate with students in Spain or Mexico—creating the virtual equivalent of a foreign-study program at a fraction of the cost.

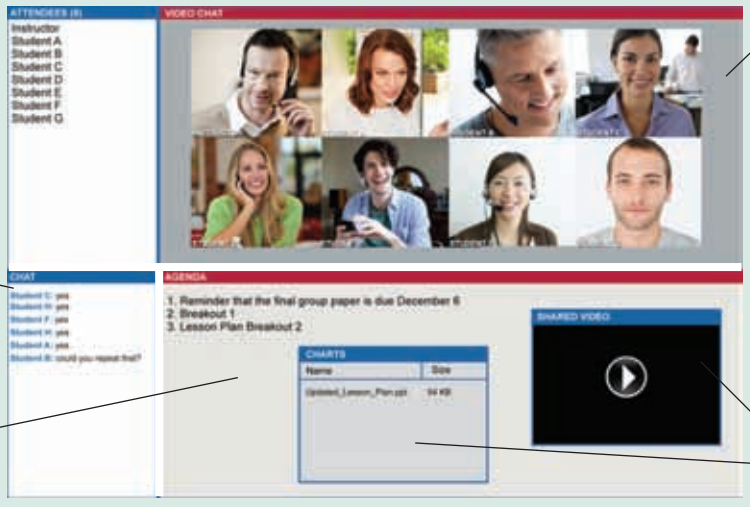
In addition, as we discussed earlier, technology can expose more students to the best teachers. A teacher no longer needs to be physically present in the classroom—he or she can now record or stream lectures, thus greatly expanding his or her ability to reach students. In Korea, for example, Megastudy offers students in so-called cram schools recorded lectures from star teachers. Because these courses are far less expensive than traditional ones and are accessible wherever there is Internet access, Megastudy now serves 2.8 million students, or about half of Korea's college-bound high-school seniors.

The University of Southern California (USC) has also employed many of these new tools in creating its online Master of Arts in Teaching program. (See Exhibit 5.) Students in this program do not take classes on campus—but they are still able to take advantage of "office hours" by conducting live video chats with professors. The online courses include live streaming lectures that use interactive whiteboards. Students are asked to record and then upload clips of their student-teaching experiences so that other students and faculty might comment on them. Students in this online master's program are already reporting higher completion rates than students in the traditional on-campus program. And 12 times as many

Exhibit 5. USC's Online Program Delivers a Classroom-Like Experience

"It's going to sound strange, but I feel like the level of interaction is much higher in this classroom. It's not like a lecture hall where someone's sitting in the back and could be texting."

Illustrative example of online features



"If you want to ask a question, you just raise your hand, or there's a button you press and it raises the hand on the professor's computer. He answers right away just like you're in a normal classroom."

"There's a chat area where I can type a question if I missed something, and the professor will see that right away."

"There is a chalkboard where the professor can write notes and highlight important things that people say. It helps you get a better understanding of the material."

"It's like *The Brady Bunch*. We each have a window."

"The professor can ask a question in a pop-up. It's just like *Who Wants to Be a Millionaire*. We respond and he can see if, say, only 50 percent of us know the answer, and then that's an area he needs to explain more."

"He can show us slides or videos and make the video full-screen. So everyone is watching the video together."

"Students can instant-message each other privately during class if, for example, they really liked what someone said but didn't want to interrupt the class."

Sources: University of Southern California Master of Arts in Teaching program (mat.usc.edu); interview with Susan Metros, associate vice provost for technology-enhanced learning and deputy chief information officer for USC, August 2010; interviews with USC students; BCG analysis.

students are being served by the online program as by the campus-based one.

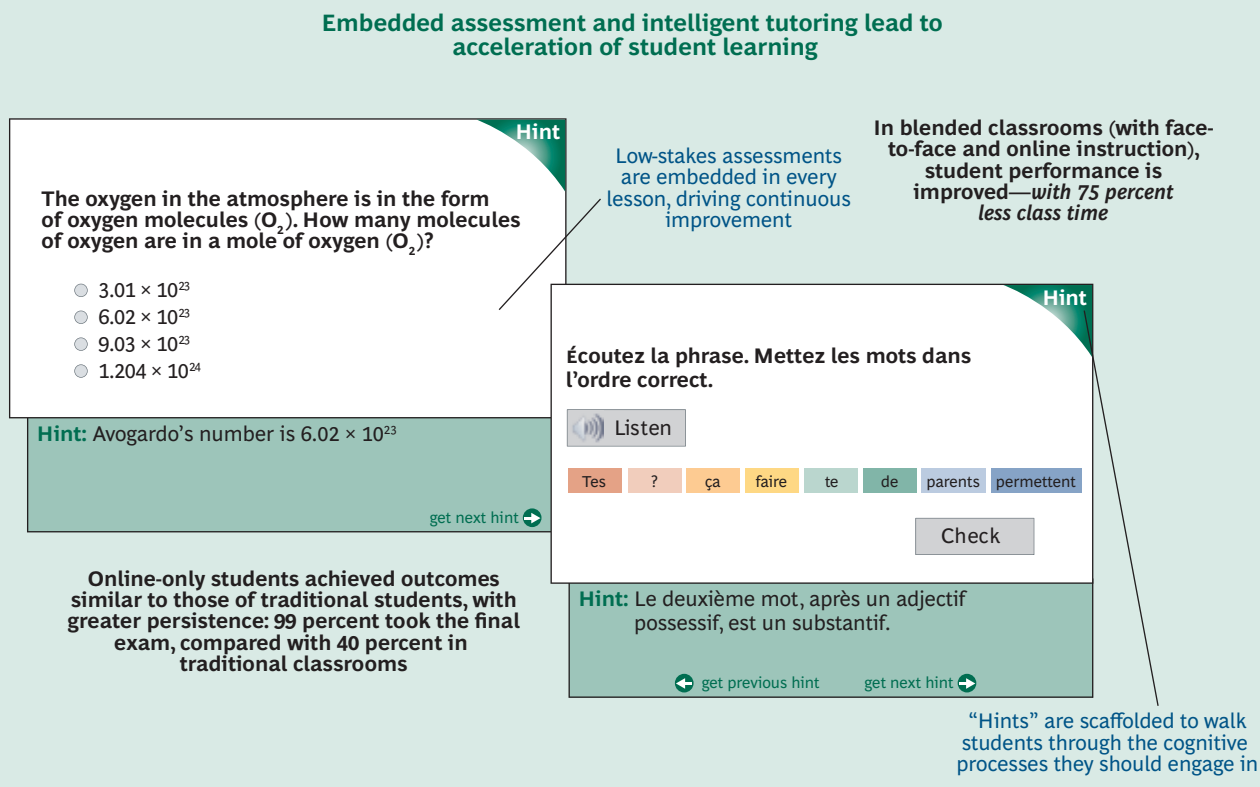
Embed frequent assessment with real-time, continuous feedback. While educators have long recognized the critical importance of assessing student performance, the sheer logistics of grading tests has often delayed these assessments until it's too late to intervene effectively—at least during the relevant school year. Technology can accelerate this process enormously, facilitating real-time feedback on how students are doing.

Take the online courses developed by Carnegie Mellon University's Open Learning Initiative (OLI). The bedrock of OLI's courses is "embedded assessment," in which short tests are woven throughout the online curriculum. (See Exhibit 6.) Students taking a course in probability and statistics, for instance, encounter a series of learning games, questions, and problem sets as they move through learning modules online. These activities are designed to assess the students' comprehension by using real-time data, with a scaffolded series of predetermined "hints" that help students if they're having difficulty.

Throughout the program, students receive instantaneous feedback on their progress while their instructors gain a real-time view of the concepts that are challenging to individual students and the class as a whole. This knowledge arms instructors to better tailor their in-person teaching time to the immediate needs of their students. OLI's leadership attributes the program's positive results largely to the value of the embedded assessments.

Provide appropriate intervention with immediacy and customization. Even when an assessment reveals a clear need for intervention, accessing the appropriate help can often pose a big challenge in the traditional educational environment. But technology is radically revising

Exhibit 6. Carnegie Mellon's Open Learning Initiative Uses Instructional Feedback Loops to Improve Outcomes



Sources: Interview with Candace Thille, director, Carnegie Mellon's Open Learning Initiative, June 2010; http://oli.web.cmu.edu/openlearning/; BCG analysis.

Many nations—and states and provinces—have only just begun to think about how they might use technology to improve their education systems. They have much to learn from locales that have adopted aggressive technology strategies, notably the state of Victoria in Australia. Victoria's experience offers important lessons to other nations, states, provinces, and education systems that aim to optimize their use of technology to transform education effectively.

Victoria, Australia

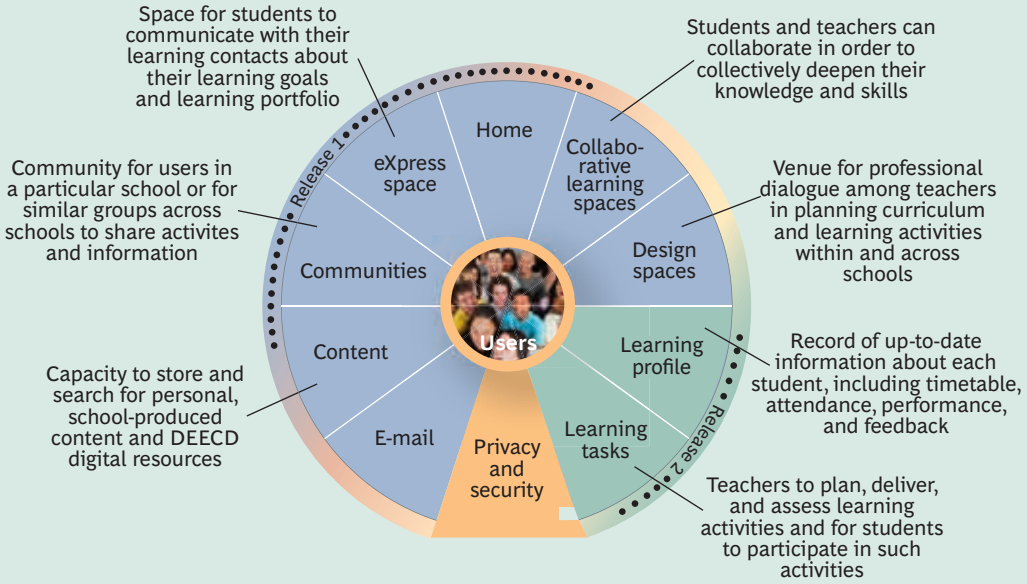
The Australian state of Victoria—best known for its largest city, Melbourne—offers the most encouraging example that we have encountered of a major system that seems to be getting it right. In 2010, Victoria launched a sweeping e-learning initiative known as the Ultranet. The Ultranet is a knowledge management framework for schools and their communities; it assists teachers in planning and delivering learning activities, and it facilitates the collaboration and sharing of curriculum content among teachers.

> The Ultranet aims to unite all 1,550 schools in Victoria in a student-centric online-learning environment.

To create the Ultranet as it exists today, Victoria spent a decade and more than $4 billion to build infrastructure and improve its schools. The Ultranet aims to unite all 1,550 schools in the state—along with more than 500,000 students, 70,000 teachers, and 1.1 million parents—in a dynamic, student-centric online-learning environment. It incorporates many of the key elements of a closed-loop system. It also facilitates curriculum development by offering a so-called design space where teachers can work together online to plan curriculum and learning activities. (See the exhibit "Victoria's Ultranet Enables Stakeholders to Collaborate and Communicate.") And it offers considerable support to students, including opportunities to communicate with other students and teachers.

Although it is far too early to assess the Ultranet's ultimate impact, Victoria's endeavor in educational technology is differentiated from others by the attention its designers have paid to developing a comprehensive

Victoria's Ultranet Enables Stakeholders to Collaborate and Communicate



Source: BCG analysis.
Note: DEECD is the Department of Education and Early Childhood Development, Victoria.

Educational Technology on a Large Scale (continued)

change-management plan—and by the efforts of clearly identified leaders who can drive systemic change. Reasoning that teachers are more likely to respond to coaching from their peers than from technical experts, Victoria selected 68 teachers to become regional-level Ultranet coaches and to support schools in their region. At each school, the principal is expected to champion the Ultranet among teachers, students, and parents. Finally, each school has "super users," who are responsible for providing professional training to staff and training them in the effective use of the Ultranet to improve the teaching and learning processes. This layered approach to leadership recognizes how critical the human element is in deploying educational technology. Without strong buy-in from teachers and principals, technology is not likely to launch fundamental change.

what is possible and helping students access the specialized tutoring they need. The data provided by continuous assessment make it feasible for instructors to quickly pinpoint exactly where a student is having a problem, and the emerging industry of "intelligent tutoring" can then respond by quickly delivering a tutor with the precise skills needed to help the student.

Consider Tutor.com: since its launch in 1998, the company has emerged as the leading online provider of tutoring services. Tutor.com connects students to a network of thousands of tutors, and help is available 24-7. It also offers its services to individuals and through libraries, schools, community colleges, and the U.S. military. Its success is spurring new entrants, such as Apangea Learning, which offers three levels of support that range from an "automated learning coach" to one-on-one sessions with a tutor. Apangea says that it can help students boost assessment scores by as much as 30 percent.

Track outcomes through ICT-enabled data-management systems. For those who run education systems, technology can be used to track what students are learning far more precisely and quickly than ever before. Today, administrators often have to wait months for data on students' achievement and performance. Even then, the data they get are often too rudimentary to allow firm conclusions about which approaches are working. But existing technology can enable teachers and administrators to understand what is currently working at the level of an individual lesson or course, program of study, or school—or even an entire system. The data can then become a powerful management tool for administrators as they allocate resources and decide which programs to continue or curtail.

Such data systems require significant up-front investment, however, and that has been a key barrier to their adoption. Yet, the importance of data systems has been recognized at the national level in the U.S. One of the four major priorities of President Barack Obama's Race to the Top initiative is "building data systems that measure student growth and success and inform teachers and principals about how they can improve instruction."

A second barrier to widespread adoption has been the limited types of data being collected. To date, these data have been confined largely to academic test results. But to truly personalize learning, educators will also need data on each student's learning preferences and interests and on which instructional approaches work best for him or her. The ultimate goal is for those who lead education systems to use these data to make better, faster, and more customized decisions about how to serve individual students as well as the entire school system.

Closing the Loop

Clearly, there are many examples of how educators are using technology to enhance each stage of the closed loop. However, realizing the full potential of the approach requires combining all of these elements into a seamless system. Achieving this goal is far from automatic, and bringing all the pieces together requires strong leadership.

Still, we are encouraged by a number of ongoing efforts that seek to use technology in a holistic way in an effort to create a closed loop. One excellent example is OLI. Begun in 2002, OLI set out to conduct research on the most

effective ways to foster online and "blended" learning; the latter combines online and campus-based instruction. To develop world-class curricula in subjects ranging from statistics and economics to chemistry and French, OLI formed teams consisting of subject-matter experts, specialists in the human-computer interface, IT professionals, and students.

The teams establish learning objectives for each course, and they develop a series of online course modules that are carefully designed to leverage technology to meet those objectives. The curriculum and assessments are entirely online, with no textbooks to reference. As noted earlier in this report, courses incorporate a series of embedded assessments and deliver real-time feedback on performance to both students and faculty. In the blended environment, instructors have been able to use technology to reduce the amount of in-person class time by 75 percent for a typical semester-long course. Students learn the material largely outside of class, allowing instructors to use class time more efficiently to focus on the areas where students are clearly having trouble understanding the material. In this way, instructors are able to intervene in a highly personalized and customized fashion to meet their students' identified and individual learning needs.

Carnegie Mellon closely tracks the outcomes from these courses and identifies the strategies that are proving most effective. The combination of embedded assessments, continuous feedback loops, and careful research has created a continuous improvement cycle. This approach is accelerating student learning: one study showed that students in an OLI statistics course learned a full semester's worth of material in half the time it took their peers in a traditional classroom. Furthermore, in the blended model, the percentage of students passing the courses has increased. These courses, which have won recognition from the U.S. government, are now being used elsewhere, including community colleges.

The Closed-Loop Revolution

A Road Map for Leaders

We turn now to a broader question: what should educators, policymakers, and other stakeholders do now to strategically adopt and deploy technology that enables the closed-loop system?

In the coming years, the technology revolution in education has the potential to gather strength and momentum as visionary leaders take up a technology-enabled closed-loop approach to instruction. But whether and how quickly this happens within systems (and even nations) will depend in part on the policy environment—and the extent to which it encourages and fosters the use of technology.

Another critical variable will be how quickly individual institutions move to adopt and implement *effective* technology. To date, there has not been a strong policy push to adopt educational technologies at the primary and secondary levels, despite the groundswell of activity in post-secondary education.

In short, while a technology revolution is now possible, it is hardly inevitable. And this suggests that gaps in relative system performance may widen, depending on the extent to which policymakers and leaders in education seize these opportunities.

Recommendations for Leaders and Policymakers

Crafting the education system of the future requires both education leaders and policymakers to take decisive action today.

Embrace a holistic strategy. Often, leaders in education work with various technology vendors in silos and build a system of disconnected parts. Or they focus on building infrastructure, with little or no provision for the instructional experience or for the resources necessary to train teachers. Or they focus on one element of the closed-loop system, such as rich digital content, while ignoring other elements that are essential if that content is to truly improve student outcomes.

By contrast, a holistic strategy starts by setting clear educational goals and then designing a closed-loop system tailored to meet those goals. The strategy is not primarily about how to put the latest, greatest software or device to use but rather about how to employ available technologies and people to address a specific educational need. Furthermore, although "holistic" does not necessarily mean putting all of the pieces in place at once, it does mean that strategies must address all of the steps of the closed-loop system. An initiative that is only about curriculum, or only about delivery or assessment, may drive modest improvements—but it is less likely to produce a significant change in outcomes.

Enable teachers to use and leverage technology in the classroom. Teachers are especially important and are arguably the most significant factor (of those that are within a school's purview) in determining student outcomes. Starting at the beginning, schools of education need to develop courses and concentrations that aim to build the teachers of tomorrow. The next critical step in creating a highly skilled and highly energized corps of digital instructors requires educational institutions to adopt a comprehensive approach to recruiting, developing, and retaining top teaching talent. Such an approach will have a positive impact on student outcomes no mat-

ter how an institution uses technology—and it will facilitate a more successful implementation of technology initiatives.

Educational institutions must also address other teacher-related imperatives. First, it is critical to provide teachers with technology-related training at multiple levels. The past two decades have provided ample evidence that the average teacher doesn't have the time or energy to figure out new tools and systems on his or her own. Teacher training must go beyond how to operate a new device to cover how to integrate technology into the curriculum and how to teach in a technology-enabled environment. Imparting such knowledge often requires drawing on outside expertise.

The promise of technology extends far beyond what most students experience in school today.

Second, new approaches should be designed to take into account the obstacles that teachers face. For many teachers, lack of time is the greatest constraint. Technologies that save time and make the teacher's job easier are more likely to be adopted than those that add complexity. Technology is well suited to helping teachers break through some of their current constraints—such as the time it takes to assess student performance. But even when a new approach seems promising, it must be designed with its overall impact on the teacher in mind.

Third, vehicles for professional development must be multifold: classes and seminars alone are insufficient. The same technology that has the potential to revolutionize student learning should empower institutions to provide teachers with more customized help, as well as offer online communities that aid them in supporting one another and exchanging ideas.

Create an engaging student experience. Leaders must ask themselves and their teams whether technology is being used to provide a fundamentally more engaging experience for students or merely to replicate the status quo in electronic form.

The promise of technology extends far beyond what most students experience in school today. As we have described, new technologies can help achieve both scale and personalization in learning. Many more students can have access to the best content and instruction. At the same time, students can expect more frequent feedback on their strengths and areas for improvement, along with customized learning plans to guide that improvement, online communities for interacting with fellow learners, and in-person and virtual tutors to provide help along the way.

For most students, especially in primary and secondary schools, technology works best when incorporated into a blended environment. (See the sidebar "Tuning In and Turning On in the Tech-Enabled Classroom—and Beyond.") Although online-only experiences will be appropriate for some, this is not likely the answer for the majority of traditional students (aged 24 and younger). Rather, the goal is to use digital tools to greatly enhance instruction and interaction—and, in the process, transform school into something both less confining and more relevant for individual students.

Promote the development of high-quality digital assessments that enable continuous feedback. If we're going to build a true technology-based closed-loop instructional system, we must develop continuous feedback loops that deliver real-time performance data to education leaders, instructors, parents, and students. These start with high-quality digital assessments—not only formative, embedded assessments (exercises conducted during the course of instruction to determine where further instruction is needed) but also end-of-course summative assessments (so-called because they summarize the student's educational development)—that provide performance data much more quickly than current assessments do.

Currently, it can take up to six months for data to become available from even the most comprehensive of the summative assessment systems, such as the Florida Comprehensive Assessment Test (FCAT). Effective use of technology could greatly accelerate these processes, delivering faster feedback to schools, teachers, parents, and students. Embedded assessments will position teachers to create so-called micro–feedback loops for quickly identifying their students' immediate needs, delivering customized interventions, and seeing the results immediately. Continuous, data-enabled feedback loops will also help districts, states, and nations identify the best or preferred providers in education on the basis of their ability to deliver better outcomes.

Tuning In and Turning On in the Tech-Enabled Classroom—and Beyond

Imagine how a high-school U.S. history course might be delivered using the technologies available today. To begin a unit on the tumultuous 1960s, students would log into their course website and work through a class module. But rather than spending classroom time listening to their teacher lecture about dates and concepts, the students would use a computer or device while at home or in the library—or anywhere—to view videos featuring interviews with Cold War scholar John Lewis Gaddis, lectures from Todd Gitlin discussing his book *The Sixties: Years of Hope, Days of Rage,* or discussions with Doris Kearns Goodwin about Presidents Kennedy and Johnson.

They would then use the Internet to access primary documents such as Martin Luther King Jr.'s "Letter from a Birmingham Jail" and would work through interactive online modules designed to explore the key issues of that decade, from the civil rights movement to the Vietnam War. Personal devices—smartphones or tablets or a mix of both—would allow the students to continue working on the modules while they traveled to and from school, waited to be picked up after practice, or worked at home.

Since students would cover most of the material while outside of the classroom, the teacher would be able to devote class time to developing the students' critical-thinking skills through group discussions and debates about the era. Because the teacher would spend less time disseminating facts, the focus would be on providing students with individualized assistance. He or she would be equipped with quantitative and up-do-date data on how well the students understood and applied the material, since the online modules would include embedded assessments that would instantly feed results to the teacher.

In addition, the teacher would work individually with students to guide them in crafting projects exploring the 1960s in greater depth. Technology would allow the students to roam far afield in their research and to access both primary sources and analysis too new or comprehensive to have been published in textbooks. One student might use Skype to interview a Vietnam veteran, while another might explore the digital archives of the Library of Congress to learn about the antiwar movement. To develop, present, and share their insights, the students would create videos, podcasts, or interactive online modules of their own or use other Web-enabled technologies or tools.

It is important to note that it isn't the technology itself that makes this an advanced or modern approach. Certainly, students in prior generations could have accomplished some of these same activities—watching videos, reading the primary text of King's letter—without devices, interactive modules, or online technologies. Instead, the technology facilitates a full integration of all the materials, instruction, assessments, and interventions related to the lessons.

Ultimately, this blended approach could immerse the students in the issues that dominated the turbulent 1960s in a far more meaningful and enlightening way than current teaching methods can. Meanwhile, it would also enable teachers to provide customized coaching and to focus in particular on developing the students' higher-order thinking skills.

Develop a critical mass of research that confirms—or refutes—technology's benefits. To date, research on online and blended instructional formats and strategies has been small in scale and reach. Also, the press has been flooded with articles that purport to demonstrate that educational technology doesn't "work." But as Clayton Christensen, Michael Horn, and Curtis Johnson have argued in their book, *Disrupting Class,* research needs to examine technology use at a deeper level to answer the questions of where, when, and how it is best deployed.

The most compelling research so far has been done at the postsecondary level: Carnegie Mellon has shown that blended learning can both improve and accelerate student outcomes. This research, which was conducted in introductory-level mathematics courses at an elite university, must be supplemented by equally careful research into how technology is best deployed in other settings—such as secondary schools and community colleges—and in less "linear" subjects.

Online universities and virtual schools, with their vast populations and course catalogs, present amazing opportunities for large-scale research agendas. Given the speed at which real-time assessments can provide data, we should expect an explosion of research evaluating how

students learn. In turn, this should pave the way for faster improvement in the ways students are taught.

A key element in the building of this trove of high-quality research on educational technology will be the development of robust longitudinal data systems. These data systems, which permit the tracking of student outcomes across years and school systems, will support both high-quality research and the careful evaluation of digital providers.

Enact policies that encourage and facilitate the proliferation of digital learning. In higher education, competitive market pressures will no doubt encourage many institutions to catch up with online pioneers such as Carnegie Mellon. But in markets with few competitive pressures, states and nations must adopt supportive policies that create a similar impetus for change. In the U.S., the *Digital Learning Now!* report, released by former Governors Jeb Bush and Bob Wise in late 2010, provides a helpful blueprint for such policies. Among its recommendations are the following:

- *Promote more flexible use of funding.* In today's budget-constrained environment, it may not be realistic for governments and schools at any level to increase overall technology spending. But shifting how and where current funding is directed could make a big difference. If funding streams are made more flexible, school districts could deploy funds where they are most effective instead of simply where regulations dictate. For instance, print textbooks and digital content should compete on a level playing field; districts should not be prevented from using budgets for instructional materials to procure digital content. In addition, funding should increasingly be based on student outcomes rather than on enrollment numbers or "seat time"—the hours spent attending class. In the world of digital education, students should progress faster if they can demonstrate that they have already mastered material. And funding for education providers should reflect this shift from traditional, linear progress.

- *Remove obstacles to innovation.* Existing policies, particularly in the primary and secondary educational system in the U.S., limit the ability of educators to restructure the traditional classroom through digital means. For example, caps on class size or teacher-student ratios obviate one of technology's major benefits—the ability to reach more students with fewer, or differently structured, resources. Education officials need to promote policies that focus more on outcomes than resource inputs.

- *Eliminate geographic barriers to quality.* Policymakers need to consider a range of changes governing issues such as textbook adoption and teacher certification. The goal should be to empower schools and students to seek the highest-quality options, no matter where they might be based. Digital instructors must be able to teach students at multiple school sites and across multiple states. In the U.S., adoption of the Common Core State Standards (already adopted by more than 40 states) will serve as a critical step in catalyzing digital providers to develop universal, state-neutral curricula and to benefit from improved scale. (The Common Core State Standards Initiative is a state-led effort coordinated by the National Governors Association Center for Best Practices and the Council of Chief State School Officers. The standards were developed in collaboration with teachers, school administrators, and experts to provide a clear and consistent framework to prepare children for college and the workforce.)

Funding should be based on student outcomes rather than on enrollment or "seat time" in class.

Build an ICT infrastructure that enables the closed loop. Each educational system will start from a different point in terms of its existing ICT infrastructure and education-related software applications—so each will require a customized technology road map. High-speed Internet and wireless access are the minimum essentials, but in many countries outside the U.S., even these are not widely available. After creating the basic ICT infrastructure, many organizations struggle to invest in the right software applications and end-user devices. Vendors are innovating profusely, but because few standards exist, the solutions often are not interoperable. For example, the applications that run on Apple's iPad and those that run on Google's Android tablet are not interoperable, frustrating school administrators who are trying to deploy tablets in their institutions.

Given the proliferation of applications and devices and the emergence of cloud computing, there is likely to be significant change in the technology landscape of the future. As a result, it will be important for nations, states,

and school systems alike to keep their technology options open, especially in the absence of standards. This reality will require approaches such as partnering, outsourcing, leasing, and otherwise making the cost of technology investments more variable. It also implies using the computing cloud as a way to minimize exposure to changing standards and to reduce up-front investments.

Implementing a closed-loop system will demand a holistic ICT and applications strategy; such a strategy will systematically build toward and reinforce the closed loop. It is critical to design modular target architecture so that individual components can be swapped in and out as new applications and technologies emerge. Each organization will therefore require a capable chief information officer who understands how technology will be used in instruction and learning. Also critical to making the right choices will be an integrated decision-making process in which key stakeholders (such as principals, teachers, parents, and students) are engaged.

The early winners will have the support of policymakers willing to create a supportive ecosystem for change.

A Call to Action

Carnegie Mellon's OLI and the many other examples cited in this report demonstrate that the technology revolution in education is no longer hypothetical. It has already begun, especially in the postsecondary space. And we are convinced that it holds the extraordinary potential to transform primary and secondary education—not only in terms of how students learn but also how much and how quickly they learn. We are also excited about the opportunities that this technology revolution presents to countries beyond the U.S.—nations in both the developed and the developing world that are looking to dramatically improve their educational systems.

In today's global economy—from rural villages in India to the heart of Silicon Valley—no nation or neighborhood can afford to ignore this opportunity. In this report, we have highlighted several governments, educational institutions, and school systems that have undertaken ambitious plans to use technology to enhance learning. Some of the stories we have presented clearly illustrate the challenges that can limit the impact of even large, expensive efforts. But we are confident that these lessons will help guide other countries, states, districts, and institutions that decide to embark on this journey.

Today's technology has the power to break down the barriers and constraints that have long frustrated educators, while also equipping students with the new skills that they will need to succeed in the twenty-first-century economy. Products and services are available today that were not even thought possible just a few years ago, and costs are dropping rapidly. Meanwhile, the demand for technology in education is increasing every day, as educators look for new ways to improve student outcomes in an era of fiscal constraints—and as today's students expect classrooms to employ the kind of technology that they use in their personal lives.

Nonetheless, this revolution has not yet realized its full potential. Since computers were first introduced in classrooms, we've learned that technological devices, software, and Web-based content are not enough to fundamentally restructure teaching and learning. Rather, creating this revolution will require leadership in crafting a holistic strategy for educational technology, efforts to tap and leverage teachers, an engaging student experience, high-quality continuous feedback, solid research and data, supportive policies—and an underlying and true commitment across all levels of the educational system. Consequently, even as some institutions and systems take full advantage of technology, others will lag far behind.

The early winners won't necessarily be the best-endowed districts and systems, but they will have the support of farsighted policymakers who are willing to create a supportive ecosystem for change. They will also be headed by leaders who truly grasp technology's potential and who are committed to the kind of multifaceted professional development that will empower teachers to use technology to improve student outcomes.

We feel certain that at least some of these leaders will come from the charter school movement, which was founded with the mission of proving that schools that are publicly funded but independently run can deliver superior results. By nature, such schools are better able to take a "clean sheet" approach to education and are less encumbered by legacy systems. These schools, along with

some bold school districts, will demonstrate that technology can be an enormously powerful tool in improving educational outcomes. Eventually, their leadership will inspire a much broader transformation.

Another common key to success will be a holistic approach to integrating technology into a closed-loop system. This approach will increasingly separate the best education systems from their more mediocre counterparts. We recognize that there are risks—from making the wrong investments to failing to execute a technology strategy—and thus a need for careful execution. But we are also persuaded that the rewards will be enormous.

Note to the Reader

The analysis in this report has grown out of dozens of education projects that BCG has conducted over the past ten years while working with clients ranging from national, state, and local governments around the world to school districts, charter school operators, universities, and for-profit higher-education companies. All illuminated the immense challenges that educators face—and the pressing need for innovative solutions.

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