CQ Researcher

Digital Education

Can technology replace classroom teachers?

Digital technology is becoming increasingly commonplace in K-12 education, and many researchers argue that it will save money and transform schools into more effective institutions. But other experts contend that the evidence so far is slim on exactly what computers can accomplish in the classroom. The dominance of standardized testing means digital technologies must raise students' test scores to levels administrators and policymakers deem significant. But computer-based learning may not be well suited for that task, and further efforts to computerize education may require schools to shift away from standardized testing, experts say. Until now, most successful computer-learning initiatives have required specialized training for teachers. But experts say developing technology that will be easy for nonspecialists to use remains a challenge. Meanwhile, despite the debate over the effectiveness of computerized education, all-online K-12 schools are proliferating nationwide, and enrollment in online courses is soaring.

Ten-year-old Mirei Hosono uses an iPad in his English-as-a-second-language class at Center Grove Elementary School in Greenwood, Ind., on Oct. 28, 2011. The school received a $200,000 grant from the state to buy 230 of the devices. Education experts say computers and other digital devices increasingly are taking on roles once filled solely by teachers.

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Digital Education

By Marcia Clemmitt

The Issues

Students learning to read have long followed a familiar routine: They read a passage of text aloud in class and wait for the teacher to correct their pronunciation.

But in the digitized world of 21st-century education, computers are increasingly taking on the teachers' role. Computers can now "hear" students speak, for example, correct their pronunciation and evaluate their progress over time, says Michael L. Kamil, a professor emeritus at the Stanford University School of Education. "Until recently, computers couldn't listen to oral reading and understand it," he says. But new programs make it possible.

Such advances are part of a much bigger movement to integrate technology into classrooms, creating what education scholars call a "blended learning environment." As computers increasingly dominate every realm of business and life, experts say schools must prepare young people not only to use digital technology but also to understand how to program it, how it shapes culture and behavior and how it can be harnessed to perform tasks once considered the sole realm of humans.

Yet, while digital devices have become ubiquitous worldwide, debate is raging over whether — and which — technologies have proved their worth as learning tools. Some school systems have fully embraced technology, for example by providing every student with a laptop computer. But critics argue that money for such programs would be better spent on teachers.

And in some localities, technology

Corina Dill and other low-income middle-school students in San Angelo, Texas, participate in a new program on Oct. 8, 2011, that teaches them to use open-source software. The students can take the computers home after completing three Saturday workshops at Angelo State University. Debate is raging over whether digital technologies have proven their worth as learning tools.

is threatening teachers' very jobs. In cash-strapped Ohio, for example, schools could attain a 50-1 student-teacher ratio — more than twice the conventional 20 or so pupils per teacher — by combining live teaching with large amounts of online study, Robert Sommers, director of the Office of 21st Century Education in the Ohio governor's office, told the state legislature last spring. [1] Similar proposals are surfacing in many other states.

"I teach a class for aspiring school administrators, and the first thing I tell them is that the schools you are in today are not the schools you are going to be leading," says James Lerman, director of the Progressive Science Initiative, a program at Kean University in Union, N.J., which helps experienced teachers become certified to teach math and science. "What hap-

pened to the music industry and the publishing industry" as the digital revolution turned their business models upside down "is just beginning to happen to schools."

Digital learning has been getting a boost in localities across the nation this year. For example, Idaho became the first state to require high-school students to complete two or more online courses to receive a diploma. [2] And a mere two years after spending $500 million to upgrade Internet access in its public schools, New York City announced it will spend the same amount in 2012 on more technical improvements. [3]

Many education specialists are somewhere in the middle on the issue of computerized education. Decades of experience make clear that computer software can effectively train people to perform certain complex tasks, says David Moursund, an emeritus professor of education at the University of Oregon, at Eugene. "We've known for a long time that computers could take on part of the task of the human teacher or tutor," notably by teaching basic skills such as multiplication or spelling, and do the job as well as the average teacher, says Moursund.

The military and the airline industry, he notes, both use computer simulations to train people for tough, high-stakes jobs such as distinguishing between incoming missiles and harmless radar-screen blips, and servicing jet aircraft. "With enough money, you can develop simulation that's quite good, nearly indistinguishable from the real thing," Moursund says. Similarly, software programs that tutor students in subjects such as arithmetic are customizable for any skill level and

Views Differ on Online Courses

Sixty percent of adults believe online courses do not offer the same educational value as a traditional classroom courses. More than half of college presidents say online courses are of equal value.

Does an online course provide an equal educational value compared with a course taken in person in a classroom?

(Percentage of college presidents)

	All adults	All presidents	4-year private	4-year public	2-year private/public	For profit
Yes	29%	51%	36%	50%	66%	54%
No	60%	48%	62%	48%	34%	45%
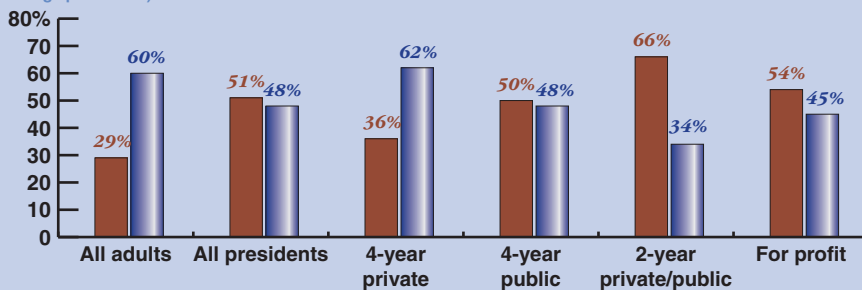
* Don't know/refused responses not shown.

Source: Paul Taylor, et al., "The Digital Revolution and Higher Education," Pew Internet & American Life Project, August 2011, pp. 11, 13, www.pewinternet.org/~/media//Files/Reports/2011/PIP-Online-Learning.pdf

thus uniquely helpful in schools, said John Danner, co-founder of Palo Alto, Calif.-based Rocketship Education, which operates a network of well-regarded K-5 charter schools in low-income Northern California communities. "When students learn things that are developmentally appropriate for where each of them are, they learn things much faster than if you teach to the middle," as classroom teachers typically must do, he said. [4]

Nevertheless, computers can never replace the human touch in elementary and high school classrooms, experts say. Teachers do what technology can't, "such as being a live person who cares about you," says Grover J. Whitehurst, director of the Brown Center on Education Policy at the Brookings Institution, a centrist think tank in Washington.

"Blended models" of schooling that combine computer-based learning with live classes seem to be emerging as the most common model, Whitehurst says. In fact, as computers increasingly take over routine tasks and the In-

ternet provides easy access to unlimited streams of information, demands for teachers to possess more sophisticated conceptual skills will increase, some analysts say. But education specialists worry that teachers aren't receiving adequate training to function in this new, digitally dominated world.

"The teacher of the future helps you navigate the ocean of information" that the online world provides, says Paulo Blikstein, an assistant professor of education at Stanford University and director of its Transformative Learning Technologies Lab. "I can go to Wikipedia to memorize historical figures' names, but I need somebody to talk with me about power relations" and other concepts, "to help me make sense" of the facts. Teachers will "need to know much more about learning how to learn, about how to help students make sense of these huge amounts of information, where you need to interpret what you see," Blikstein says. "But we're not training teachers to help with these things." [5]

Some digital-technology enthusiasts argue that computer games tailored for learning could be an education booster. But many education-technology scholars say that, so far, most games developed as teaching tools don't actually teach much. [6]

Learning claims for games such as the popular "Oregon Trail" — a simulation game developed in the 1970s to teach about pioneer life — are overblown and rest on the too-frequent misunderstanding that student motivation guarantees learning, says Kamil, at Stanford's School of Education. For players to learn from a game, winning and enjoying the game must both depend on whether the player learns something that the game intends to impart, he says. "If you watch a bunch of boys play "Oregon Trail" they spend all their time shooting deer," clearly enjoying themselves, but not accruing any history-related skills or knowledge.

Too many games can be won by using non-learning-related strategies such as repeated blind guessing, Kamil says. "They may get kids engaged, but they don't get them engaged in an actual learning task."

Nevertheless, some games do contain the seeds of very effective learning, but researchers are only just learning the principles that underlie such games, education-technology analysts say.

A game in which a player enters some virtual world and advances through it by solving challenges that involve uncovering the rules of the place offer the very highest form of learning, wrote James Gee, a professor of literacy studies at Arizona State University. A game in which a player solves a science mystery, for example, could be a much more fruitful learning experience than an ordinary biology course in which a student learns facts and repeats them on a test. In fact, "decades of research have shown that students taught under such a regime . . . cannot actually apply their knowledge to . . . understand the conceptual

lay of the land in the area they are learning," said Gee. [7]

By contrast, a computer game can closely approximate an activity such as practicing biology in real life, Gee wrote. "Biology is not a set of facts but a 'game' certain types of people 'play'" by doing certain activities, using particular tools and languages, holding certain principles and playing "by a certain set of 'rules,'" all activities that games players do in virtual game worlds. "Keep in mind that . . . 'Full Spectrum Warrior'" — a computer-simulation game about anti-guerrilla fighting — "is a game when I buy it off the rack but serious learning when a soldier 'plays' the professional training version," Gee wrote. [8]

As policymakers and schools struggle to keep up with ever-advancing digital technology, here are some of the questions that are being asked:

### Are computers in schools improving education?

Hopes have been high for decades that computer games, tutoring software and other digital technologies could make students more engaged and effective learners. But with many schools now coming online with high-speed Internet connections, the evidence on learning outcomes remains mixed.

For elementary-school students, decades of research demonstrate that "we can develop computer programs that teach kids to do more mundane things" — such as add, subtract and multiply — better than the average classroom teacher can, says Moursund of the University of Oregon.

Computers' strength as skills instructors lies partly in data-gathering and data-analysis abilities that humans can't match, says Moursund. For example, to learn to type on a keyboard, "a program can time how long you touch a key, tally mistakes, note your fast and slow fingers" and adjust the task in real time to provide additional exercise for an individual's weak spots. "A human
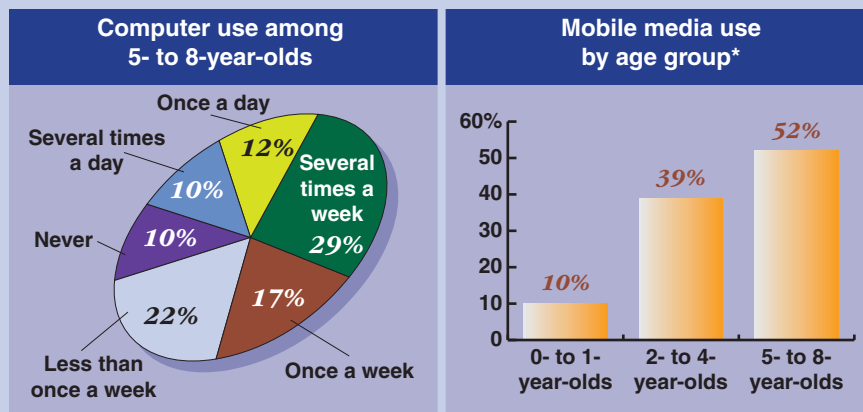
tutor can't possibly adjust so much" and thus is less efficient, he says.

"If you asked me to bet" on whether "picking an elementary teacher at random or a million-dollar piece of software" would produce better learning outcomes for "30 young kids learning an essential" basic skill such as adding or recognizing how different combinations of letters sound, "I'd pick the software," says Brookings' Whitehurst.

But technology is often put into classrooms with little technical support and thus is seldom as effective as it might be, says Paul Resta, director of the Learning Technology Center at the University of Texas, Austin. "If a teacher has technical problems [with operating a software program] more than once" and can't get a quick remedy from an information-tech specialist, which many schools don't have, "guess what's going to become of that software" after that? "I call it the dark-screen phenomenon."

Some research on computer-based learning initiatives shows small or no learning gains.

In a 2009 study for the Texas state government, analysts at a nonprofit research group found that a pilot project that "immersed" some high-need middle schools in technology by providing a wireless computer for every teacher and student increased participants' ability to use technology and modestly improved math scores, especially among higher-achieving students. But the technology didn't improve students' ability to direct their own learning, apparently worsened their school-attendance rates and had no apparent effect on reading-test scores. [9]

In the technology-intensive Kyrene School District in Chandler, Ariz., classrooms have numerous laptop computers with Internet access and interactive software that provide a wide variety of instructional opportunities: drills in every subject, individual-study programs and multimedia projects that help students create blogs and social-networking profiles for books they read in class. But according to one key benchmark — standardized

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Digital-Media Use Common Among Young

Fifty-one percent of 5- to 8-year-olds use computers at least several times a week. Only 10 percent have never used a computer (left). More than half of children 5 to 8 years old have used a smartphone, iPad or other kind of mobile device at least once (right).

Computer use among 5- to 8-year-olds

Once a day 12%
Several times a day 10%
Several times a week 29%
Never 10%
Once a week 17%
Less than once a week 22%

Mobile media use by age group*

0- to 1-year-olds 10%
2- to 4-year-olds 39%
5- to 8-year-olds 52%

* Percentages do not add to 100 because of rounding.

Source: "Zero to Eight: Children's Media Use in America," Common Sense Media, *Fall 2011, p. 9, www.commonsensemedia.org/sites/default/files/research/zeroto eightfinal2011.pdf*

'Virtual' Public Schools Gaining Students

Students excel in some but struggle in others.

Online K-12 schools are spreading across the country, but controversy is simmering over how well they perform and whether all students should be eligible to "attend" them.

As of 2010, at least 27 states had at least one entirely full-time, publicly funded online school, including high schools and schools serving pre-kindergarteners through 12th grade. While enrollment numbers are hard to find, researchers estimate that more than 150,000 K-12 students nationwide attended virtual schools full time in the 2009-2010 school year. [1]

Online-only schools originally were set up to accommodate students facing illness, pregnancy, bullying or some other issue, but they have since begun to accommodate those who, for whatever reason, wish not to attend a brick-and-mortar institution.

But about two dozen states prohibit students whose schooling is tax-supported from taking all their courses online and insist that publicly funded schools include some live instruction, according to researchers at the National Education Policy Center at the University of Colorado in Boulder.

The number of students taking online courses has soared at many state-run virtual schools. At the Florida Virtual School, established in 1997, attendance rose 39 percent in the 2009-2010 school year and another 22 percent in 2010-11. At New Mexico's IDEAL (Innovative Digital Education and Learning) school, established in 2008, the number of courses rose 37 percent in 2009-2010 and 85 percent in 2010-11. [2]

Some all-online schools are established by individual school districts and others by states. Some are available only to students living in certain school districts, while others are open to out-of-state students. Most, however, draw taxpayer funding according to much the same per-student formula used for traditional schools. Yet most virtual schools — though not all — are operated by private companies. [3]

While online schooling is a growing phenomenon, some researchers say it is not appropriate for students to attend virtual schools full time — that is, without taking at least some classes in a traditional classroom setting.

Online-only education provides a helpful haven for some, however, says James Lerman, director of the Progressive Science Initiative, a program at Kean University in Union, N.J., that helps experienced teachers become certified to teach math and science. For example, when the Florida Virtual School opened, "it was for kids who had problems going to regular school, such as being pregnant, having failed before, being disaffected or having to work," he says. For those students, he says, virtual schools may provide welcome shelter from a hostile climate they might face in a traditional school.

But whether large numbers of students would benefit from all-virtual education and whether online schools produce academic-achievement results equal to those of traditional schools remain in hot dispute.

test scores — the technology hasn't helped learning. Since 2005, the district's math and reading scores have remained stagnant, even as scores statewide have risen. [10]

The results baffle local school leaders. "My gut is telling me we've had growth. But we have to have some measure that is valid, and we don't have that," said Kyrene school Superintendent David K. Schauer. [11]

In a review of high school math programs that blend customized tutoring software with in-class lessons, both developed by researchers from Pittsburgh's Carnegie-Mellon University, the U.S. Department of Education found that the programs had "no discernible effect" on students' math-test scores. [12] The widely used and highly regarded "Cognitive Tutor" software,

developed by Pittsburgh-based Carnegie Learning Inc., a startup created by cognitive and computer scientists, also came up short in other federal analyses. Carnegie Learning was recently bought by Apollo Group Inc., the owners of the online, for-profit University of Phoenix. [13]

Can computers replace classroom teachers?

In search of budget savings, some public officials are touting online learning and so-called "blended" classes that use both computer-based and in-person instruction as potential means of saving money on teacher salaries. However, some technology experts say getting rid of teachers is a mistake. Instead, they say, school districts should be helping students navigate

the digital world by searching out the best learning technology and hiring more teachers who are well trained in using it.

Still, financial strains and demands for better performance by schools mean that schools must — and ultimately will — replace some teaching slots with digital technologies, says Christopher Dede, a Harvard University professor of learning technologies. A "perfect storm" of trends is driving toward that outcome, he says.

Because of "permanent" financial problems in K-12 education, Dede wrote, "student-teacher ratios are climbing to levels unworkable for even the best conventional instruction. We cannot solve this problem by the personal heroism of individual teachers," on whom schools have largely relied up

In a 2007 study of both full- and part-time online students, the nonpartisan Florida TaxWatch research group found that Florida Virtual School students "consistently outperformed their public school counterparts" on reading and math in state achievement tests. The school earned "high marks" for both student achievement and cost-effectiveness, said the group. [4]

Studies in some other states have found problems, though.

A 2011 study of Pennsylvania's virtual schools by Stanford University's Center for Research on Education Outcomes (CREDO) found that in both reading and math achievement students at all eight online schools performed "significantly worse" than their counterparts at brick-and-mortar institutions. [5]

In a 2006 audit of online schools in Colorado, state analysts found that "in the aggregate, online students performed poorly" on state achievement exams, were "about four to six times more likely to repeat a grade than students statewide" and had a dropout rate between three and six times higher than the statewide rate. [6]

High dropout rates — in the range of 50 percent or greater — are common among online schools, but that's not surprising, says Paul Kim, chief technology officer of Stanford University's School of Education. "Why? They joined the online school because they hated regular school, and the online school turned out to be just like it" in stressing standardized testing and rote memorization, for example, he says.

In addition, while teachers in virtual schools communicate individually with students via email, chat programs and other Internet-based modes, in general "online schools don't give students the support they need" to learn from computer-based material on their own, Kim says. Unlike students in traditional schools, those who learn online must pace themselves through their studies. And to succeed, they need skills of "self-regulation and self-assessment," he says. "A lot of this is not supported in the online school."

— Marcia Clemmitt

[1] Gene V. Glass and Kevin G. Welner, "Online K-12 Schooling in the U.S.: Uncertain Private Ventures in Need of Public Regulation," National Education Policy Center, University of Colorado Boulder, October 2011, http://nepc.colorado.edu/files/NEPC-VirtSchool-1-PB-Glass-Welner.pdf.

[2] "Keeping Pace with K-12 Online Learning: An Annual Review of Policy and Practice," Evergreen Education Group, 2011, p. 30, http://kpk12.com/cms/wp-content/uploads/EEG_KeepingPace2011-lr.pdf.

[3] *Ibid.* See also Glass and Welner, *op. cit.*

[4] "Final Report: A Comprehensive Assessment of Florida Virtual School," Florida TaxWatch, www.inacol.org/research/docs/FLVS_Final_Final_Report%2810-15-07%29.pdf.

[5] "Charter School Performance in Pennsylvania," CREDO, Stanford University, April 2011, http://credo.stanford.edu/reports/PA%20State%20Report_20110404_FINAL.pdf.

[6] "Online Education/Department of Education Performance Audit," State Auditor, State of Colorado, November 2006, www.cde.state.co.us/onlinelearning/download/2006%20Report%20of%20the%20State%20Auditor.pdf.

to now to succeed in difficult conditions. Instead, Dede added, administrators "must find technology-based strategies effective for classroom teaching and learning with large numbers of pupils." [14]

But, he adds, so far few technologies have been up to the task. While many computer-based learning programs require well-trained, intensely committed teachers to be effective, "large-scale educational improvement requires more," Dede wrote. He urged education researchers to double their efforts to create learning technologies that will work even in the worst of circumstances, including in schools with scant resources and many ill-prepared teachers, since those are conditions many students face. [15]

Experience outside of education

proves this is achievable, Dede wrote. "All other professions are successfully transforming to affordable models that use technology to empower typical professionals to be effective," so there's no reason technology can't be developed to help average teachers spur strong student learning, too, he wrote. [16]

"We may be at a transition point" at which "we can offload some teachers' responsibilities" onto software, to free teachers to do other tasks, such as working with students on special projects, says Brookings' Whitehurst. At least a few college-level institutions, notably the private, nonprofit Salt Lake City-based Western Governors University, seem to have mastered the knack of delivering low-cost computer-based education that works, so there seems no reason that good technology-based

approaches can't be developed for K-12 as well, he says.

Demands to improve student learning — perhaps using technology — fall heaviest on the lowest-performing schools, most of which enroll many disadvantaged students. Yet, in these schools it's particularly unlikely that technology could replace staff, says Stanford's Blikstein. "This is the critical part of the story. These kids need so much help to be brought up to speed. I don't think this kind of technology could replace a teacher."

At the college level, where computer-based courses have taken a stronger hold, nearly 64 percent of public-university faculty who have taught both online and traditional courses said in a 2009 survey that it took "somewhat more" or "a lot more" effort to teach online than

Selective Schools Offer Fewest Online Courses

Eighty-two percent of community college presidents say their institutions offer online courses, slightly more than their counterparts at research universities and noticeably more than presidents at liberal arts colleges. Similarly, 86 percent of presidents at the least selective schools say they have online classes, more than those at more selective institutions. Education experts say online offerings vary depending on the educational mission of each school.

Percentages of Colleges Offering Online Classes
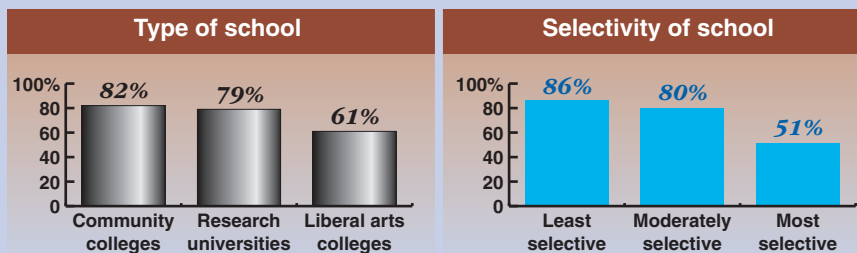
Source: Paul Taylor, et al., "The Digital Revolution and Higher Education," Pew Internet & American Life Project, August 2011, p. 6, www.pewinternet.org/~/media//Files/Reports/2011/PIP-Online-Learning.pdf

in person. Nearly 85 percent said it takes more effort to develop online courses than regular ones. [17]

Making good use of digital technology requires substantial change in how teachers view their roles. "It comes back to authority and control," says Christine Greenhow, an assistant professor in the School of Education and Information Studies at the University of Maryland, College Park. "If you see your job as pouring knowledge into the minds of students who are empty vessels," that doesn't mesh with the technology revolution, she says. Today's students have cell phones, laptops and other devices on which they can research anything and everything on their own, she says.

Eventually, computer-teaching systems will diagnose students' learning problems on the spot, based on data collected from the students' interaction with the software, then design appropriate interventions. Those interventions might include calling for a live teacher, many of whom, in the future, may act more like "coaches" who address particular problems that learning software has identified, predicts Paul Kim, chief technology officer at Stanford's School of Education.

Tomorrow's teachers will have to both tailor instruction more individually and deal with deeper, more conceptual learning, many analysts say. For example, "one challenge, especially at upper grade levels, is to come up with questions for which Wikipedia won't supply good answers," says Stanford education Professor Daniel Schwartz.

Within a few decades, teachers may be sharply divided into an elite class of professionals who are savvy at both technology and teaching and a second, less-prestigious group who act more or less as babysitters, managing students in classrooms, wrote Whitehurst. A teacher will be "either . . . an expert on the design and delivery of instruction through technology or . . . the equivalent of a hall monitor or a tutor for struggling students, with commensurate salaries." [18]

Are computer games effective for learning?

From computer games' earliest development, in the 1950s and '60s, it was clear that they motivated players to commit time and energy to conquering their challenges to a degree that school lessons seldom do. This discovery, together with computers' ability to hold massive amounts of text, pictures and sound, encouraged development of games especially tailored for learning. However, not every game that has academic content and motivates students to play it actually provides a learning experience, some scholars say.

In many current games, players, alone or in groups, enter virtual worlds — such as Yellowstone National Park, in the game "WolfQuest" — or real-world sites that they visit while accessing added digital information about the place via technology such as smartphones. The idea is to explore the real or virtual place and solve problems there, explains a new report on games and learning by the National Research Council (NRC), a federal agency staffed by scholarly researchers. [19] In the well-regarded game "River City," developed by Harvard's Dede, for example, players explore a highly detailed simulation of a 19th-century American city to uncover and solve a public-health crisis. [20]

The NRC said games that challenge students to solve complicated problems in rule-based virtual worlds have the potential to kick-start the kind of inquiry- and project-based scientific learning that many education theorists have sought for decades. Such games can help students "visualize, explore and formulate scientific explanations for scientific phenomena" that they wouldn't otherwise be able to observe and manipulate, the NRC said. The games also tend to "spark high levels of engagement, encourage repetition and practice and motivate learners with challenges and rapid feedback," it said. [21]

Still, many researchers say they're less interested in figuring out how to

increase the supply of educational computer games than in discovering the principles that fuel enthusiasm and hard work by students.

"I don't think we should make school into a game," says Barry Fishman, an associate professor of learning technologies at the University of Michigan. "My objective is to find out why people work so hard at games" and then figure out how the same principles might be applied to many kinds of learning situations.

Hoping to find out why his 6-year-old son enjoyed computer games so much, Gee says he "failed many times" at the first game he tried, one he picked randomly from a store shelf: "The New Adventures of the Time Machine." He says he "had to engage in a virtual research project via the Internet to learn some things I needed to know" to play. Gee grew amazed that "lots of young people pay lots of money" to get this difficult experience and "realized that this was just the problem our schools face: How do you get someone to learn something long, hard and complex and yet enjoy it?" [22]

Research is revealing underlying principles of effective learning games, says Eric Klopfer, an associate professor of education at the Massachusetts Institute of Technology (MIT). Such games allow for many different solutions to the problems and questions they pose; encourage both collaboration with other players and independent action on the part of players; set up novel problems for players to solve and provide feedback to help players advance, he says. A compelling narrative and characters to identify with also are important, he says.

But many games don't operate on those principles, and some don't teach much, or anything, of value, critics say.

"In trivial games, you solve a problem and then get a reward," but the learning and the other aspects of the game aren't connected, so that the game only provides some traditional

Defining Online Learning

Traditional academic courses typically use no online technology and deliver content through face-to-face interactions between instructors and students. In contrast, online courses deliver at least 80 percent of content through the Internet. Other courses may use the Internet to complement traditional in-person meetings.

How Different Types of Courses Use Online Technology

Proportion of content delivered online	Course type	Description
0%	Traditional	No online technology used. Content is delivered orally or in writing.
1%-29%	Web facilitated	Uses Web-based technology to facilitate face-to-face interactions. Often uses course-management system or Web pages to post syllabi and assignments.
30%-79%	Blended/ hybrid	Substantial portion of content delivered online. Typically uses online discussions and has a reduced number of in-person meetings.
80+%	Online	Most content is delivered online; course typically lacks face-to-face meetings.

Source: I. Elaine Allen and Jeff Seaman, "Class Differences: Online Education in the United States, 2010," Sloan Consortium, November 2010, p. 5, sloan consortium.org/publications/survey/pdf/class_differences.pdf

drill-type instruction rather than deep learning, says Klopfer. In the popular "MathBlaster" game, for example, players earn opportunities to participate in an outer-space adventure video game by giving the right answers to math questions, but the questions aren't conceptually connected to the game's story.

Adding elements of play or contest to all learning activities, including rote memorization, is what some education theorists call for when they suggest "gamifying everything." But that's a shallow use of game principles and an approach that may even be inferior to more traditional educational methods, Klopfer suggests.

In fact, not all researchers find that games are useful at motivating and engaging students. In a 2007 study based on student surveys and interviews, Nicola Whitton, a research fellow in educational-games technology at Manchester Metropolitan University in England, found that "a large proportion" of students "do not find games motivational at all" and that "there is no evidence of a relationship between an individual's motivation to play games recreationally and his or her motivation to use games for learning." [23]

Serious attempts to develop highly effective learning games are in their infancy, experts say.

One barrier is that "gamers and educators are very different cultures, and you need to get them together" to have a real shot at figuring out how the principles of the two disciplines may intersect, says Stanford's Schwartz. The two sides often resist such cross-disciplinary discussions, he says.

Furthermore, the effectiveness of any education technology, including games, "depends on a combination of the technology and the context in which it's delivered," which includes school and classroom conditions, teacher skills and more, says MIT's Klopfer. Generally, for a game to succeed as a learning tool, a teacher or a community of people must be available to support and help players navigate it, he says.

Currently, teachers often don't use games to optimize learning and in many cases aren't equipped to do so, the NRC said. In the "River City" game, for example, players are supposed to explore the town, then formulate and test original hypotheses about what's causing disease there. But "some teachers have asked students to use the curriculum to simply confirm correct answers that the teachers provided in advance," essentially canceling out the opportunity for intellectual initiative, the NRC said. Behind teachers' misuse of the game lie lack of time, pressure to prepare for high-stakes standardized tests and a lack of the "deep-content knowledge and effective teaching strategies" suitable for inquiry-based learning, the group said. [24]

BACKGROUND

A Digital World

The Information Age is only decades old. But many scholars argue that, eventually, digital technology will change everything, including concepts

Mike Kerr, principal of the KIPP Empower Academy in Los Angeles, said kindergarteners participated in an experiment last year with "blended learning," which uses both computers and classroom teachers. Results from the trial year were so promising that school administrators decided to continue using computers in kindergarten. The charter school serves minority and low-income students in impoverished south Los Angeles.

Getty Images/McClatchy Tribune/Jonathan Alcorn

of learning, as surely as the greatest upheavals in history have done. [25]

"We can liken this age to the age of the invention of the printing press, and I don't think that's an exaggeration," says Kean University's Lerman.

Especially in these early days, however, "there's more than one way things can change," he says.

Technology can be employed to "do old things in new ways," Lerman says. For example, he says, teachers can learn to give more effective lectures, and students can learn from master teachers they'll never meet if outstanding lectures are archived on YouTube. However, digital technology also can encourage "doing new things" to transform education into the student-driven, lifelong enterprise that many scholars see as the wave of the future, Lerman says.

Experts say that many characteristics of the Information Age will transform schools and learning, and each raises important questions about the future of education.

For example, "in the Age of Information, everything can be customized, and the last frontier is education," says Stanford's Blikstein. One need only pick up an American pre-calculus, biology or history textbook to see that the number of possible subjects of study is huge and beyond the ability of any one student or class to cover, even within a single discipline. Rather than trying to cram in as many as possible, as schools tend to do today, future schools with extensive access to online and other computer-learning technologies can allow students to pursue subjects of special interest. "Apart from the very basic things" — such as reading and basic math — "you should learn things that relate to your life and community," with one student studying trigonometry

Chronology

1960s *More schools have computers, but most are used for record-keeping, other administrative purposes.*

1963
Vocational Education Act provides funds for school technology. . . . Two Dartmouth College scholars create the simple BASIC programming language, mainly for student use. . . . Scientists at IBM and Stanford University develop programmed-learning materials for grade-school math and reading.

1966
IBM introduces computer adapted to run instructional programs.

1967
MIT scientist Seymour Papert invents LOGO drawing language to expand programming and logic training in grade schools.

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1970s-1980s
More schools adopt tutoring software and require programming classes; firms begin selling educational software.

1974
"Oregon Trail" computer game, designed to teach about pioneer life, is introduced.

1975
Twenty-three percent of schools use computers in the classroom.

1984
Apple's Macintosh computer is introduced and quickly gains popularity, especially in elementary schools.

1987
Students in National Geographic's KidsNet program collect local data on acid rain and water pollution and email their findings to schools and scientists around the country.

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1990s *Schools use CD-ROMs, videodiscs and the Web to provide multimedia materials.*

1991
Students in 72 countries participate in KidsNet.

1994
President Bill Clinton's Education secretary, Richard Riley, convenes first White House conference on expanding computer-based education.

1996
Telecommunications Act of 1996 requires telecom companies to discount their services for schools.

1997
Florida Virtual School, the first state online school, is founded.

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2000s *Enrollment in computer-science and programming classes drops, but school social-media use expands.*

2000
Maine Gov. Angus King, an Independent, announces that the state will provide laptops to all middle-school students and for teacher training in computer-based education.

2005
MIT architecture Professor Nicholas Negroponte forms One Laptop Per Child program to develop low-cost computers for distribution to children in developing countries and other low-income areas.

2007
MIT developers introduce online Scratch community as an after-school hobby destination, where children and teens can create games and multimedia using the Scratch programming language. . . . First One Laptop Per Child computers go to children in Uruguay, Peru and Birmingham, Ala. . . . College computer-science enrollment drops to half its 2000 level.

2009
College Board drops one of its two Advanced Placement tests in computer science.

2010
With online-course enrollments reportedly growing 30 percent per year, Wyoming appoints its first state director of distance learning. . . . San Francisco Flex Schools open as California's first public schools to offer a blend of traditional and online courses. . . . Connecticut authorizes online courses to fulfill high school graduation requirements.

2011
New Florida law allows charter schools and individual school districts to offer online instruction and permits elementary-school students to study full time at Florida Virtual School. . . . Idaho becomes first state to require students to complete two or more online courses as a graduation requirement. . . . Computer Science Education Act introduced in the House and Senate to bring more programming and computer-problem-solving classes to K-12 schools. . . . New York City announces new investments in school technology while laying off teachers and canceling school construction projects. . . . Young Scratch hobbyists have posted more than 2 million media projects online.

Big Hurdles Confront Learning-Technology Developers

"You can't just have big companies, or you'll have no revolution."

Good digital tools can improve learning, but the system for developing them is riddled with pitfalls, technology analysts say.

For one thing, creating effective educational technology takes time, but software and hardware can become obsolete nearly overnight, says Michael L. Kamil, a professor emeritus at the Stanford University School of Education. Technology's short shelf life has doomed numerous projects, he says.

"We developed a game for Nintendo" that became useless when a new version of the popular device hit the market, Kamil says. Glitches in new technology often can be fixed, but that usually entails delays and more financing, which education researchers may not have, he says.

In some cases, fast-moving technology has doomed educational materials irrecoverably. In the mid-1990s, for example, many CD-ROMs were developed based on solid educational principles. But as content migrated to the Internet, CD-ROMs "were quickly left behind, and you couldn't fix them" for use as online media, Kamil says.

The size and clout of a developer also play a big role in a technology's success or failure. Digital technology developed by small companies and academic researchers may be suitable and effective in the classroom, but it can have a hard time competing with products offered by large companies. Giants like Dell and Apple have successfully placed digital technologies in schools because they are adept at doing business in the fast-moving technology world and generally don't delay product rollout to test its educational effectiveness, says Barry Fishman, an associate professor of learning technologies at the University of Michigan.

"I don't fault Dell or Apple. Their job is to sell," he says. But "some things widely sold to schools are adapted from the [corporate] board room," and aren't necessarily very helpful to schools, he says.

A case in point is the expensive digital whiteboard that displays, records and stores information and graphics and has replaced traditional whiteboards in many schools, Fishman says. "Only about 5 percent of teachers are doing anything interesting with them," making their high cost largely a waste, he says.

Evaluation standards pose another challenge. The U.S. Department of Education analyzes learning technologies and posts on its "What Works" website conclusions about whether and how well they work. But the standards for evaluation, which are borrowed from medical research, don't give technologies a fair shake, many researchers say.

Steven M. Ross, director of Johns Hopkins University's Center for Research and Reform in Education, says the "clinical-trial" evaluation model, used to gauge whether a particular technology is effective in the classroom, is problematic. The model demands that a learning methodology produce better results than traditional instructional methods before it can be deemed a success. But that standard is unreasonable for computer-based learning tools, Ross says.

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and another studying statistics, for example, Blikstein says.

Furthermore, with digital devices ubiquitous, "we're emerging into the era of student as content creator," says Lerman. "That has profound implications for almost everything we do in schools." How, he asks, does one assess learning when students create their own projects? What, Lerman continues, is the role of a teacher, if not as the sole "expert dispenser of validated knowledge?"

As much of the world's information moves online, learning facts becomes less important than knowing how to find and use them. "Should we require students to regurgitate facts they've assimilated from classes, or should we allow students to access on a test any information they want" and use it to analyze a problem and propose a solution? asks Lerman. "In business, we'd call that collaboration. In school, we call it cheating."

Tutor, Tool, Tutee

Electronic computers were invented in the early 1940s and used as early as 1943 for a wartime educational purpose — as flight simulators whose mock aircraft "controls" responded to pilots' actions the same way controls on real planes did. In the 1960s computers entered K-12 classrooms after software was developed to lead students step-by-step through a process such as long division.

Soon the number of computers in schools began rising. In 1963, just 1 percent of high schools used computers for instruction. By 1975, 55 percent had computers, though only 23 percent used them primarily for learning. The rest used them for administrative purposes. [26]

Robert P. Taylor, a professor at Columbia University Teachers College in New York City, identified three ways computers can aid learning. [27]

First, step-by-step instructional software can "tutor" students in some subjects. In 1963, computer giant IBM partnered with Stanford's Institute for Mathematical Studies in the Social Sciences to develop programmed-learning software for elementary schools, jointly created by computer scientists and learning experts. In 1966, IBM introduced its Model 1500 computer, especially designed to run instructional programming.

"If you use technology in a tutorial program and the kids do just as well" as they do with a live tutor or teacher, he says, "then the technology is freeing up a teacher" to undertake other teaching tasks that only a human can perform. That, he says, means the technology is a useful addition to a schools' repertoire of learning strategies.

Money is yet another challenge for educational-technology creators. The research and development needed to produce a good piece of educational software can cost millions of dollars, notes Grover J. Whitehurst, director of the Brown Center on Education Policy at the Brookings Institution, a centrist think tank in Washington. "Where do you get the venture capital" to support it? he asks. Would-be investors are hesitant because they know schools may not buy "if they have to spend $500 a student," Whitehurst says. The federal government could bolster technology development by "providing a guaranteed market," such as the worldwide network of schools that serve children of Defense Department personnel, for some products, he suggests.

Then there is a real, although largely unintended, bias toward big software developers. The Department of Education generally throws out the findings of small research studies on learning technologies on the grounds that they don't provide enough evidence to warrant a conclusion, says Daniel Schwartz, a Stanford University professor of education. But the only developers who can pay for "the big clinical trials" that the department considers gold-standard evidence are the "big, established, heavily capitalized companies," he says.

"The big question is, how do you make it possible to disseminate and test" educational technology so that small players with innovative ideas can gather sufficient data on their products, Schwartz says. "You can't just have big companies, or you'll have no revolution, just bookkeeping."

Schwartz envisions a "continual-improvement" system in which the government establishes an infrastructure to help academic researchers test their technologies-in-development in a few schools. Because digital products such as learning software can be continuously tinkered with, "I can put something out and keep collecting data over time about how it works" and mine user feedback for problems and suggested changes, Schwartz says. "Teachers could post commentaries on how things work" and how to use them, he says.

Perhaps the biggest barrier to developing innovative technology is the current student-assessment system, which relies on standardized tests that mainly gauge rote-memorization skills, many researchers say. "What gets tested is what gets taught," says James Lerman, director of the Progressive Science Initiative, a program at Kean University in Union, N.J., that helps experienced teachers become certified to teach math and science. With testing focused on old-fashioned rote learning and ignoring technology use altogether, Lerman and others say, the chances that innovative digital-learning tools will be developed and widely used are greatly diminished.

— Marcia Clemmitt

The computer had unusual-for-the-time features such as audio capability and a "light pen" that allowed users to write on the computer screen.

Second, Taylor wrote, a computer can serve as a tool, such as a calculator or word processor. In fact, he said, outside of schools, "tool-mode computing is popularly seen as synonymous with computer use, period." [28] (Nevertheless, schools often have ignored the potential usefulness of digital tools such as database and spreadsheet software for homework and vocational training, instead expecting students to learn such programs on their own, says Stanford's Kamil.)

Finally, Taylor wrote, a student can learn to program a computer to do new tasks, effectively acting as the machine's "tutor."

"Because you can't teach what you don't understand, the human tutor" — the programmer — "will learn what he or she is trying to teach the computer," wrote Taylor. Furthermore, "learners gain new insights into their own thinking through learning to program." [29]

This argument — that students should learn the inner workings of computers and learn to "teach," or program them — proved persuasive. In the 1970s and '80s, many schools installed computer labs and required every high school student to take a programming course, the aim being to teach thinking skills and prepare young people for computer-science careers.

Special programming languages were developed for beginners. Many high school courses used BASIC, invented in

1964, which featured short programs and simple-to-understand error messages. In the early days, the classes seemed successful. Student programmers have "taught" computers to "tutor younger students in arithmetic operations, to drill students on French verb endings, to play Monopoly, to calculate loan interest, . . . draw maps" and "to generate animated pictures," Taylor wrote in 1980. [30]

LOGO, a language created in 1967 to extend the supposed benefits of programming to elementary-school students, allowed students to move a cursor — called a "Turtle" — around a screen to draw simple pictures.

A child gradually learns the different programming commands — expressed in words and numbers typed on a keyboard — that move the Turtle around

Technology Opens New Doors to Learning

Scholars say "transformative ideas" could bolster student engagement.

The digital revolution, with its staggering number of inexpensive new tools and capabilities, eventually will change the way students learn, many education scholars say.

Handheld GPS-equipped cell phones can enhance science or history field trips and more, says Barry Fishman, an associate professor of learning technologies at the University of Michigan. Teachers can set up applications — or "apps" — that allow students' phones to point out interesting information or pose puzzles to be solved at certain locations. For example, University of Michigan undergraduates have been introduced to the school's complex library system via such interactive walk-throughs. "That's a possibly transformative idea" that could "lead to more student engagement," Fishman says.

Websites' multimedia features can help students travel virtually around the globe by posting live and archived videos, photographs, sound recordings, text, chat logs and more, and inviting visitors to interact with the material and each other, says Aaron Doering, an associate professor of curriculum and instruction at the University of Minnesota. Through his "adventure learning" website, Go North! (www.polarhusky.com), students can follow along as he and a team of environmental researchers explore oil drilling and global warming in the Canadian Arctic, in real time and in archives. "What brings people back is that there is a narrative" of the journey "that individuals can connect to. We feed the students all the media and interviews we do."

The Web allows everybody, including kids, to publish their work and find an audience, so students can share their own scientific adventures, says Doering. In a new project, he's encouraging classes to document local environmental conditions and share them in what could become a student-generated knowledge map of large geographical regions. Students in New Orleans, for example, document with photos and videos what's happening with frogs in the Mississippi River near their homes and share their observations with students 1,000 miles north in Minnesota who are studying their local stretch of the Mississippi, Doering says.

Digital devices drastically lower the cost of taking scientific measurements, and computers make once-formidable data analysis easy, says Paulo Blikstein, an assistant professor of education at Stanford University and director of its Transformative Learning Technologies Lab. Today, a $50 science-lab setup can include data loggers — digital devices that can record physical measurements such as temperature, humidity, light intensity or voltage and upload them to a computer, where the data can be put into visual form, graphed and analyzed mathematically. The low price and ability to analyze data without having advanced math skills put deep science concepts within reach of high-school-age and even younger students, Blikstein says.

By showing who's connected to whom, social media can give students a "sense of being connected to a larger network and to the world" and encourage them to link their learning with real-world action, says Christine Greenhow, an assistant professor in the Schools of Education and Information Studies at the University of Maryland, College Park. When studying a topic such as global warming, for example, Web-connected students find ways of connecting with stakeholders, policymakers and other interested citizens. Such work can increase students' engagement with their academic studies and also increase their civic engagement, she says.

Computer software that collects detailed information about exactly how a student behaves when taking a test or working math problems can help pinpoint the kind of help the student needs, says Daniel Schwartz, a Stanford education professor. It's always been one of the toughest nuts for schools to crack, Schwartz says.

"A kid's taking a test and fails. Now what? What do you do? There are a million possible reasons why he may be getting things wrong," each calling for a different remedial strategy, Schwartz says. "Does he have a misconception" about the subject? "Does he not persevere" in problem-solving? "If you can find out exactly what the student's process is" — when he hesitated, moved through a question too fast, changed an answer and so on — the information provides the clues to help him improve. Digital sensing, data collection and data analysis to reveal subtle behavior patterns are exactly what computers do well — and humans can't do at all, Schwartz says.

— Marcia Clemmitt

the screen to draw a picture, wrote LOGO inventor Seymour Papert, an MIT mathematician. The challenge of drawing on the screen by typing out a series of programming commands "is engaging enough to carry children through" the lengthy process of ferreting out how to write LOGO programs to create any design that they envision, said Papert. [31]

Ultimately, the process "can change the way they learn everything," by encouraging habits such as exploring new situations to figure out the rules by which they operate and accepting mistakes as inevitable consequences of exploration that are correctable with patience and logic, Papert said. [32]

Research has failed, however, to pro- duce evidence that problem-solving skills used in programming classes transfer to other types of learning or even to later programming work, wrote Roy D. Pea, director of Stanford's Center for Innovations in Learning. Children who studied programming engaged in "very little preplanning" when they worked on new programs, he said. Rather than using

logic to "debug" nonworking programs — as programming classes teach — they usually just erased them and started over from scratch, Pea reported. "Transfer of problem-solving strategies between dissimilar problems" proved "notoriously difficult . . . even for adults." [33]

By the 1990s, enthusiasm for teaching programming to students all but died out for a "whole host of reasons," says Yasmin B. Kafai, a professor of learning and technology at the University of Pennsylvania's Graduate School of Education.

For one thing, most schools "had not integrated programming into the rest of the curriculum," leaving it without obvious applications to other activities, Kafai says. Then, beginning around 1990, multimedia CD-ROMS provided a more immediately attractive use for computers, with games to play and videos to view.

Many teachers weren't up to the task of teaching programming adequately, says Oregon's Moursund. When training teachers to teach LOGO, Moursund says he found that "many had no insight into problem solving" and thus couldn't teach students the deeper thinking skills that programming could impart.

Proponents of getting students to program didn't give up, however. In the 1990s and 2000s, new languages for beginners emerged. Perhaps the most prominent is Scratch, a free online Web community designed to teach programming concepts by letting users create and post online videos, music, graphics and computer games. Scratch's developers, which include the National Science Foundation and MIT, aimed to make the language a favorite hobby rather than a school subject. [34]

"Kids only spend 18 percent of their waking hours in school, so there's lots of time outside that can be leveraged," says Kafai, a Scratch developer and researcher. In the past, students had no access to programming resources except through schools, "but now the situation has flipped. Every child has a smart-

Growth in Online Courses Predicted

The presidents of four-year public colleges expect nearly half of their undergraduate students to be taking an online course in 10 years, up from only 14 percent now. Two-thirds of presidents at two-year colleges and 54 percent at for-profit colleges predict that more than half their students will be taking online courses in 10 years.

Percent of College Presidents Saying Undergraduate Students Are Taking or Will Be Taking an Online Class
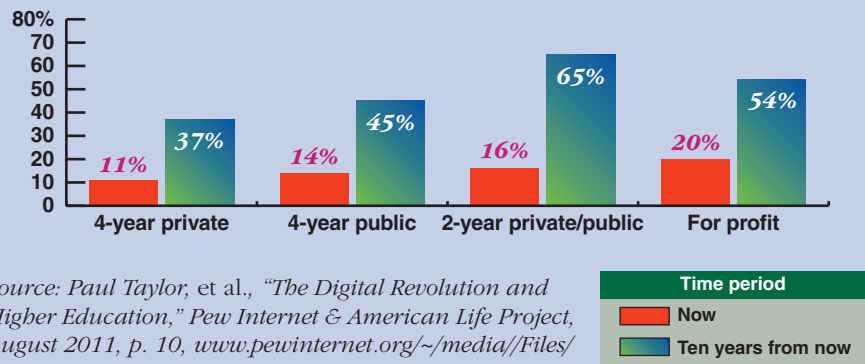
Source: Paul Taylor, et al., "The Digital Revolution and Higher Education," Pew Internet & American Life Project, August 2011, p. 10, www.pewinternet.org/~/media//Files/Reports/2011/PIP-Online-Learning.pdf

phone" that can be used to program. As of October, the website had 921,785 registered members, 270,318 of whom had created more than 2.1 million projects. [35]

After enrollment surged in the 1980s and '90s, the percentage of high schools offering elective introductory courses in computer science dropped from 78 percent to 65 percent between 2005 and 2009. During the same period the percentage offering Advanced Placement (AP) courses also declined, from 40 to 27 percent. [36] The College Board, which had offered two levels of computer-science exams, ended its more advanced AP exam after the May 2009 tests. [37]

College computer-science enrollment also fell, from a record per-department average of 100 newly enrolled students in 2000 to 50 by 2007. [38]

Enrollments have remained "in a trough" in recent years, says Joan Peckham, a professor of computer science at the University of Rhode Island, in Kingston. Part of the problem is image. "Research finds that students have a very poor image of computing" as "boring"

and "full of these nerdy people facing a screen all day," she says. There's a lot to lose should interest remain low, Peckham says. "We have a technical and an interdisciplinary world" in which virtually every profession depends on sophisticated computer applications.

Connected Computers

Perhaps the heaviest blow to programming came from the Internet. As schools gained online access, networked computers' potential to serve as tools of hitherto unimagined power for accessing information and communicating quickly outpaced other computer uses. Internet-connected learning provides a tantalizing glimpse of the world of personalized study that many scholars say the Information Age will ultimately bring.

The Internet allows students and teachers to try out different ways of learning, something that was hard to do when every learning methodology

was available only as a pricey textbook or software purchase, says Stanford's Schwartz. For example, the Kahn Academy offers a large number of short lectures posted on YouTube on such subjects as solving quadratic equations and learning the parts of a cell. MIT graduate Salman Kahn's videos are "a good example of stuff that's easy to use" and that multiplies learning options cheaply, Schwartz says.

Original documents, maps, archived film footage and interviews with people involved in historical events began appearing online in the past 15 years, providing opportunities for more in-depth, self-directed learning, says Resta of the University of Texas. For example, with primary sources online, "you can have kids actually practice historical thinking" by using original sources to construct their own versions of how and why some historical events happened, he says.

As the Internet has provided learning opportunities, it has increased pressure on schools to provide Internet-connected devices.

"An infrastructure for learning should support learning in and out of the classroom," and thus an effective, modern education system should find a way to supply students and educators with Internet-access devices for around-the-clock use, said the federal government's most recent national education-technology plan, issued in 2010. [39] Some school districts and one state, Maine, as well as countries such as Uruguay and Peru, have implemented one-digital-device-per-student programs, typically dispensing laptop computers to students in some grades.

Maine debuted the biggest U.S. program in 2002, placing a laptop into the hands of every middle-school student. The program didn't mandate specific uses but provided training for teachers to help them integrate the computers into the curriculum. "If you just drop the computers on the kids' desks, it won't work," said Gov. Angus

King, an Independent. "It's a fundamentally different way of teaching. It's not standing up in front of the classroom lecturing." [40]

Research on one-child, one-device programs supports King's contention, scholars say.

Few studies show that laptop programs raise standardized-test scores significantly. However, "greater quantity and improved quality of writing; more teacher and peer feedback on student work; wider opportunities to access information from a wide variety of sources; and deeper exploration of topics through in-depth research" are demonstrated outcomes of programs that are integrated into the curriculum, according to Mark Warschauer, a professor of education and informatics at the University of California, Irvine. [41]

Some studies do show test-score improvement. For example, between 2000 and 2005 the percentage of Maine's eighth-graders who met the state's proficiency standard for writing rose from 29.1 percent to 41.4 percent, and classes that used laptops for drafting and editing outperformed those that didn't. [42]

Other one-child, one-device programs operate on the principle that ownership of computers is enough by itself to improve learning. "When every child has a connected laptop, limits are erased as they can learn to work with others around the world, to access high-quality, modern materials, to engage their passions and develop their expertise," according to the Cambridge, Mass.-based One Laptop Per Child Foundation, which distributes laptops free to children in developing countries. [43]

But research fails to back up that contention, some scholars contend.

In Birmingham, Ala., researchers found that two years into a program that gave students computers but didn't formally integrate them into curricula, only 20 percent used the laptops "a lot" in class, while 60 percent

used them "a little" and 20 percent said they never used them. [44]

In Uruguay, which received laptops from the foundation in 2007, "only about 25 percent of the kids are bringing them to class," says Kim, at Stanford's School of Education. He cites the limited use as evidence that before students can be motivated to use free laptops in class, educators must actively engage them in projects that encourage them to do their own Internet research.

In the past few years, as cell phones have aqcuired as much memory as computers, some schools have been flirting with the notion of bring-your-own-technology programs. Such initiatives generally allow students to use their own devices — usually smartphones — in class while allowing students who don't own Internet technology to borrow devices that belong to the school. In a survey of school administrators in the fall of 2010, nearly two-thirds said they were unlikely to allow students to use their own mobile devices in class. However, just under a quarter said they were likely to do so. [45]

Using bring-your-own-technology programs to save schools money and encourage student engagement raises fears, however. Besides worrying about unfairness to students who don't own high-tech phones, administrators see murky areas of legal liability if students access inappropriate Web pages, cheat or disrupt classes using their own equipment. [46]

"You can see the tension as some schools say, 'We have to ban personal cell phones in class,' " says Kean University's Lerman. But many young phone owners are discovering phones' productive capabilities, doing "unbelievable things," he says. "Some have written novels." Schools should encourage such innovations, not ban them, he says. ∎

At Issue:

Should schools use as much digital technology as they can afford?

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WRITTEN FOR *CQ RESEARCHER*, DECEMBER 2011

*d*espite persistent budget dilemmas and constraints, this is no time to ban, control, limit or passively ignore possible uses of technology in teaching and learning. Instead, it should be an age filled with heavy doses of learning-technology experimentation and creative initiatives. With proper planning, discussion and evaluation, there is much that technology dollars can afford, even for the smallest or most impoverished school or district.

A couple of years ago, I authored the book *The World Is Open: How Web Technology Is Revolutionizing Education*. In it, I detailed many free and openly available resources for learning. With careful budgeting, laptops, tablet computers such as the iPad or other hardware can be acquired and embedded with a wide range of free tools and applications for learning basic mathematics, spelling, grammar and scientific concepts.

Is that not enough? Then have students explore learning portals containing the works of Shakespeare, Darwin, Einstein, Jane Austen, Jane Goodall, the Dalai Lama and other major historical figures. For those concerned about resource quality, such contents are often created by NASA, the U.S. government, the Smithsonian, National Geographic, the United Nations, MIT, Berkeley, and many other reputable sources.

Digital technologies offer much hope to learners and educators today. Students can be inspired by mentors and role models from all corners of the Earth. Feedback on one's ideas can be received in the early morning hours or late at night. E-books can be loaded into mobile devices that can represent events through simulations, animations, videos and hyperlinked text.

Web technology situates students in authentic contexts analyzing real world data and interacting with their global peers about the results of their investigations. If this requires a cheap $20 membership in some service that fosters such expert advice or interaction, that is $20 well spent. Ditto the tens of thousands of dollars many school districts are spending today on iPads and other learning technologies.

Effective learning requires an environment designed for multiple paths to success. In the 21st century, digital technologies — social networking, e-books, shared online video, mobile applications, virtual worlds, collaborative tools, etc. — enhance the learning opportunities for untold millions of learners. The maximization of technologies in the learning space, in effect, provides a distinct advantage for learning. Now is the time to move ahead, not retrench or retrace.

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WRITTEN FOR *CQ RESEARCHER*, DECEMBER 2011

*t*echnology represents the essence of American consumerism by feeding our popular clamor for acquiring the current hot thing. Yet the ever-increasing significance of technology in our daily lives and its contribution to powerful advances as well as a widening equity gap place education in a complex paradox.

Author Kurt Vonnegut quipped, "Novels that leave out technology misrepresent life as badly as Victorians misrepresented life by leaving out sex." As with novels, so with schools, I believe, but we must take one step beyond "whether schools should address technology" to "how."

Two experiences from my 18 years teaching high school English inform my belief that schools should not incorporate as much digital technology as finances allow. I began teaching in the 1980s during the rise of MTV and witnessed my field make a claim that text was dead, and thus English teaching had to shift to the brave new video world — failing to anticipate instant messaging, email, texting, blogging and the text-rich social-media boom.

The intersection of technology's unknowable future, its inflated costs, and its inevitable obsolescence must give us pause as we spend public funds. Let me suggest simply looking into the closets and storage facilities at schools across the United States, where cables, monitors and other artifacts costing millions of dollars lie useless, replaced by the next-best thing we then had to acquire. In fact, just think of one thing, the Laserdisc video player (soon to be joined by interactive "smart" whiteboards in those closets).

Chalkboard, marker board, interactive board — this sequence has not insured better teaching or learning, but has guaranteed greater costs for schools and profits for manufacturers.

In *Walden*, Henry David Thoreau offered two warnings that should guide how we approach technology: "We are in great haste to construct a magnetic telegraph from Maine to Texas; but Maine and Texas, it may be, have nothing important to communicate," and, "We do not ride on the railroad; it rides upon us."

The foundational principles of public education for democracy and human agency must not fall prey to preparing children for the future by perpetually acquiring new technology because we can never know that future. Thus, we must not squander public funds on ever-changing technology but instead focus on the human interaction that is teaching and learning as well as the critical literacy and numeracy every child needs. We can anticipate only one fact of our futures — change.

CURRENT SITUATION

Digital Expansion

Tight school budgets and concerns about preparing students for technology-heavy workplaces are driving efforts to expand computer-based learning. But controversy continues over whether fast-changing digital technology is the best use of scarce funds.

The New York City Department of Education last spring announced it would boost technology spending by $542 million for the 2011-12 school year to pay for new wiring and other infrastructure upgrades, despite imposing major cuts elsewhere. Over the next three years, the city will cut $1.3 billion from planned school construction and eliminate 6,100 teachers — more than 6 percent of the city's workforce — 4,600 through layoffs. The new tech spending comes on top of an initiative, completed in 2009, that equipped every classroom with plug-in and wireless Internet connections. [47]

"If we want our kids to be prepared for life after school in the 21st century, we need to consider technology a basic element of public education," said New York's Deputy Chancellor of Education John White. [48]

But history shows it's all too easy to make flawed technology purchases, some analysts say. "We have seen circumstances where schools have overbought for bandwidth that they didn't touch," said Douglas A. Levin, executive director of the State Educational Technology Directors Association, a national membership group. [49]

A growing number of states are expanding access to so-called "virtual" or online public schools, where students take all or some of their courses via the Internet using technologies such as tutoring software and webcasts and are assisted by teachers using email or chat software. [50] (*See sidebar, p. 1006.*)

And some states now require students to undertake online study. In November, Idaho became the first to require students to take at least two online courses to graduate. The state Board of Education approved the plan to begin in the 2012-2013 school year, though the legislature will review the decision in 2012. [51] After prolonged debate, the board substantially scaled back an original proposal by Idaho state School Superintendent Tom Luna to require eight online credits. [52]

"There is no magic bullet . . . that is going to meet every single need for every single student," but making online study mandatory "is saying that there is," said Sue Darden, a teacher in the Meridian School District, near Boise. "Those of us in education can tell you that that's just not going to work." [53]

But advocates of online courses say they aren't much different from courses in brick-and-mortar schools. "There is still a live teacher. It may be at a distance, but that teacher is still instructing and interacting with the student," said Susan Patrick, president of the International Association for K-12 Online Learning, a membership group for public and private entities involved in online education. [54]

Idaho joins three other states that already had approved online-study requirements. Alabama and Michigan require high-school students to complete some online learning as a prerequisite for graduation but not necessarily an entire course. In June, Republican Gov. Rick Scott of Florida signed legislation requiring students to complete one online course for graduation. [55]

As concerns grow that lack of computer-science education — mainly training in programming and the theory and methods of stating problems in a form computers can solve — may threaten economic competitiveness, bills were filed in both the House and the Senate this fall to beef up computer-science instruction in K-12 schools.

Sponsored by Sen. Robert Casey, D-Pa., and Rep. Jared Polis, D-Colo., the Computer Science Education Act would fund grants to states to improve

President Barack Obama visits Parkville Middle School and Center of Technology in Baltimore on Feb. 14, 2011, to promote his 2012 budget proposal, which calls for increasing investment in math, science and engineering education. Some public officials are promoting online learning and so-called "blended" classes that use both computer-based and in-person instruction.

AFP/Getty Images/Tim Sloan

computer-science education; pay for teacher training; appoint a national commission to coordinate state efforts; and develop a plan for independent evaluation of programs. [56]

Scaling Up

The number of digital devices in K-12 classrooms continues to climb. While computers proliferate, however, adequate support and appropriate curricula to ensure they're used productively are still lacking, and many classroom computers are still being used mainly by teachers, not students.

Use of digital technologies to improve learning "is working in pockets, but scaling up is very difficult," says the University of Maryland's Greenhow.

Many education schools include technology training in their curricula, but aspiring teachers still "often end up doing their student teaching in an environment where they don't have this stuff," says Steven M. Ross, director of the Johns Hopkins University's Center for Research and Reform in Education.

Several recent surveys put the percentage of K-12 classrooms with computers at more than 90 percent, says Karin S. Forssell, program director for Stanford's master's degree program in Learning, Design and Technology. However, says Forssell, while "a lot of stats we have say that there is a computer in nearly every classroom, they're not necessarily in the hands of the students." In an extensive survey Forssell conducted of California teachers at all grade levels who hold national board certifications, about 75 percent said their classrooms include work with computers. While one can't generalize too much from the limited survey, it suggests that the 90-plus percent estimates of classrooms with computers don't reflect student access, she says.

Schools sensibly start by giving the teacher a computer to serve as a grade book, communicate using websites and email and replace audio-visual aids such as overhead projectors, Forssell says. Helping teachers become comfortable with technology is an important first step toward helping them figure out how to use it productively for student learning, she says.

While many schools now have digital equipment, far fewer have overhauled curricula and teaching practices to facilitate productive use of it.

"We've got schools wired, and we have significant purchases of instructional software," says Brookings' Whitehurst. However, "it's at the back of the room," rather than in daily use by all students, and few schools have integrated computers into well-thought-out curriculum goals, he says. ■

OUTLOOK

Transformers?

A transformative shift in education to the personalized, student-focused, lifetime-learning model that the Information Age demands will happen, many scholars say. It's just a question of when.

"Years of budget cuts, with more to come," plus the need to train more math, science and engineering students, will help drive the shift to more computer-based learning, says Harvard's Dede. "If the United States doesn't fix its education, in 10 years we'll be like a developing country."

Change might come quickly, Dede suggests. "A century ago the United States reinvented its education system in a very short time, moving from one-room schoolhouses to the industrial model" of large classes of same-age students all studying the same thing at the same time, he says. That model was "based on best practices in industry at that time." Pushback from supporters of the current system may slow progress, though. "The one-room schoolhouse was not set up to defend itself," while today many people have a vested interest in keeping major change at bay, Dede says.

There are more barriers to a quick transformation than teacher resistance, however, say many experts.

"We haven't really solved" the problem of how to successfully teach "the reading and writing tool" to all students yet, "and now we've got a new tool" — the computer — for which successful learning methods must be developed, says the University of Oregon's Moursund. "We should do it systematically and put a lot of government effort into it, or we'll have a boondoggle."

Despite hopes by some that online courses can accommodate ever more students, brick-and-mortar "schools won't go away quickly," says the University of Michigan's Fishman. For one thing, "people need someone to watch the kids while they work," so switching to all-online education would require overhauling other major social structures as well.

Overhauling the curriculum to include digital technology will be contentious, says Stanford's Blikstein. "There's lots of legacy stuff in the curriculum, and there is lots of fighting if someone suggests" eliminating traditional subjects, he says. "But if we don't get rid of some of them, you can't move forward. Some will think that the basics are always the basics, but a lot of the math we teach," for example, was originally included in textbooks because other subjects, such as physics, depended on it, he says. Today, when computers handle much of the physics computation, many traditional high school math topics could be dropped, he says.

Up to now, most research demonstrating the success of computer-based learning tools has carried the caveat that the technologies produced significant gains only in classrooms with

well-trained teachers and a carefully designed curriculum.

But Dede says that to move forward as the nation's technological and economic future requires, learning-technology designers must develop computer-based educational products that work under challenging circumstances.

" 'Boutique' interventions that work only under ideal conditions for success (skilled teachers, motivated and well-prepared students, special resources) are useful for theoretical development," Dede wrote. "However, large-scale educational improvement requires . . . interventions that work at scale under a variety of adverse circumstances." [57] ∎

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