Transforming American Education

Learning

Powered by Technology

National Education Technology Plan 2010

U.S. Department of Education
Office of Educational Technology

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Section 2422 of the *Elementary and Secondary Education Act* specifies that the secretary shall update and publish, in a form readily accessible to the public, a national long-range technology plan that describes how the secretary will promote: (a) higher student academic achievement through the integration of advanced technologies, including emerging technologies, into curricula and instruction; (b) increased access to technology for teaching and learning for schools with a high number or percentage of children from families with incomes below the poverty line; and (c) the use of technology to assist in the implementation of state systemic reform strategies. In addition, Section 2422 specifies that this report should also include a description of joint activities of the Department of Education and other federal departments or agencies that will promote the use of technology in education. In accordance with that requirement, the Office of Educational Technology of the Department of Education is publishing this report.

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U.S. Department of Education
Arne Duncan
Secretary

Office of Educational Technology
Karen Cator
Director

November 2010

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Contents

THE SECRETARY OF EDUCATION

WASHINGTON, DC 20202

November 2010

Dear Members of Congress:

Education is vital to America's individual and collective economic growth and prosperity, and is necessary for our democracy to work. Once the global leader in college completion rates among young people, the United States currently ranks ninth out of 36 developed nations. President Obama has articulated a bold vision for the United States to lead the world in the proportion of college graduates by 2020, thereby regaining our leadership and ensuring America's ability to compete in a global economy. To achieve this aggressive goal, we need to leverage the innovation and ingenuity this nation is known for to create programs and projects that every school can implement to succeed.

To that end, I am presenting you with the Administration's National Education Technology Plan, *Transforming American Education: Learning Powered by Technology*. The plan calls for applying the advanced technologies used in our daily personal and professional lives to our entire education system to improve student learning, accelerate and scale up the adoption of effective practices, and use data and information for continuous improvement.

The model of learning described in this plan calls for engaging and empowering personalized learning experiences for learners of all ages. The model stipulates that we focus what and how we teach to match what people need to know and how they learn. It calls for using state-of-the-art technology and Universal Design for Learning (UDL) concepts to enable, motivate, and inspire all students to achieve, regardless of background, languages, or disabilities. It calls for ensuring that our professional educators are well connected to the content and resources, data and information, and peers and experts they need to be highly effective. And it calls for leveraging the power of technology to support continuous and lifelong learning.

The National Education Technology Plan presents five goals with recommendations for states, districts, the federal government, and other stakeholders. Each goal addresses one of the five essential components of learning powered by technology: Learning, Assessment, Teaching, Infrastructure, and Productivity. The plan also calls for "grand challenge" research and development initiatives to solve crucial long-term problems that we believe should be funded and coordinated at a national level.

The plan's development was led by the Department of Education's Office of Educational Technology and involved the most rigorous and inclusive process ever undertaken for a national education technology plan. It builds on the insights and recommendations of a technical working group of leading education researchers, learning and assessment experts, and practitioners. We also engaged with and incorporated input received from hundreds of industry experts, thousands of educators, and the public. I urge you to consider this vision for transforming American education by using the best and most inclusive modern technology to power up the core functions of learning, teaching, assessment, and continuous improvement efforts, as described in this plan.

Sincerely,

/s/

Arne Duncan

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Executive Summary

Education is the key to America's economic growth and prosperity and to our ability to compete in the global economy. It is the path to good jobs and higher earning power for Americans. It is necessary for our democracy to work. It fosters the cross-border, cross-cultural collaboration required to solve the most challenging problems of our time.

Under the Obama administration, education has become an urgent priority driven by two clear goals:

- We will raise the proportion of college graduates from where it now stands (around 41 percent) so that 60 percent of our population holds a two-year or four-year degree by 2020.
- We will close the achievement gap so that all students graduate from high school ready to succeed in college and careers.

These are aggressive goals and achieving them is a sizable challenge. Add to the challenge the projections of most states and the federal government of reduced revenues for the foreseeable future, and it is clear we need cost-effective and cost-saving strategies that improve learning outcomes and graduation rates for millions of Americans.

Specifically, we must embrace innovation, prompt implementation, regular evaluation, and continuous improvement. The programs and projects that work must be brought to scale so every school has the opportunity to take advantage of their success. Our regulations, policies, actions, and investments must be strategic and coherent.

Transforming American Education

The National Education Technology Plan 2010 (NETP) calls for revolutionary transformation rather than evolutionary tinkering. It urges our education system at all levels to

- Be clear about the outcomes we seek.
- Collaborate to redesign structures and processes for effectiveness, efficiency, and flexibility.
- Continually monitor and measure our performance.
- Hold ourselves accountable for progress and results every step of the way.

The plan recognizes that technology is at the core of virtually every aspect of our daily lives and work, and we must leverage it to provide engaging and powerful learning experiences and content, as well as resources and assessments that measure student achievement in more complete, authentic, and meaningful ways. Technology-based learning and assessment systems will be pivotal in improving student learning and generating data that can be used to continuously improve the education system at all levels. Technology will help us execute collaborative teaching strategies combined with professional learning that better prepare and enhance educators' competencies and expertise over the course of their careers. To shorten our learning curve, we should look to other kinds of enterprises, such as business and entertainment, that have used technology to improve outcomes while increasing productivity.

We also should implement a new approach to research and development (R&D) in education that focuses on scaling innovative best practices in the use of technology in teaching and learning, transferring existing and emerging technology innovations into education, sustaining the R&D for education work that is being done by such organizations as the National Science Foundation, and creating a new organization to address major R&D challenges at the intersection of learning sciences, technology, and education.

A Model of Learning Powered by Technology

The NETP presents a model of learning powered by technology, with goals and recommendations in five essential areas: learning, assessment, teaching, infrastructure, and productivity. The plan also identifies far-reaching "grand challenge" R&D problems that should be funded and coordinated at a national level.

The challenging and rapidly changing demands of our global economy tell us what people need to know and who needs to learn. Advances in learning sciences show us how people learn. Technology makes it possible for us to act on this knowledge and understanding.

Learning: Engage and Empower

The model of learning described in this plan calls for engaging and empowering learning experiences for all learners. The model asks that we focus what and how we teach to match what people need to know, how they learn, where and when they will learn, and who needs to learn. It brings state-of-the art technology into learning to enable, motivate, and inspire all students, regardless of background, languages, or disabilities, to achieve. It leverages the power of technology to provide personalized learning and to enable continuous and lifelong learning.

Many students' lives today are filled with technology that gives them mobile access to information and resources 24/7, enables them to create multimedia content and share it with the world, and allows them to participate in online social networks where people from all over the world share ideas, collaborate, and learn new things. Outside school, students are free to pursue their passions in their own way and at their own pace. The opportunities are limitless, borderless, and instantaneous.

The challenge for our education system is to leverage the learning sciences and modern technology to create engaging, relevant, and personalized learning experiences for all learners that mirror students' daily lives and the reality of their futures. In contrast to traditional classroom instruction, this requires that we put students at the center and empower them to take control of their own learning by providing flexibility on several dimensions.

A core set of standards-based concepts and competencies should form the basis of what all students should learn. Beyond that, students and educators should have options for engaging in learning: large groups, small groups, and work tailored to the individual goals, needs, interests, and prior experience of each learner. Technology should be leveraged to provide access to more learning resources than are available in classrooms and connections to a wider set of "educators," including teachers, parents, experts, and mentors outside the classroom. It also should be used to enable 24/7 and lifelong learning.

What and How People Need to Learn

Whether the domain is English language arts, mathematics, sciences, social studies, history, art, or music, 21st-century competencies and such expertise as critical thinking, complex problem solving, collaboration, and multimedia communication should be woven into all content areas. These competencies are necessary to become expert learners, which we all must be if we are to adapt to our rapidly changing world over the course of our lives. That involves developing deep understanding within specific content areas and making the connections among them.

How we need to learn includes using the technology that professionals in various disciplines use. Professionals routinely use the Web and tools, such as wikis, blogs, and digital content for the research, collaboration, and communication demanded in their jobs. They gather data and analyze the data using inquiry and visualization tools. They use graphical and 3D modeling tools for design. For students, using these real-world tools creates learning opportunities that allow them to grapple with real-world problems—opportunities that prepare them to be more productive members of a globally competitive workforce.

Assessment: Measure What Matters

The model of learning requires new and better ways to measure what matters, diagnose strengths and weaknesses in the course of learning when there is still time to improve student performance, and involve multiple stakeholders in the process of designing, conducting, and using assessment. In all these activities, technology-based assessments can provide data to drive decisions on the basis of what is best for each and every student and that, in aggregate, will lead to continuous improvement across our entire education system.

The nation's governors and state education chiefs have begun to develop standards and assessments that measure 21st-century competencies and expertise in all content areas. Technology-based assessments that combine cognitive research and theory about how students think with multimedia, interactivity, and connectivity make it possible to directly assess these types of skills. This can be done within the context of relevant societal issues and problems that people care about in everyday life.

When combined with learning systems, technology-based assessments can be used formatively to diagnose and modify the conditions of learning and instructional practices while at the same time determining what students have learned for grading and accountability purposes. Both uses are important, but the former can improve student learning in the moment (Black and Wiliam 1998). Furthermore, systems can be designed to capture students' inputs and collect evidence of their knowledge and problem-solving abilities as they work. Over time, the system "learns" more about students' abilities and can provide increasingly appropriate support.

Using Data to Drive Continuous Improvement

With assessments in place that address the full range of expertise and competencies reflected in standards, student-learning data can be collected and used to continually improve learning outcomes and productivity. For example, such data could be used to create a system of interconnected feedback for students, educators, parents, school leaders, and district administrators.

For this to work, relevant data must be made available to the right people at the right time and in the right form. Educators and leaders at all levels of our education system also must be provided with support—tools and training—that can help them manage the assessment process, analyze relevant data, and take appropriate action.

Teaching: Prepare and Connect

Just as leveraging technology can help us improve learning and assessment, the model of learning calls for using technology to help build the capacity of educators by enabling a shift to a model of connected teaching. In such a teaching model, teams of connected educators replace solo practitioners, classrooms are fully connected to provide educators with 24/7 access to data and analytic tools, and educators have access to resources that help them act on the insights the data provide.

Professional educators are a critical component of transforming our education systems, and therefore strengthening and elevating the teaching profession is as important as effective teaching and accountability. All are necessary if we are to attract and retain the most effective educators and achieve the learning outcomes we seek. Just as leveraging technology can help us improve learning and assessment, it also can help us shift to a model of connected teaching.

In a connected teaching model, classroom educators are fully connected to learning data and tools for using the data; to content, resources, and systems that empower them to create, manage, and assess engaging and relevant learning experiences; and directly to their students in support of learning both in and out of school. The same connections give them access to resources and expertise that improve their own instructional practices and guide them in becoming facilitators and collaborators in their students' increasingly self-directed learning.

In connected teaching, teaching is a team activity. Individual educators build online learning communities consisting of their students and their students' peers; fellow educators in their schools, libraries, and after-school programs; professional experts in various disciplines around the world; members of community organizations that serve students in the hours they are not in school; and parents who desire greater participation in their children's education.

Episodic and ineffective professional development is replaced by professional learning that is collaborative, coherent, and continuous and that blends more effective in-person courses and workshops with the expanded opportunities, immediacy, and convenience enabled by online environments full of resources and opportunities for collaboration. For their part, the colleges of education and other institutions that prepare teachers play an ongoing role in the professional growth of their graduates throughout the entire course of their careers.

Connected teaching enables our education system to provide access to effective teaching and learning resources where they are not otherwise available and more options for all learners. This is accomplished by augmenting the expertise and competencies of specialized and exceptional educators with online and blended (online and offline) learning systems, on-demand courses, and other self-directed learning opportunities.

21st-Century Resources for Professional Educators

The technology that enables connected teaching is available now, but not all the conditions necessary to leverage it are. Many of our existing educators do not have the same understanding of and ease with using technology that is part of the daily lives of professionals in other sectors. The same can be said of many of the education leaders and policymakers in schools, districts, and states and of the higher education institutions that prepare new educators for the field.

This gap in technology understanding influences program and curriculum development, funding and purchasing decisions about educational and information technology in schools, and preservice and in-service professional learning. This gap prevents technology from being used in ways that would improve instructional practices and learning outcomes.

Still, we must introduce connected teaching into our education system rapidly, and therefore we need innovation in the organizations that support educators in their profession—schools and districts, colleges of education, professional learning providers, and professional organizations.

Infrastructure: Access and Enable

An essential component of the learning model is a comprehensive infrastructure for learning that provides every student, educator, and level of our education system with the resources they need when and where they are needed. The underlying principle is that infrastructure includes people, processes, learning resources, policies, and sustainable models for continuous improvement in addition to broadband connectivity, servers, software, management systems, and administration tools. Building this infrastructure is a far-reaching project that will demand concerted and coordinated effort.

Although we have adopted technology in many aspects of education today, a comprehensive infrastructure for learning is necessary to move us beyond the traditional model of educators and students in classrooms to a learning model that brings together teaching teams and students in classrooms, labs, libraries, museums, workplaces, and homes—anywhere in the world where people have access devices and an adequate Internet connection.

Over the past 40 years, we have seen unprecedented advances in computing and communications that have led to powerful technology resources and tools for learning. Today, low-cost Internet access devices, easy-to-use digital authoring tools, and the Web facilitate access to information and multimedia learning content, communication, and collaboration. They provide the ability to participate in online learning communities that cross disciplines, organizations, international boundaries, and cultures.

Many of these technology resources and tools already are being used within our public education system. We are now, however, at an inflection point for a much bolder transformation of education powered by technology. This revolutionary opportunity for change is driven by the continuing push of emerging technology and the pull of the critical national need to radically improve our education system.

Always-on Learning

An infrastructure for learning is always on, available to students, educators, and administrators regardless of their location or the time of day. It supports not just access to information, but access to people and participation in online learning communities. It offers a platform on which developers can build and tailor applications.

An infrastructure for learning unleashes new ways of capturing and sharing knowledge based on multimedia that integrate text, still and moving images, audio, and applications that run on a variety of devices. It enables seamless integration of in- and out-of-school learning. It frees learning from a rigid information transfer model (from book or educator to students) and enables a much more motivating intertwinement of learning about, learning to do, and learning to be.

On a more operational level, an infrastructure for learning brings together and enables access to data from multiple sources while ensuring appropriate levels of security and privacy. The infrastructure integrates computer hardware, data and networks, information resources, interoperable software, middleware services and tools, and devices, and connects and supports interdisciplinary teams of professionals responsible for its development, maintenance, and management and its use in transformative approaches to teaching and learning.

Productivity: Redesign and Transform

To achieve our goal of transforming American education, we must rethink basic assumptions and redesign our education system. We must apply technology to implement personalized learning and ensure that students are making appropriate progress through our P–16 system so they graduate. These and other initiatives require investment, but tight economic times and basic fiscal responsibility demand that we get more out of each dollar we spend. We must leverage technology to plan, manage, monitor, and report spending to provide decision-makers with a reliable, accurate, and complete view of the financial performance of our education system at all levels. Such visibility is essential to meeting our goals for educational attainment within the budgets we can afford.

Improving productivity is a daily focus of most American organizations in all sectors—both for-profit and nonprofit—and especially in tight economic times. Education has not, however, incorporated many of the practices other sectors regularly use to improve productivity and manage costs, nor has it leveraged technology to enable or enhance them. We can learn much from the experience in other sectors.

What education can learn from the experience of business is that we need to make the fundamental structural changes that technology enables if we are to see dramatic improvements in productivity. As we do so, we should recognize that although the fundamental purpose of our public education system is the same, the roles and processes of schools, educators, and the system itself should change to reflect the times we live in and our goals as a world leader. Such rethinking applies to learning, assessment, and teaching processes and to the infrastructure and operational and financial sides of running schools and school systems.

Rethinking Basic Assumptions

One of the most basic assumptions in our education system is time-based or "seat-time" measures of educational attainment. These measures were created in the late 1800s and early 1900s to smooth transitions from K–12 into higher education by translating high school work to college admissions offices (Shedd 2003) and made their way into higher education when institutions began moving away from standardized curricula.

Another basic assumption is the way we organize students into age-determined groups, structure separate academic disciplines, organize learning into classes of roughly equal size with all the students in a particular class receiving the same content at the same pace, and keep these groups in place all year.

The last decade has seen the emergence of some radically redesigned schools, demonstrating the range of possibilities for structuring education. These include schools that organize around competence rather than seat time and others that enable more flexible scheduling that fits students' individual needs rather than traditional academic periods and lockstep curriculum pacing. In addition, schools are beginning to incorporate online learning, which gives us the opportunity to extend the learning day, week, or year.

The United States has a long way to go if we are to see every student complete at least a year of higher education or postsecondary career training. There is no way to achieve this target unless we can dramatically reduce the number of students who leave high school without getting a diploma and/or who are unprepared for postsecondary education.

A complex set of personal and academic factors underlie students' decision to leave school or to disengage from learning, but support should start as early as possible, before children enter school, and should become intensified for those students who need it as they move through school. Practices supported with technology can help address the problem, including learning dashboards that keep students on track with their course requirements and earning credits for courses taken online.

Redesigning education in America for improved productivity is a complex challenge that will require all 50 states, the thousands of districts and schools across the country, the federal government, and other education stakeholders in the public and private sector to come together to design and implement innovative solutions. It is a challenge for educators—leaders, teachers, and policymakers committed to learning—as well as technologists, and ideally they will come together to lead the effort.

A Rigorous and Inclusive Process

This plan, led by the Department of Education's Office of Educational Technology, was developed using a rigorous and inclusive process built on the report of a technical working group of leading education researchers and practitioners.

In keeping with the White House's Open Government Directive, the Department invited extensive public participation in the development of the plan. Broad outreach efforts and state-of-the-art communications and collaboration technology enabled tens of thousands of individuals to learn about and contribute to the development of the plan over its 9-month development period.

The Time To Act Is Now

The NETP accepts that we do not have the luxury of time: We must act now and commit to fine-tuning and midcourse corrections as we go. Success will require leadership, collaboration, and investment at all levels of our education system—states, districts, schools, and the federal government—as well as partnerships with higher education institutions, private enterprises, and not-for-profit entities.

In the United States, education is primarily a state and local responsibility. State and local public education institutions must ensure equitable access to learning experiences for all students and especially students in underserved populations—low-income and minority students, students with disabilities, English language learners, students in rural and frontier schools, and others. States and districts need to build capacity for transformation. The Department of Education has a role in identifying effective strategies and implementation practices; encouraging, promoting, and actively supporting innovation in states and districts; and nurturing collaborations that help states and districts leverage resources so the best ideas can be scaled up.

Postsecondary education institutions—community colleges and four-year colleges and universities—will need to partner more closely with K–12 schools to remove barriers to postsecondary education and put plans of their own in place to decrease dropout rates. Clearly, postsecondary institutions would be key players in the national R&D efforts recommended in this plan.

Education has long relied on the contributions of organizations in both the private and not-for-profit sectors, and this will not change.

As we enter the second decade of the 21st century, there has never been a more pressing need to transform American education or a better time to act. The NETP is a 5-year action plan that responds to an urgent national priority and a growing understanding of what the United States needs to do to remain competitive in a global economy.

Goals and Recommendations

To transform education in America, we must turn ideas into action. The NETP presents five goals that address the key components of this plan—learning, assessment, teaching, infrastructure, and productivity—along with recommendations for states, districts, the federal government, and other stakeholders in our education system for achieving these goals.

1.0 Learning: Engage and Empower

All learners will have engaging and empowering learning experiences both in and out of school that prepare them to be active, creative, knowledgeable, and ethical participants in our globally networked society.

To meet this goal, we recommend the following:

1.1 States should continue to revise, create, and implement standards and learning objectives using technology for all content areas that reflect 21st-century expertise and the power of technology to improve learning.

Our education system relies on core sets of standards-based concepts and competencies that form the basis of what all students should know and should be able to do. Whether the domain is English language arts, mathematics, sciences, social studies, history, art, or music, states should continue to consider the integration of 21st-century competencies and expertise, such as critical thinking, complex problem solving, collaboration, multimedia communication, and technological competencies demonstrated by professionals in various disciplines.

1.2 States, districts, and others should develop and implement learning resources that use technology to embody design principles from the learning sciences.

Advances in learning sciences, including cognitive science, neuroscience, education, and social sciences, give us greater understanding of three connected types of human learning—factual knowledge, procedural knowledge, and motivational engagement. Technology has increased our ability to both study and enhance all three types. Today's learning environments should reflect what we have learned about how people learn and take advantage of technology to optimize learning.

1.3 States, districts, and others should develop and implement learning resources that exploit the flexibility and power of technology to reach all learners anytime and anywhere.

The always-on nature of the Internet and mobile access devices provides our education system with the opportunity to create learning experiences that are available anytime and anywhere. When combined with design principles for personalized learning and Universal Design for Learning, these experiences also can be accessed by learners who have been marginalized in many educational settings: students from low-income communities and minorities, English language learners, students with disabilities, students who are gifted and talented, students from diverse cultures and linguistic backgrounds, and students in rural areas.

1.4 Use advances in learning sciences and technology to enhance STEM (science, technology, engineering, and mathematics) learning and develop, adopt, and evaluate new methodologies with the potential to inspire and enable all learners to excel in STEM.

New technologies for representing, manipulating, and communicating data, information, and ideas have changed professional practices in STEM fields and what students need to learn to be prepared for STEM professions. Technology should be used to support student interaction with STEM content in ways that promote deeper understanding of complex ideas, engage students in solving complex problems, and create new opportunities for STEM learning throughout our education system.

2.0 Assessment: Measure What Matters

Our education system at all levels will leverage the power of technology to measure what matters and use assessment data for continuous improvement.

To meet this goal, we recommend the following actions:

2.1 States, districts, and others should design, develop, and implement assessments that give students, educators, and other stakeholders timely and actionable feedback about student learning to improve achievement and instructional practices.

Learning science and technology combined with assessment theory can provide a foundation for new and better ways to assess students in the course of learning, which is the ideal time to improve performance. This will require involving experts from all three disciplines in the process of designing, developing, and using new technology-based assessments that can increase the quality and quantity of feedback to learners.

2.2 Build the capacity of educators, education institutions, and developers to use technology to improve assessment materials and processes for both formative and summative uses.

Technology can support measuring performances that cannot be assessed with conventional testing formats, providing our education system with opportunities to design, develop, and validate new and more effective assessment materials. Building this capacity can be accelerated through knowledge exchange, collaboration, and better alignment between educators (practitioners) and experts.

2.3 Conduct research and development that explores how embedded assessment technologies, such as simulations, collaboration environments, virtual worlds, games, and cognitive tutors, can be used to engage and motivate learners while assessing complex skills.

Interactive technologies, especially games, provide immediate performance feedback so that players always know how they are doing. As a result, they are highly engaging to students and have the potential to motivate students to learn. They also enable educators to assess important competencies and aspects of thinking in contexts and through activities that students care about in everyday life. Because interactive technologies hold this promise, assessment and interactive technology experts should collaborate on research to determine ways to use them effectively for assessment.

2.4 Conduct research and development that explores how Universal Design for Learning can enable the best accommodations for all students to ensure we are assessing what we intend to measure rather than extraneous abilities a student needs to respond to the assessment task.

To be valid, an assessment must measure those qualities it is intended to measure and scores should not be influenced by extraneous factors. An assessment of science, for example, should measure understanding of science concepts and their application, not the ability to see print, to respond to items using a mouse, or to use word processing skills. Assessment and technology experts should collaborate to create assessment design tools and processes that make it possible to develop assessment systems with appropriate features (not just accommodations) so that assessments capture examinees' strengths in terms of the qualities that the assessment is intended to measure.

2.5 Revise practices, policies, and regulations to ensure privacy and information protection while enabling a model of assessment that includes ongoing gathering and sharing of data on student learning for continuous improvement.

Every parent of a student under 18 and every student 18 or over should have the right to access the student's own assessment data in the form of an electronic learning record that the student can take with them throughout his or her educational career. At the same time, appropriate safeguards, including stripping records of identifiable information and aggregating data across students, classrooms, and schools, should be used to make it possible to supply education data derived from student records to other legitimate users without compromising student privacy.

3.0 Teaching: Prepare and Connect

Professional educators will be supported individually and in teams by technology that connects them to data, content, resources, expertise, and learning experiences that enable and inspire more effective teaching for all learners.

To meet this goal, we recommend the following actions:

3.1 Expand opportunities for educators to have access to technology-based content, resources, and tools where and when they need them.

Today's technology enables educators to tap into resources and orchestrate expertise across a school district or university, a state, the nation, and even around the world. Educators can discuss solutions to problems and exchange information about best practices in minutes, not weeks or months. Today's educators should have access to technology-based resources that inspire them to provide more engaging and effective learning opportunities for each and every student.

3.2 Leverage social networking technologies and platforms to create communities of practice that provide career-long personal learning opportunities for educators within and across schools, preservice preparation and in-service education institutions, and professional organizations.

Social networks can be used to provide educators with career-long personal learning tools and resources that make professional learning timely and relevant as well as an ongoing activity that continually improves practice and evolves their skills over time. Online communities should enable educators to take online courses, tap into experts and best practices for just-in-time problem solving, and provide platforms and tools for educators to design and develop resources with and for their colleagues.

3.3 Use technology to provide all learners with online access to effective teaching and better learning opportunities and options especially in places where they are not otherwise available.

Many education institutions, particularly those serving the most vulnerable students and those in rural areas, lack educators with competencies in reaching students with special needs and educators with content knowledge and expertise in specialized areas, including STEM. Even in areas where effective teaching is available, students often lack options for high-quality courses in particular disciplines or opportunities for learning that prepare them for the modern world. Online learning options should be provided to enable leveraging the best teaching and make high-quality course options available to all learners.

3.4 Provide preservice and in-service educators with professional learning experiences powered by technology to increase their digital literacy and enable them to create compelling assignments for students that improve learning, assessment, and instructional practices.

Just as technology helps us engage and motivate students to learn, technology should be used in the preparation and ongoing learning of educators to engage and motivate them in what and how they teach. This will require synthesizing core principles and adopting best practices for the use of technology in preparing educators. Technology also should be an integral component of teaching methods courses and field experiences rather than treated as a discrete skill distinct from pedagogical application.

3.5 Develop a teaching force skilled in online instruction.

As online learning becomes an increasingly important part of our education system, we need to provide online and blended learning experiences that are more participatory and personalized and that embody best practices for engaging all students. This creates both the need and opportunity for educators who are skilled in instructional design and knowledgeable about emerging technologies. Crucial to filling this need while ensuring effective teaching are appropriate standards for online courses and teaching and a new way of approaching online teacher certification.

4.0 Infrastructure: Access and Enable

All students and educators will have access to a comprehensive infrastructure for learning when and where they need it.

To meet this goal, we recommend the following actions:

4.1 Ensure students and educators have broadband access to the Internet and adequate wireless connectivity both in and out of school.

Students and educators need adequate broadband bandwidth for accessing the Internet and technology-based learning resources. "Adequate" should be defined as the ability to use the Internet in school, on the surrounding campus, throughout the community, and at home. It should also include simultaneous use of high-bandwidth resources, such as multimedia, communication and collaboration environments, and communities. Crucial to providing such access are the broadband initiatives being individually and jointly managed by various federal agencies.

4.2 Ensure that every student and educator has at least one Internet access device and appropriate software and resources for research, communication, multimedia content creation, and collaboration for use in and out of school.

Only with 24/7 access to the Internet via devices and technology-based software and resources can we achieve the kind of engagement, student-centered learning, and assessments that can improve learning in the ways this plan proposes. The form of these devices, software, and resources may or may not be standardized and will evolve over time. In addition, these devices may be owned by the student or family, owned by the school, or some combination of the two. The use of devices owned by students will require advances in network filtering and improved support systems.

4.3 Support the development and use of open educational resources to promote innovative and creative opportunities for all learners and accelerate the development and adoption of new open technology-based learning tools and courses.

The value of open educational resources is now recognized around the world, leading to the availability of a vast array of learning, teaching, and research resources that learners of any age can use across all content areas. Realizing this value will require new policies concerning the evaluation and selection of instructional materials so that digital resources are considered and processes are established for keeping educational resource content up to date, appropriate, and tagged according to identified content interoperability standards.

4.4 Build state and local education agency capacity for evolving an infrastructure for learning.

Building an infrastructure for learning is a far-reaching project that will demand concerted and coordinated effort. The effort should start with implementing the next generation of computing system architectures and include transitioning computer systems, software, and services from in-house datacenters to professionally managed data centers in the cloud for greater efficiency and flexibility. This will require leveraging and scaling up the human talent to build such an infrastructure, which should ultimately save money and enable education IT professionals to focus more on maintaining the local infrastructure and supporting teachers, students, and administrators.

4.5 Develop and use interoperability standards for content and student-learning data to enable collecting and sharing resources and collecting, sharing, and analyzing data to improve decision making at all levels of our education system.

Fragmented content and resources and student-learning data siloed in different proprietary platforms and systems, along with a lack of common standards for collecting and sharing data, are formidable barriers to leveraging resources for teaching and learning. These barriers exist because we lack common content interoperability standards and tools to enable use of such standards. The lack of common standards affects the quality of tools because developers limit their R&D investments into narrow markets and are not able to leverage overall market advancements in research and development. Interoperability standards are essential to resolving these issues.

4.6 Develop and use interoperability standards for financial data to enable data-driven decision making, productivity advances, and continuous improvement at all levels of our education system.

Just as content, resources, and student learning data are fragmented in disconnected technology systems and throughout our education system, the same is true for financial data. Therefore, we also need financial data interoperability standards and tools that enable the use of these standards.

5.0 Productivity: Redesign and Transform

Our education system at all levels will redesign processes and structures to take advantage of the power of technology to improve learning outcomes while making more efficient use of time, money, and staff.

To meet this goal, we recommend the following actions:

5.1 Develop and adopt a common definition of productivity in education and more relevant and meaningful measures of outcomes, along with improved policies and technologies for managing costs, including those for procurement.

Education has not incorporated many of the practices other sectors regularly use to measure outcomes, manage costs, and improve productivity, a number of which are enabled or enhanced by technology. As other sectors have learned, we are unlikely to improve outcomes and productivity until we define and start measuring them. This starts with identifying what we seek to measure. It also requires identifying costs associated with components of our education system and with individual resources and activities so that the ratio of outcomes to costs can be tracked over time.

5.2 Rethink basic assumptions in our education system that inhibit leveraging technology to improve learning, starting with our current practice of organizing student and educator learning around seat time instead of the demonstration of competencies.

To realize the full potential of technology for improving performance and increasing productivity, we must remove the process and structural barriers to broad adoption. The education system must work to identify and rethink basic assumptions of the education system. Some of these include measurement of educational attainment through seat time, organization of students into age-determined groups, the structure of separate academic disciplines, the organization of learning into classes of roughly equal size, and the use of time blocks.

5.3 Develop useful metrics for the educational use of technology in states and districts.

Current data on the use of educational and information technology in our system consist of records of purchases and numbers of computers and Internet connections. Very little information on how technology is actually used to support teaching, learning, and assessment is collected and communicated systematically. Only by shifting our focus to collecting data on how and when technology is used will we be able to determine the difference it makes and use that knowledge to improve outcomes and the productivity of our education system.

5.4 Design, implement, and evaluate technology-powered programs and interventions to ensure that students progress seamlessly through our P–16 education system and emerge prepared for college and careers.

The United States has a long way to go if we are to see every student complete at least a year of higher education or postsecondary career training. Achieving this target will require dramatically reducing the number of students who leave high school without getting a diploma and/or who are unprepared for postsecondary education. A complex set of personal and academic factors underlie students' decisions to leave school or to disengage from learning, and no one strategy will prevent every separation from the education system. Collaboration between P–12 and higher education institutions and practices supported with technology are crucial to addressing the problem.

Getting Started Now

The Department of Education has a role in identifying effective strategies and implementation practices; encouraging, promoting, and actively supporting innovation and best practices in states and districts; and nurturing collaborations that help states and districts leverage resources so the best ideas can be scaled up. To help ensure the successful implementation of this plan, the Department of Education can take action around the following priorities:

Convening education stakeholders, in person and online, to share content, insights, and expertise and to collaborate on key elements of this plan. Ideas and best practices that emerge from these convenings will be shared throughout our education system.

The Department of Education can

Convene learning science researchers, developers of educational technology, curriculum developers, public and private sector organizations, and Universal Design for Learning experts to share information and research for developing the next generation of technology-based learning platforms, resources, courses, and tools.

Facilitate collaboration between states and private and public sector organizations to design, develop, validate, and scale up new technology-based assessment resources for both formative and summative uses. These efforts should include exploring the use of embedded assessment technologies, such as simulations, collaboration environments, virtual worlds, and games in new assessment resources.

Convene P–12 and higher education institutions, states, and districts to collaborate on strategies for creating persistent student electronic learning records and using student data for continuous improvement.

Facilitate collaboration between states, districts, universities, other research and development organizations, other agencies, and the commercial sector to develop and leverage open educational resources. Designs for use and reuse and new business models will be included.

Convene states, teacher accreditation organizations, colleges of education, and organizations representing online learning providers to promote states' consideration of voluntary standards for online courses and for online teaching. This activity should include the promotion of reciprocity agreements between states for certifying online teachers.

Convene states and education leadership organizations to identify and rethink basic assumptions in our education system, starting with but not limited to the measurement of educational attainment through seat time. Other assumptions that should be reexamined are the organization of students into static age-determined groups and the organization of learning into classes of roughly equal size, as well as the structure of separate academic disciplines. The use of online learning and combining offline and online learning to provide options for flexibility, additional learning time, and more effective use of the time allotted should be explored.

Convene states, districts, and education and technology experts from the academic, private, and public sectors to define useful metrics for the use of technology in support of teaching and learning and improved operations that states and districts can use to guide technology purchases.

Promote collaboration between two- and four-year postsecondary education institutions, P–12 programs, and educational technology developers in the private and public sectors to design programs and resources to engage and/or reengage students and motivate them to graduate from high school ready for postsecondary education. Facilitate collaboration on alternative programs that take advantage of technology to reconnect with students and help them complete learning programs.

Supporting efforts to ensure that all students and educators have 24/7 access to the Internet via devices, including mobile devices, and that states, districts, and schools adopt technologies and policies to enable leveraging the technology that students already have.

The Department of Education can

Endorse and actively support the broadband initiatives of the *American Recovery and Reinvestment Act of 2009,* which are intended to accelerate deployment of Internet services in unserved, underserved, and rural areas and to strategic anchor institutions, such as schools, that are likely to provide significant public benefits. These initiatives are the Broadband Technology Opportunities Program of the Department of Commerce's National Telecommunications and Information Administration, the Rural Development Broadband Program of the Department of Agriculture, and the interagency National Broadband Plan developed by the Federal Communications Commission.

Work with districts, states, and the private sector to articulate effective technology support models for 24/7 access including using school- and student-owned devices. New support models for this type of access will require improved security systems, more intelligent filtering systems that allow blocking and enabling access within this type of infrastructure, and personnel and/or systems capable of providing around-the-clock support for school-, student-, and educator-owned devices used for learning.

Participating in efforts to ensure that transitioning from predominantly print-based classrooms to digital learning environments promotes organized, accessible, easy-to-distribute and easy-to-use content and learning resources.

The Department of Education can

Support the development of an open architecture mapping and navigation platform that will enable the visual depiction of learning progressions across all content areas and reflect 21st-century expertise. Accessible online, these learning progressions can be used to reenvision content, resources, assessments, curricula, and professional learning for teachers and encourage the sharing of best practices and new approaches to improve teaching and learning. This platform would encourage a variety of mashups and spur innovation.

Initiate an interagency effort to create, publish, and maintain open standards for content, student learning, and financial data interoperability. State and district requests for proposals for assessment and data systems should require appropriate use of these standards.

Create a learning registry, an open-standard registry of all content developed by various agencies throughout the federal government so that states, districts, and schools can access and leverage it and combine it with their own repositories of content.

Expand the availability of digital-learning content, resources, courses, and tools and ensure their continuous improvement by funding the research and development of open educational resources. Facilitate states working together to pool resources for identifying and evaluating or issuing requirements for developing open educational resources.

Support research and evaluation efforts focused on the effectiveness of online and blended learning environments at all levels.

Encourage the use of technology and online learning courses and resources in federally funded programs that expand learning opportunities for underserved populations and others who need it most.

Encourage states, districts, P–12 programs, and postsecondary education institutions to experiment with such resources as online learning, online tutoring and mentoring, games, cognitive tutors, immersive environments, and participatory communities and social networks both within and across education institutions to give students guidance and information about their own learning progress and strategies for seamless completion of a comprehensive P–16 education.

Funding online communities of practice to ensure that teachers are connected to data, resources, experts, and peers to prepare and enable connected teaching.

The Department of Education can

Fund a contract for design research on online communities of practice and apply the design to a series of at least six communities of practice in order to leverage the use of educational technology and social networking to improve teaching, assessment, learning, and infrastructure in schools. The communities of practice will be designed to ensure teachers and other education professionals are highly connected to data, resources, content, experts, peers, and just-in-time expertise on a variety of topics.

Leverage the design work on online communities of practice to inform contracts and grants for providing technical assistance throughout the Department of Education.

Ensuring a sustained focus on R&D for education, including scaling up and sustaining innovations, technology transfer, and grand challenge problems.

The Department of Education can

Implement an approach to R&D for education that focuses on five areas:

- Transferring existing and emerging technology innovations from sectors such as business, consumer, and entertainment into education.
- Transferring appropriate developments from the Department of Defense Advanced Research Projects Administration to the public education sector.
- Supporting and sustaining the education R&D that is currently happening throughout the National Science Foundation by designing a commercialization strategy.

- Creating a new organization (the National Center for Research in Advanced Information and Digital Technologies) with the mission of serving the public good through R&D at the intersection of learning sciences, technology, and education.
- Providing competitive grants for scaling up innovative and evidence-based practices through the Department of Education's Investing in Innovation Fund.

Encouraging states and districts to move to more integrated use of technology in teaching and learning.

The Department of Education can

Encourage states to assign responsibility for educational technology to senior-level individuals who will provide leadership in connecting the planning for educational and information technology to the core functions of curriculum and instruction, assessment, and professional learning and in ensuring that the most efficient and effective purchases are made. These individuals will be invited to participate on a cross-functional team organized by the Department of Education to share insights and best practices and collaborate on technology for teaching and learning.

Encourage every federal grant program and expenditure to consider how technology can be a multiplier for support and scale in education.

Leading a national initiative to identify strategies for increasing productivity in education and work with states, districts, and schools to build their capacity for implementing them.

The Department of Education can

Start a national initiative and develop an ongoing research agenda dedicated to improving productivity in the education sector. The initiative will focus on defining productivity in education and establishing new and more useful metrics and methods for measuring it. The initiative will promote continuous improvement and data-driven decision making, leveraging technology to plan, manage, monitor, and report spending so that education decision-makers can be provided with a reliable, accurate, and complete view of the financial performance of our education system at all levels.

Encourage states to adopt common cost accounting standards to allow benchmarking and analysis of costs and provide a platform for sharing strategies for cost saving and productivity improvement and highlight policies at the federal, state, and local level that might inhibit progress, for example, in procurement.

Develop new and better ways of assessing the efficacy of technology in teaching and learning and in the financial operations of education institutions.

Introduction

> *"By 2020, America will once again have the highest proportion of college graduates in the world."*
>
> *—President Barack Obama, Address to Congress, Feb. 24, 2009*

Education is the key to America's economic growth and prosperity and to our ability to compete in the global economy. It is the path to good jobs and higher earning power for Americans. It is necessary for our democracy to work.

With this in mind, America needs a public education system that provides all learners—including low-income and minority students, English language learners, students with disabilities, gifted and talented students, early childhood learners, adult workforce learners, and seniors—with engaging and empowering learning experiences. Our education system also should help learners set goals, stay in school despite obstacles, earn a high school diploma, and obtain the further education and training needed for success in their personal lives, the workplace, and their communities.

We want to develop inquisitive, creative, resourceful thinkers; informed citizens; effective problem-solvers; groundbreaking pioneers; and visionary leaders. We want to foster the excellence that flows from the ability to use today's information, tools, and technologies effectively and a commitment to lifelong learning. All these are necessary for Americans to be active, creative, knowledgeable, and ethical participants in our globally networked society.

To accomplish this, schools must be more than information factories; they must be incubators of exploration and invention. Educators must be more than information experts; they must be collaborators in learning, seeking new knowledge and constantly acquiring new skills alongside their students. Students must be fully engaged in school—intellectually, socially, and emotionally. This level of engagement requires the chance to work on interesting and relevant projects, the use of technology environments and resources, and access to an extended social network of adults and peers who support their intellectual growth.

Education reform has been on the national agenda for decades. Still, we no longer have the highest proportion of college graduates in the world, and we have a system that too often fails our students. According to current data,

- Approximately 25 percent of young people in the United States fail to graduate on time with a regular diploma (Stillwell 2010). That number jumps to almost 40 percent for Latino and African-American students.

- Some 5,000 schools persistently fail year after year, and about 2,000 high schools produce about half the nation's dropouts and three-quarters of minority dropouts (Balfanz and Legters 2004; Tucci 2009).

- Of students who do graduate from high school, one-third are unprepared for postsecondary education, forcing community colleges and four-year colleges and universities to devote precious time and resources to remedial work for incoming students (National Center for Education Statistics 2003).

- By 2016—just six years from now—four out of every 10 new jobs will require some advanced education or training (Dohm and Shniper 2007). Fifteen of the 30 fastest-growing fields will require a minimum of a bachelor's degree (Bureau of Labor Statistics 2007).

- Only about 41 percent of young people earn a two-year or four-year college degree (OECD 2010). Enrollment rates are unequal: 69 percent of qualified white high school graduates enter four-year colleges compared with just 58 percent of comparable Latino graduates and 56 percent of African-American graduates (National Center for Education Statistics 2007).

- Thirty million adults have below-basic levels of English literacy, and another 63 million read English only at a basic level, which means that 44 percent of adults living in America could benefit from English literacy instruction (National Center for Education Statistics 2009).

As Secretary of Education Arne Duncan has said, the current state of our education system is "economically unsustainable and morally unacceptable" (Duncan 2010).

Transforming American Education: An Urgent Priority

Under the Obama administration, education has become an urgent priority driven by two clear goals set by the president:

- By 2020, we will raise the proportion of college graduates from where it now stands (about 41 percent) so that 60 percent of our population holds a two-year or four-year degree (National Center for Public Policy and Higher Education 2008).

- We will close the achievement gap so that all students graduate from high school ready to succeed in college and careers.

To accomplish these goals, we must embrace a strategy of innovation, careful implementation, regular evaluation, and continuous improvement. The programs and projects that work must be brought to scale so that every learner has the opportunity to take advantage of that success. Our regulations, policies, actions, and investments must be strategic and coherent.

To this end, Secretary Duncan has identified four major areas where our investments and efforts can have the greatest impact:

- States should adopt standards and assessments that prepare students to succeed in college and the workplace and compete in the global economy.
- States should build data systems that measure student growth and success and inform educators about how they can improve instruction.
- States should recruit, reward, develop, and retain effective educators, especially in underserved areas where they are needed most.
- States should turn around their lowest-achieving schools.

In addition, in November 2009 President Obama launched the Educate to Innovate campaign to improve the participation and performance of all U.S. students, including underrepresented groups such as girls and women, in science, technology, engineering, and mathematics (STEM).

We are guided in these and other education initiatives by Secretary Duncan's conviction that we need revolutionary transformation, not evolutionary tinkering, and we know that transformation cannot be achieved through outdated reform strategies that take decades to unfold.

We must be clear about the outcomes we seek. We must apply the core principles of process redesign to quickly evaluate our education system for effectiveness, efficiency, and flexibility and design and implement new processes where needed. We must monitor and measure our performance to continually improve learning outcomes while managing costs. We must hold ourselves accountable. To do all these things, we must apply the advanced technology available in our daily lives to student learning and to our entire education system.

Above all, we must accept that we do not have the luxury of time. We must act now and commit to fine-tuning and midcourse corrections as we go. We must learn from other kinds of enterprises that have used technology to improve outcomes and increase productivity.

Drivers of Change

The Department of Education's decisions and actions—and those of the entire education system and its stakeholders throughout the United States—must be guided by the world we live in, which demands that we think differently about education than we have in the past. Technology and the Internet have fostered an increasingly competitive and interdependent global economy and transformed nearly every aspect of our daily lives—how we work; play; interact with family, friends, and communities; and learn new things.

The context of global interdependence is especially important for this generation of students because only individuals and nations working together will solve many of today's challenges. The leadership of the United States in the world depends on educating a generation of young people who are capable of navigating an interdependent world and collaborating across borders and cultures to address today's great problems.

Another important context is the growing disparity between students' experiences in and out of school. Students use computers, mobile devices, and the Internet to create their own engaging learning experiences outside school and after school hours—experiences that too often are radically different from what they are exposed to in school. Our leadership in the world depends on educating a generation of young people who know how to use technology to learn both formally and informally.

Technology itself is an important driver of change. Contemporary technology offers unprecedented performance, adaptability, and cost-effectiveness.

Technology can enable transforming education but only if we commit to the change that it will bring to our education system. For example, students come to school with mobile devices that let them carry the Internet in their pockets and search the Web for the answers to test questions. While such behavior traditionally has been viewed as cheating, with such ubiquitous access to information is it time to change what and how we teach? Similarly, do we ignore the informal learning enabled by technology outside school, or do we create equally engaging and relevant experiences inside school and blend the two?

We know from our rankings in the world in terms of academic achievement and graduation rates that what we have been doing to fill our education pipeline and ensure students graduate is not working. Getting students to stay in school is crucial, and equipping them with the skills they need to learn to be successful throughout their lives is equally important.

The essential question facing us as we transform the U.S. education system is this: What should learning in the 21st century look like?

Learning Powered by Technology

Building on the report of a technical working group of leading researchers and practitioners and on input received from many respected education leaders and the public, this National Education Technology Plan tackles this essential question and other important questions. The plan presents goals, recommendations, and actions for a model of learning informed by the learning sciences and powered by technology. Advances in the learning sciences give us valuable insights into how people learn. Technology innovations give us the ability to act on these insights as never before.

The plan is based on the following assumptions:

- Many of the failings of our education system stem from our failure to engage the hearts and minds of students.
- What students need to learn and what we know about how they learn have changed, and therefore the learning experiences we provide should change.
- How we assess learning focuses too much on what has been learned after the fact and not enough on improving learning in the moment.
- We miss a huge opportunity to improve our entire education system when we gather student-learning data in silos and fail to integrate the information and make it broadly available to decision-makers at all levels of our education system—individual educators, schools, districts, states, and the federal government.
- Learning depends on effective teaching, and we need to focus on extended teams of connected educators with different roles who collaborate within schools and across time and distance and who use technology resources and tools to augment human talent.
- Effective teaching is an outcome of preparing and continually training teachers and leaders to guide the type of learning we want in our schools.
- Making engaging learning experiences and resources available to all learners anytime and anywhere requires state-of-the-art infrastructure, which includes technology, people, and processes that ensure continuous access.
- Education can learn much from such industries as business and entertainment about leveraging technology to continuously improve learning outcomes while increasing the productivity of our education system at all levels.
- Just as in health, energy, and defense, the federal government has an important role to play in funding and coordinating some of the R&D challenges associated with leveraging technology to ensure the maximum opportunity to learn.

The plan also assumes that with technology we can provide engaging and powerful learning content, resources, and experiences and assessment systems that measure student learning in more complete, authentic, and meaningful ways. With technology-based learning and assessment systems, we can improve student learning and generate data that can be used to continuously improve the education system at all levels. With technology, we can execute collaborative teaching strategies combined with professional learning strategies that better prepare and enhance educators' competencies and expertise over the course of their careers. With technology, we can redesign and implement processes to produce better outcomes while achieving ever higher levels of productivity and efficiency across the education system.

Collaboration and Investment for Success

Transforming U.S. education is no small task, and accomplishing it will take leadership throughout our education system—states, districts, schools, and the federal government—as well as partnerships with higher education institutions, private enterprises, and not-for-profit entities.

In the United States, education is primarily a state and local responsibility. State and local public education institutions must ensure equitable access to learning experiences for all students and especially students in underserved populations—low-income and minority students, students with disabilities, English language learners, preschool-aged children, and others. States and districts need to build capacity for transformation. The Department of Education has a role in identifying effective strategies and implementation practices; encouraging, promoting, and actively supporting innovation in states and districts; and nurturing collaborations that help states and districts leverage resources so the best ideas can be scaled up.

Building capacity for transformation also will require investment. But we must resolve to spend investment dollars wisely, with clear expectations about what we expect in terms of learning outcomes and process improvements.

Implementing the plan depends on the broadband initiatives of the *American Recovery and Reinvestment Act of 2009,* which are intended to accelerate deployment of Internet services in unserved, underserved, and rural areas and to strategic institutions that are likely to create jobs or provide significant public benefits. These initiatives are the Broadband Technology Opportunities Program of the Department of Commerce's National Telecommunications and Information Administration, the Rural Development Broadband Program of the Department of Agriculture, and the interagency National Broadband Plan developed by the Federal Communications Commission (FCC).

The plan also draws guidance and inspiration from the report of the National Science Foundation (NSF) Task Force on Cyberlearning, *Fostering Learning in the Networked World: The Cyberlearning Challenge and Opportunity,* published in June 2008, and the work of the President's Council of Advisors on Science and Technology (PCAST).

The plan will be best served if postsecondary education institutions—community colleges and four-year colleges and universities—partner with K–12 schools to remove barriers to postsecondary education and put plans of their own in place to decrease dropout rates. In addition, postsecondary institutions are key players in the transformation of teacher preparation and the national R&D efforts recommended in this plan.

Education has long relied on the contributions of organizations in both the private and not-for-profit sectors, and this will not change.

As we enter the second decade of the 21st century, there has never been a more pressing need to transform American education, and there will never be a better time to act. In keeping with the appropriate role of the federal government, this Nation Education Technology Plan is not a prescription but rather a common definition and a five-year action plan that responds to an urgent national priority and a growing understanding of what the United States needs to do to remain competitive in a global economy.

Accessibility of Web Content

Not all of the websites identified in this plan, at the time of its publication, meet the technical requirements for Web accessibility established by Section 508 of the Rehabilitation Act of 1973, *as amended (see http://www.Section508.gov for these requirements). The Department of Education will take appropriate steps to bring all websites subject to Section 508 into compliance with those accessibility requirements as soon as reasonably possible. Moreover, as Secretary of Education Duncan stated in the cover letter to this plan, the Department is committed to taking a leadership role in ensuring that the benefits of educational technology are accessible to all learners "regardless of background, languages, or disabilities." To meet that goal, the Department will not only exercise its authority under sections 508 and 504 of the* Rehabilitation Act of 1973* *as necessary to achieve compliance, but also will work with and encourage the broader educational community to ensure that individuals with disabilities are not denied the benefits of educational technology due to accessibility issues.*

* *Section 504 provides that:*
No otherwise qualified individual with a disability in the United States, as defined in section 705(2) of this title, shall, solely by reason of her or his disability, be excluded from the participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance or under any program or activity conducted by any Executive agency or by the United States Postal Service.

Learning: Engage and Empower

Goal: All learners will have engaging and empowering learning experiences both in and out of school that prepare them to be active, creative, knowledgeable, and ethical participants in our globally networked society.

Our education system today supports learning, mostly in classrooms and from textbooks, and depends on the relationship between individual educators and their students. The role technology plays in the nation's classrooms varies dramatically depending on the funding priorities of states, districts, and schools and individual educators' understanding of how to leverage it in learning in meaningful ways.

Meanwhile, many students' lives outside school are filled with technology that gives them mobile access to information and resources 24/7, enables them to create multimedia content and share it with the world, and allows them to participate in online social networks and communities where people from all over the world share ideas, collaborate, and learn new things. According to a national survey by the Kaiser Family Foundation, 8- to 18-year-olds today devote an average of seven hours and 38 minutes to using entertainment media in a typical day—more than 53 hours a week (Kaiser Family Foundation 2009). The opportunity to harness this interest and access in the service of learning is huge.

Technology brings similar opportunities to professionals in many fields. Physicians use mobile Internet access devices to download x-rays and test results or to access specialized applications, such as medicine dosage calculators. Earthquake geologists install underground sensors along fault lines, monitor them remotely, and tie them in to early warning systems that signal the approach of seismic waves. Filmmakers use everyday computers and affordable software for every phase of the filmmaking process, from editing and special effects to music and sound mixing. Technology dominates the workplaces of most professionals and managers in business, where working in distributed teams that need to communicate and collaborate is the norm.

The challenge for our education system is to leverage technology to create relevant learning experiences that mirror students' daily lives and the reality of their futures. We live in a highly mobile, globally connected society in which young Americans will have more jobs and more careers in their lifetimes than their parents. Learning can no longer be confined to the years we spend in school or the hours we spend in the classroom: It must be lifelong, lifewide, and available on demand (Bransford et al. 2006).

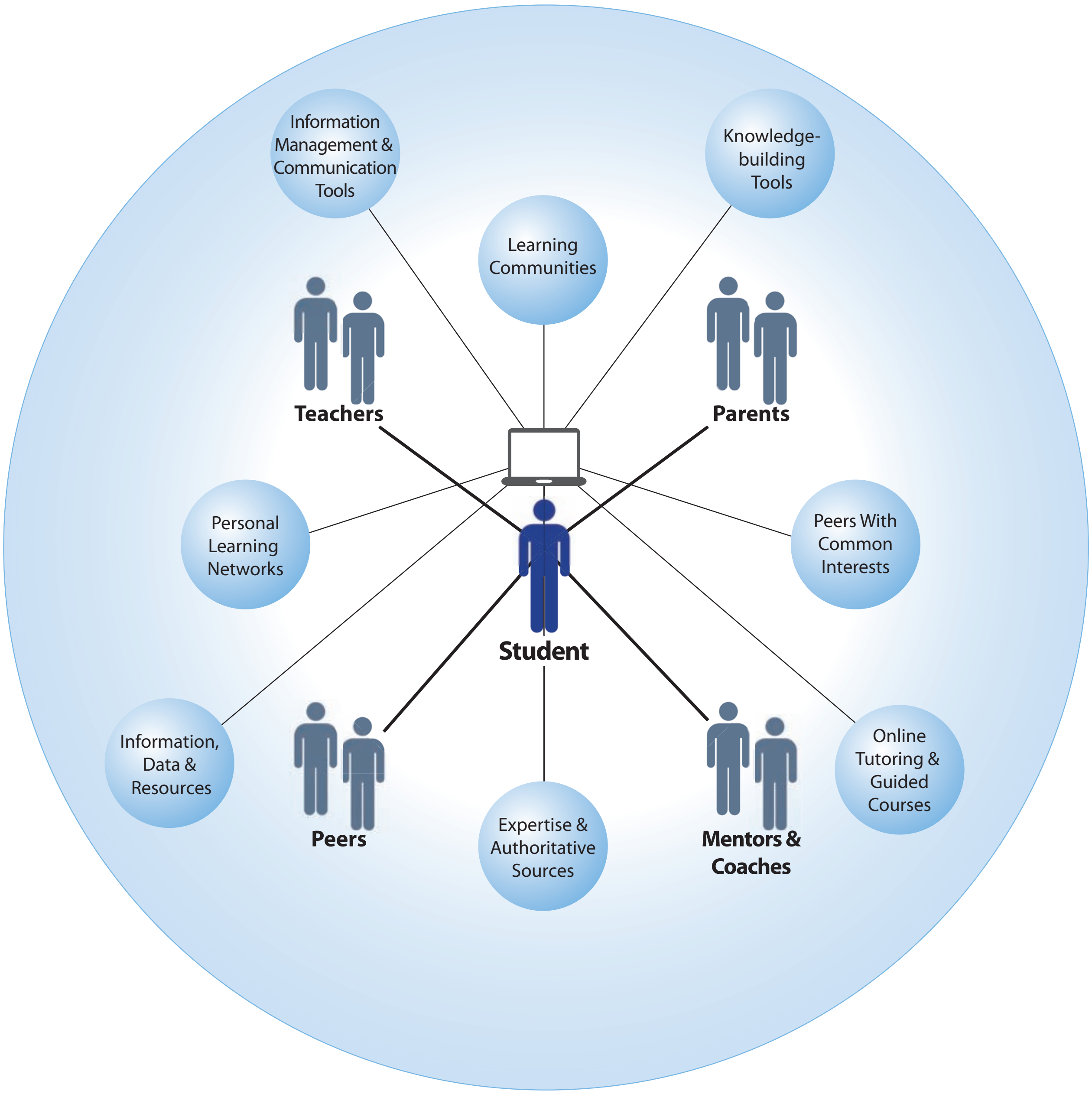
To prepare students to learn throughout their lives and in settings far beyond classrooms, we must change what and how we teach to match what people need to know, how they learn, and where and when they learn and change our perception of who needs to learn. We must bring 21st-century technology into learning in meaningful ways to engage, motivate, and inspire learners of all ages to achieve.

The challenging and rapidly changing demands of our global economy tell us what people need to know and who needs to learn. Advances in learning sciences show us how people learn. Technology makes it possible for us to act on this knowledge and understanding.

What Learning Should Look Like

Figure 1 depicts a model of learning powered by technology. In contrast to traditional classroom instruction, which often consists of a single educator transmitting the same information to all learners in the same way, the model puts students at the center and empowers them to take control of their own learning by providing flexibility on several dimensions. A core set of standards-based concepts and competencies form the basis of what all students should learn, but beyond that students and educators have options for engaging in learning: large groups, small groups, and activities tailored to individual goals, needs, and interests.

Figure 1. A Model of Learning, Powered by Technology



In this model, technology supports learning by providing engaging environments and tools for understanding and remembering content. For example, game-based courses use features familiar to game players to teach core subject content, such as history.

Technology provides access to a much wider and more flexible set of learning resources than is available in classrooms and connections to a wider and more flexible set of "educators," including teachers, parents, experts, and mentors outside the classroom. Engaging and effective learning experiences can be individualized or differentiated for particular learners

Individualized, Personalized, and Differentiated Instruction

Individualization, differentiation, and personalization have become buzzwords in education, but little agreement exists on what exactly they mean beyond the broad concept that each is an alternative to the one-size-fits-all model of teaching and learning. For example, some education professionals use personalization to mean that students are given the choice of what and how they learn according to their interests, and others use it to suggest that instruction is paced differently for different students. Throughout this plan, we use the following definitions:

Individualization *refers to instruction that is paced to the learning needs of different learners. Learning goals are the same for all students, but students can progress through the material at different speeds according to their learning needs. For example, students might take longer to progress through a given topic, skip topics that cover information they already know, or repeat topics they need more help on.*

Differentiation *refers to instruction that is tailored to the learning preferences of different learners. Learning goals are the same for all students, but the method or approach of instruction varies according to the preferences of each student or what research has found works best for students like them.*

Personalization *refers to instruction that is paced to learning needs, tailored to learning preferences, and tailored to the specific interests of different learners. In an environment that is fully personalized, the learning objectives and content as well as the method and pace may all vary (so personalization encompasses differentiation and individualization).*

(either paced or tailored to fit their learning needs) or personalized, which combines paced and tailored learning with flexibility in content or theme to fit the interests and prior experience of each learner. (See sidebar for definitions of individualized, differentiated, and personalized learning.)

An example of individualized and differentiated learning can be found in New York City's School of One pilot, a 2009 summer program that allowed students learning mathematics to learn at their own pace and in a variety of ways. On the basis of its initial success, the School of One concept was expanded in 2010 and is set for further expansion in 2011. (See sidebar on the School of One for more information.)

Personalized learning supports student learning in areas of particular interest to them. For example, a student who learns Russian to read the works of Dostoevsky in their original form and another who orders a surgical kit on eBay to practice sutures on oranges are learning things we would never ask all students to do. But these things are important because they are driven by learners' own passions.

Within specific content areas, although standards exist for what we expect all students to know and be able to do, the model also provides options for how the learning can take place. Among these options is working with others in project-based learning built around challenges with real-world relevance. Well-designed projects help students acquire knowledge in specific content areas and also support the development of more specialized adaptive expertise that can be applied in other areas (Trilling and Fadel 2009). (See sidebar on Winona Middle School for an example of such a project.)

Technology also gives students opportunities for taking ownership of their learning. Student-managed electronic learning portfolios can be part of a persistent learning record and help students develop the self-awareness required to set their own learning goals; express their own views of their strengths, weaknesses, and achievements; and take responsibility for them. Educators can use them to gauge students' development, and they also can be shared with peers, parents, and others who are part of students' extended network.

What People Need to Learn

Education is an enterprise that asks, What's worth knowing and being able to do?

Education experts have proposed answers to this question, and although they differ in the details all recognize that what we need to know goes beyond the traditional three Rs of Reading, 'Riting, and 'Rithmetic. Whether the domain is English language arts, mathematics, sciences, social studies, history, art, or music, 21st-century competencies and expertise such as critical thinking, complex problem solving, collaboration, and multimedia communication should be woven into all content areas.

We are still evolving our understanding of what it means to be a 21st-century learner. For example, what does it mean to be digitally literate in an age of constantly evolving technologies and resources, and how we can teach learners to use new technology in ways that are productive, creative, and responsible? One response to these essential questions is offered by the International Society of Technology in Education (ISTE), which has published the National Educational Technology Standards for Students (NETS–S). (See sidebar on ISTE's standards for students for more information.)

A number of other researchers and organizations also have addressed the issue either in part or whole, and the domain seems to include three categories: information literacy, the ability to identify, retrieve, evaluate, and use information for a variety of purposes; media literacy, the ability to consume and understand media, as well as communicate effectively using a variety of media types; and digital citizenship, the ability to evaluate and use technologies appropriately, behave in socially acceptable ways within online communities, and develop a healthy understanding of issues surrounding online privacy and safety. All this requires a basic understanding of technologies themselves and the ability to make increasingly sound judgments about the use of technology in our daily lives.

Answers to questions about 21st-century learning also must take into account that people no longer can learn everything there is to know in a lifetime, and the economic reality is that most people will change jobs throughout their lives. Therefore, we need adaptive learning skills that blend content knowledge with the ability to learn new things. This requires developing deep understanding within specific domains and the ability to

School of One: Individualizing and Differentiating Learning

During summer 2009, the New York City school system conducted a two-month pilot test of a radically new education concept, the School of One. Conducted at Middle School 131 in New York's Chinatown, the pilot program focused on a single subject, mathematics, and a single grade level (sixth grade). The New York City Department of Education views it as demonstration of a concept that is equally applicable in other subjects and grades.

Instead of organizing the 80 participating students into classes with one of the school's four teachers assigned to each class, the School of One used flexible arrangements of students and teachers and a large collection of alternative ways for students to learn the 77 mathematics skills that were the objectives for the program. The School of One lesson bank included more than 1,000 lessons covering those 77 mathematics skills. Rather than giving every student the same content, the School of One used data from prior assessments to identify which skills each student should work on during the summer. Inputs from teachers and from students provided information about how each student learned best (for example, "likes to learn through games" or "likes to learn alone"). A computer algorithm used information about each student's demonstrated mathematics skills and his or her learning preferences to generate individual "playlists" of appropriate learning activities.

Staff for the summer pilot included teachers whose efforts focused on large-group instruction, college students studying to be teachers who provided small-group instruction and support for online learning, and high school students who focused on tutoring and the grading of assessments.

School of One uses technology to develop a unique learning path for each student and to provide a significant portion of the instruction that is both individualized and differentiated. The New York City Department of Education now operates the School of One program in three middle schools and plans to expand the program to serve over 5,000 students by 2012.

Winona Middle School's Cultural History Project

In 1995, when the Internet was just arriving in schools, students at Winona Middle School in Winona, Minn., began to use it to support and showcase a class project about local history and the changing demographics of their town. Students gathered information about their community by visiting local museums, searching texts, and interviewing local residents. They built a website to share their findings with one another and with their community. The website began to take on a life of its own, attracting the interest of community leaders, professional historians, and individuals living halfway around the world who found they were distant relatives of the town's earliest immigrants. Students expanded the website to include the contributions of the wider community and built a searchable database of genealogical information and other artifacts.

Today, Winona's Cultural History website continues to be a valuable resource for the school and its community, and students continue to interact with others in or outside their local area to evolve an ongoing knowledge base. One of the secrets of this project's success is that it leverages very simple technology so that it can be sustained with minimal funding and maintenance.

ISTE's National Educational Technology Standards for Students

The International Society for Technology in Education has created National Educational Technology Standards for Students (NETS-S) that encompass a full range of technology competencies. The NETS standards include

- ***Creativity and innovation.*** *Students should be able to use technology and their existing knowledge to generate new ideas, products, or processes.*
- ***Communication and collaboration.*** *Students should be able to work collaboratively, both in person and at a distance, and to communicate ideas effectively to multiple audiences using new media.*
- ***Research and information fluency.*** *Students should be able to use a variety of digital media to locate, organize, analyze, and evaluate information from a variety of sources.*
- ***Critical thinking, problem solving, and decision making****. Students should be able to define problems, plan and conduct research, and identify solutions or appropriate decisions using digital tools and resources.*
- ***Digital citizenship.*** *Students should take responsibility for their own lifelong learning and should practice safe, legal, and ethical use of information and digital tools.*
- ***Technology operations and concepts.*** *Students should understand technology systems, select and use technology applications effectively, and be able to troubleshoot systems and applications.*

make connections that cut across domains—learning activities that should replace the broad but shallow exposure to many topics that is the norm in our education system today. We also need to know how to use the same technology in learning that professionals in various disciplines do.

Professionals routinely use Web resources and such participatory technology as wikis, blogs, and user-generated content for the research, collaboration, and communication demanded in their jobs. For students, these tools create new learning activities that allow them to grapple with real-world problems, develop search strategies, evaluate the credibility and authority of websites and authors, and create and communicate with multimedia (Jenkins 2009; Leu et al. 2004). For example,

- In the study of mathematics, professional-level interactive graphing and statistical programs make complex topics more accessible to all learners and help them connect to datasets that are current and relevant to their lives.
- In earth sciences, collecting data with inquiry tools, adding geotags with GPS tools, and interactively analyzing visualizations of data patterns through Web browsers bring professional scientific methods and techniques to learners of all ages and abilities.
- In history, original documents available to historians as digital resources from the Smithsonian and other institutions are available to engage learners in historical thinking and reasoning.

As these examples illustrate, the world's information and sophisticated tools for using it, which are available anytime and anywhere, demand that in addition to knowing content, we become expert learners in at least three ways:

- As skillful and strategic learners who have learned how to learn new things and communicate what we have learned;
- As motivated and engaged learners who identify ourselves as growing in competence and want to learn even more; and

- As networked learners who have the ability to tap expertise anytime and anywhere that can advance our learning.

A crucial step in transforming American education to produce expert learners is creating, revising, and adopting content standards and learning objectives for all content areas that reflect 21st-century expertise and the power of technology to improve learning.

How People Learn

Advances in the learning sciences, including cognitive science, neuroscience, education, and social sciences, give us greater understanding of three connected types of human learning—factual knowledge, procedural knowledge, and motivational engagement. Neuroscience tells us that these three different types of learning are supported by three different brain systems. (See sidebar on the neuroscience of learning.) Social sciences reveal that human expertise integrates all three types of learning. Technology has increased our ability to both study and enhance all three types of learning (National Research Council 2000, 2003, 2007, 2009; National Science Foundation 2008b).

Factual Knowledge

Students are surrounded with information in a variety of forms, and specific features of information design affect how and whether students build usable knowledge from the information they encounter. For example, computers can replicate and integrate a wide variety of media for learning and education: text, video/film, animations, graphics, photos, diagrams, simulations, and more. As a result, technology can be designed to provide much richer learning experiences without sacrificing what traditional learning media offer. Technology can

- Represent information through a much richer mix of media types. This allows the integration of media and representations to illustrate, explain, or explore complex ideas and phenomena, such as interactive visualizations of data in earth and environmental sciences, chemistry, or astronomy. Technology can help learners explore phenomena at extreme spatial or temporal scales through simulation and modeling tools. This opens up many domains and ways of learning that were formerly impossible or impractical. (See sidebar on Chesapeake Bay FieldScope.)

The Neuroscience of Learning

Three broad types of learning—learning that, learning how, and learning why—each correspond to one of three main areas of the human brain.

Learning that *is associated with the posterior brain regions (the parietal, occipital, and temporal lobes within the cerebral cortex). These regions primarily take information in from the senses and transform it into usable knowledge—the patterns, facts, concepts, objects, principles, and regularities of our world. The medial temporal lobe, including the hippocampus, provides a system of anatomically related structures essential to conscious memory for facts and events—what is called declarative knowledge (Squire, Stark, and Clark 2004).*

Learning how *is associated with the anterior parts of the brain (the frontal lobe, from the primary motor cortex to the prefrontal cortex), specialized for learning how to do things, and is expressed through performance (Squire 2004). This also has been called procedural knowledge, implicit memory, and knowing how. This type includes learning "low-level" motor skills but also high-level skills and strategies known as executive functions.*

Learning why *is associated with the interior or central brain regions, including the extended limbic system and amygdale. These evolutionarily primitive brain regions are specialized for affective and emotional learning (LeDoux 2000). They contribute to learning and remembering not what an object is or how to use it but why it is important to us. These structures underlie what attracts our attention and interest, sustains our effort, motivates our behavior, and guides our goal setting and priorities. With these regions, we learn our values and priorities: our image as a person and as a learner and the values and goals that comprise it.*

Chesapeake Bay FieldScope: Analyzing Authentic Scientific Phenomena

Chesapeake Bay FieldScope is a collaborative high school science project that combines traditional hands-on fieldwork with Web-based geospatial technology and other tools to help students build a rich understanding of the ecosystem around them. Students use National Geographic FieldScope, a Web-based mapping, analysis, and collaboration tool, to investigate water quality issues in and around the Chesapeake Bay. In the classroom, students learn about the bay using a multimedia database of scientific information. In the field, students gather their own scientific observations (such as water quality samples, written notes, or digital photos of wildlife) and then upload them to the FieldScope database. All database information is organized as points on a map, providing an intuitive geospatial format to scaffold student learning.

- Facilitate knowledge connections through interactive tools. These include interactive concept maps, data displays, and timelines that provide visual connections between existing knowledge and new ideas.

Procedural Knowledge

Procedural knowledge learning includes both content-related procedures (learning how to do science inquiry, for example) and learning-related strategies (learning how to figure out how to solve a new problem or self-monitor progress on a task). Technology can expand and support a growing repertoire of strategies for individual learners by

- Providing scaffolds to guide learners through the learning process. Many programs use interactive prompts embedded directly into the learning resources, live or virtual modeling of helpful strategies, interactive queries that prompt effective processing, and timely and informative feedback on results. These scaffolds can be designed to respond to differences in individual learning styles and be available on demand when the learner needs help and then evolve or fade as the learner builds stronger skills.

- Providing tools for communicating learning beyond written or spoken language. This can be accomplished through Web-based multimedia, multimedia presentations, or such gestural expressions as those that drive interactions in gaming systems.

- Fostering online communities. Technology can provide platforms for connecting learners in online communities where they can support each other as they explore and develop deeper understanding of new ideas, share resources, work together beyond the walls of a school or home, and gain access to a much wider pool of expertise, guidance, and support (Ito 2009).

Motivational Engagement

The field of affective neuroscience has drawn attention to the critical importance of motivation in how the brain learns. We learn and remember what attracts our interest and attention, and what attracts interest and attention can vary by learner. Therefore, the most effective learning experiences are not only individualized in terms of pacing and differentiated to fit the learning needs of particular learners, but also personalized in the sense that they are flexible in content or theme to fit the interests of particular learners.

To stimulate motivational engagement, technology can

- Engage interest and attention. Digital learning resources enable engaging individual learners' personal interests by connecting Web-learning resources to learning standards, providing options for adjusting the challenge level of learning tasks to avoid boredom or frustration, and bridging informal and formal learning in and out of school (Brown and Adler 2008; Collins and Halverson 2009; National Science Foundation 2008b). Technology also can be used to create learning resources that provide immediate feedback modeled on games to help engage and motivate learners (Gee 2004).

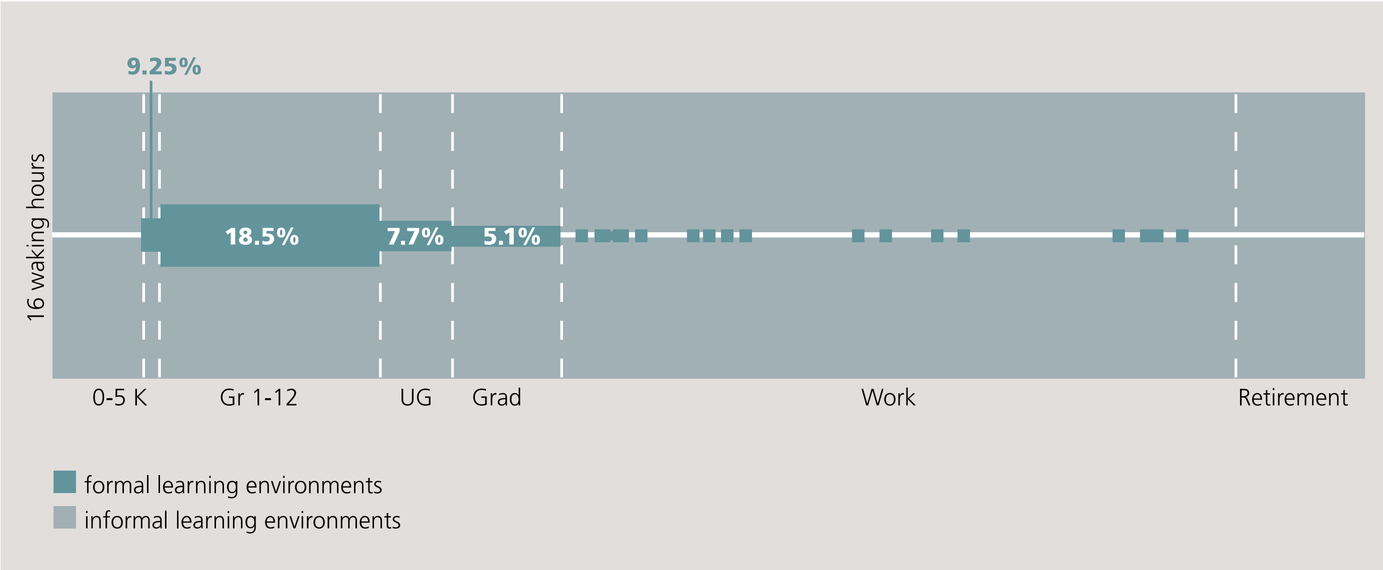
- Sustain effort and academic motivation. Technology-based learning resources can give learners choices that keep them engaged in learning, for example, by providing personally relevant content, a customized interface, options for difficulty level or alternative learning pathways, or choices for support and guidance.

- Develop a positive image as a lifelong learner. Technology can inspire imagination and intellectual curiosity that help people engage actively as learners and open new channels for success or visions of career possibilities. For example, when students use the tools of professionals to engage in real-world problems, they can begin to see themselves in productive professional roles ("I am a graphic artist," "I am a scientist," "I am a teacher"). Technology also provides opportunities for students to express themselves by engaging in online communities and sharing content they have created with the world.

Where and When People Learn

Not that long ago, people expected to learn much of the information and skills they needed for life and work within the confines of a school day and their years in school. Today, learning must be continuous and lifelong. (See Figure 2.)

Figure 2. Lifelong and lifewide learning



Source: Banks et al. 2006.

A key enabler of continuous and lifelong learning is technology. Technology gives learners direct access to learning and to the building blocks of their knowledge—organized, indexed, and available 24/7. This empowers learners to take control of and personalize their learning. Technology also can serve as a bridge across formal (in school) and informal (outside school) learning settings (Barron 2006), creating new opportunities to leverage informal learning by integrating it purposefully into the fabric of formal learning. Technology also provides ways to ensure that as students pursue self-directed and informal learning they are still guided by professional educators.

These are powerful ideas for individual learners but even more so when applied to groups of learners and learning communities—from small groups with different roles and responsibilities in pursuit of a learning project to far larger communities that may be pursuing ambitious design and learning products. Group learning especially is enhanced by social and participatory approaches, such as wikis, in which learners and teachers regardless of their location or the time of day can build knowledge structures or tackle inquiry problems that are posed together. Social media content created by teachers and learners, from blogs to podcasts to YouTube videos or creations and performances in virtual worlds (Jenkins 2009; Johnson, Levine, and Smith 2009; OECD 2008, 2009b), enrich such learning.

Specific examples of individual and collaborative learning with technology include the following:

- Inquiry and adventure environments with games and activities that foster learning.
- Online “collaboratories” (National Science Foundation 2008a) in which scientists establish protocols for collecting data with sensors from local environments across the planet. Learners and teachers learn science by doing science as they capture, upload, and then visualize and analyze geospatial and temporal data patterns from the data contributed by the globally networked community.
- Earth- and sky-mapping Web resources with data from the sciences and other fields of scholarly inquiry that anyone can use to develop virtual travel tours to be applied in learning and teaching activities.
- Augmented reality platforms and games that bring locally relevant learning resources into view for users of mobile devices with a GPS (Johnson et al. 2010).
- Use of the power of collective intelligence and crowdsourcing to tackle complex interdisciplinary problems.
- Powerful learning applications for mobile Internet access devices, such as musical instrument simulators, language-learning tools, and mathematical games.
- Sites and communities that publish academic content, including user-generated content. One notable example is the videotaped lectures of MIT physics professor Walter Lewin, available on MIT’s OpenCourseWare site as well as through commercial courseware and video-sharing sites. Lewin’s engaging and entertaining lectures have earned him a following of millions worldwide.

Who Needs to Learn

The United States cannot prosper economically, culturally, or politically if major parts of our citizenry lack a strong educational foundation, yet far too many students are not served by our current one-size-fits-all education system. The learning sciences and technology can help us design and provide more effective learning experiences for all learners.

Universal Design for Learning

Making learning experiences accessible to all learners requires universal design, a concept well established in the field of architecture, where all modern public buildings, including schools, are designed to be accessible by everyone. Principles and guidelines have been established for universal design in education based on decades of research and are known as Universal Design for Learning (UDL). The UDL principles reflect the way students take in and process information (Rose and Meyer 2002). Using them to develop goals, instructional methods, classroom materials, and assessments, educators can improve outcomes for diverse learners by providing fair opportunities for learning by improving access to content. The UDL principles are as follows:

- Provide multiple and flexible methods of presentation of information and knowledge. Examples include digital books, specialized software and websites, text-to-speech applications, and screen readers.

- Provide multiple and flexible means of expression with alternatives for students to demonstrate what they have learned. Examples include online concept mapping and speech-to-text programs.

- Provide multiple and flexible means of engagement to tap into diverse learners' interests, challenge them appropriately, and motivate them to learn. Examples include choices among different scenarios or content for learning the same competency and opportunities for increased collaboration or scaffolding.

The definition of UDL that appears in the *Higher Education Opportunity Act* of 2008 (103 U.S.C. § 42) has come to dominate the field because of its broad applicability and its research foundation in the learning sciences, both cognitive and neurosciences.

Serving the Underserved

The goal of UDL is to reach all learners, but some groups are especially underserved. In the past two decades, the disparities in access to and the use of technology have been closely associated with socioeconomic status, ethnicity, geographical location, and gender; primary language; disability; educational level; and generational characteristics (Pew Internet & American Life Project 2007). The FCC now refers to "digital exclusion" as what must be

Universal Design for Textbooks: National Instructional Materials Accessibility Standard—NIMAS

Traditional textbooks, like any standardized learning technology, are much more accessible to some learners than others. For students who are blind, who have physical disabilities, or who have reading disabilities, textbooks impose barriers rather than opportunities for learning. In the past, each classroom teacher or school had to generate some kind of work-around to overcome these barriers—contracting for a Braille version of the book, engaging an aide to help with the physical demands of textbooks, recording or purchasing an audio version for students with dyslexia, and so forth. The costs—in time, resources, learning opportunities—of retrofitting in these ways are high. Most important, the costs of such one-off accommodations are repeated in every classroom and district throughout the country—a staggering waste of money and time.

In 2006, the U.S. Congress mandated a new and more universally designed approach. In that year, regulations for the National Instructional Materials Accessibility Standard (NIMAS) went into effect. That standard stipulates that all U.S. textbooks be available as a "digital source file" (a fully marked up XML source file based on the Daisy international standard). The power of that digital source file is in its flexibility: It can be easily transformed into many different student-ready versions, including a Braille book, a digital talking book, a large-text version, and so forth. The same content can be generated once by a publisher but can be displayed in many different ways to match the different needs of diverse students.

overcome, because job applications, health information, and many other crucial information resources appear only in the digital realm (Federal Communications Commission 2009). As we use technology to reach all learners, the following groups need special attention:

- Low-income and minority learners. Despite significant gains, learners from low-income communities and underserved minority groups still are less likely to have computers and Internet access and have fewer people in their social circles with the skills to support technology-based learning at home (Warschauer and Matuchniak 2010). Some of the solutions to the access problem are capitalizing on existing programs in the public sphere—extended hours for use of networked computers in schools, libraries, community centers, and so on.

- English language learners. English is the predominant language of instruction in most U.S. classrooms and in the vast majority of Web resources. The challenges of learning the content and skills necessary to function as a 21st-century citizen are heightened if English is not a person's first language. Recent advances in language translation technology provide powerful tools for reducing language barriers. With proper design, technology can easily represent information so that there are multiple alternatives for English, multiple options for unfamiliar vocabulary or syntax, and even alternatives to language itself (use of image, video, and audio).

- Learners with disabilities. In public schools, many learners are identified as having special needs. These students need accommodations to have the opportunity to achieve at the same levels as their peers. In addition to UDL for learners with significant physical and sensory disabilities, powerful new assistive technologies are increasingly becoming available to improve access to learning opportunities. These include electronic mobility switches and alternative keyboards for students with physical disabilities, computer-screen enlargers and text-to-speech and screen readers for individuals with visual disabilities, electronic sign-language dictionaries and signing avatars for learners with hearing disabilities, and calculators and spellcheckers for individuals with learning disabilities. Many of these devices are difficult or impossible to use with traditional learning materials, such as printed textbooks. The advantage of digital resources, especially those that are universally designed, is that they can easily be made accessible through assistive technologies. (See the sidebar on universal design for textbooks.)

- Early childhood: For underserved children, learning gaps in literacy begin in early childhood and become increasingly difficult to overcome as their education progresses. Early intervention is crucial if these children are to keep pace with their peers, especially intervention that augments the linguistic, visual, and symbolic worlds that learners experience and seek to emulate. Increasingly, educational television offerings are being complemented with computer-based activities and resources for caregivers that help them engage with young learners around the learning content. A recent rigorous experimental test of such a combination, when used in daycare settings to target early literacy skills, found significant positive effects. (See the sidebar on building early literacy skills through technology.)

- Adult workforce. Many adults in the workforce are underproductive, have no postsecondary credential, and face limited opportunities because they lack fluency in English or other basic literacy skills. Unfortunately, they have little time or opportunity for the sustained learning and development that becoming fluent would require. For these learners, technology expands the opportunities for where and when they can learn, enabling them to catch up and continue to learn. Such resources as Learner Web and USA Learns make it possible for working adults to take online courses anytime and anywhere. While individual adults benefit from more opportunities for advancement, companies and agencies benefit from the increased productivity of a fully literate workforce, one continuously preparing for the future. (See the sidebar on adult learning resources.)

- Seniors. The aging population is rapidly expanding, and elders have specific disabilities—visual, hearing, motor, cognitive—that accompany the neurology of aging. At the same time, seniors have special strengths that come from their accumulated wisdom and experience. Capitalizing on those strengths in supporting lifelong learning for seniors requires careful design of learning environments and the use of technology so that sensory

Building Early Literacy Skills Through Technology-rich Learning Experiences

Although decades of research show that public media can improve literacy skills when young children watch at home (Fisch 2004; Thakkar, Garrison, and Christakis 2006), using digital media in preschools has been more controversial. Now, new research suggests that technology-rich classroom experiences can help build young children's school readiness skills (Penuel et al. 2009).

In a recent study, researchers evaluated the impact of a 10-week literacy intervention built around media-rich materials developed with support from Ready to Learn. The intervention targeted preschool children's literacy skills through a combination of teacher-led video viewings of PBS shows, educational computer games, and hands-on activities. Early childhood educators learned how to use the media as tools to support academic instruction, actively engaging children with technology to teach key learning concepts.

Children who participated in the literacy curriculum outscored the control group children on four important literacy measures that predict later reading success: the ability to name letters, know the sounds associated with those letters, recognize letters in their own names, and understand basic concepts about stories and printed words. Notably, these learning gains were of a magnitude rarely observed in preschool curriculum intervention studies (Preschool Curriculum Evaluation Research Consortium 2008), demonstrating the power of technology-based interventions to help close early learning gaps.

Adult Learning Resources

Learner Web

Developed at Portland State University, Learner Web is a learning support system for adults with a specific goal, such as earning a GED, transitioning to higher education, or gaining skills to qualify for a job. The system is structured around the adult's selected learning plan and offers courseware, work with a tutor or teacher, assessments, and an electronic portfolio. Learners can receive assistance both over the Web and by telephone.

USA Learns

The online multimedia resource USA Learns helps adult learners increase their skills in reading, writing, and speaking English. USA Learns was created for Spanish-speaking adult immigrants by the U.S. Department of Education in collaboration with the Sacramento County Office of Education and the University of Michigan Institute of Social Research. The topics, characters, and simulations in USA Learns reflect the challenges of the immigrant experience. The system is intended for home use but includes a management component that teachers or tutors can use to monitor progress if the adult learner is in a formal program. Users of USA Learns can choose to get instructions in English or Spanish, and immediate feedback and comprehension checks and quizzes help learners gauge their own progress.

weaknesses (in vision or hearing) and mnemonic capacity (in working and associative memory) do not erect insurmountable barriers to continued learning, independence, and socialization.

Enabling All Learners to Excel in STEM

The state of science and engineering in the United States is strong, but U.S. dominance worldwide has eroded significantly in recent years, primarily because of rapidly increasing capability in East Asian nations, particularly China (National Science Board 2010). In addition, new data show that U.S. 15-year-olds are losing ground in science and math achievement compared with their peers around the world (McKinsey & Company 2009).

In November 2009, President Obama launched the Educate to Innovate campaign to improve the participation and performance of America's students in STEM with the goal of enabling all learners to excel in STEM. In January 2010, the President announced a new set of public-private partnerships committing $250 million in private resources to attract, develop, reward, and retain STEM educators.

In addition, the NSF through its cyberlearning initiatives and the President's Council of Advisors on Science and Technology (PCAST) are making recommendations to guide the restructuring of STEM domains for more effective learning with technology, taking into account that technologies for representing, manipulating, and communicating information and ideas have changed professional practices and what students need to learn to be prepared for STEM professions. In particular, technology can be used to support student interaction with STEM content in ways that promote deeper understanding of complex ideas, engage students in solving complex problems, and create new opportunities for STEM learning at all levels of our education system.

Reaching Our Goal

1.0 Learning:

All learners will have engaging and empowering learning experiences both in and out of school that prepare them to be active, creative, knowledgeable, and ethical participants in our globally networked society.

To meet this goal, we recommend the following:

1.1 States should continue to revise, create, and implement standards and learning objectives using technology for all content areas that reflect 21st-century expertise and the power of technology to improve learning.

Our education system relies on core sets of standards-based concepts and competencies that form the basis of what all students should know and should be able to do. Whether the domain is English language arts, mathematics, sciences, social studies, history, art, or music, states should continue to consider the integration of 21st-century competencies and expertise, such as critical thinking, complex problem solving, collaboration, multimedia communication, and technological competencies demonstrated by professionals in various disciplines.

1.2 States, districts, and others should develop and implement learning resources that use technology to embody design principles from the learning sciences.

Advances in learning sciences, including cognitive science, neuroscience, education, and social sciences, give us greater understanding of three connected types of human learning—factual knowledge, procedural knowledge, and motivational engagement. Technology has increased our ability to both study and enhance all three types. Today's learning environments should reflect what we have learned about how people learn and take advantage of technology to optimize learning.

1.3 States, districts, and others should develop and implement learning resources that exploit the flexibility and power of technology to reach all learners anytime and anywhere.

The always-on nature of the Internet and mobile access devices provides our education system with the opportunity to create learning experiences that are available anytime and anywhere. When combined with design principles for personalized learning and UDL, these experiences also can be accessed by learners who have been marginalized in many educational settings: students from low-income communities and minorities, English language learners, students with disabilities, students who are gifted and talented, students from diverse cultures and linguistic backgrounds, and students in rural areas.

1.4 Use advances in learning sciences and technology to enhance STEM learning and develop, adopt, and evaluate new methodologies with the potential to inspire and enable all learners to excel in STEM.

New technologies for representing, manipulating, and communicating data, information, and ideas have changed professional practices in STEM fields and what students need to learn to be prepared for STEM professions. Technology should be used to support student interaction with STEM content in ways that promote deeper understanding of complex ideas, engage students in solving complex problems, and create new opportunities for STEM learning throughout our education system.

Assessment: Measure What Matters

Goal: Our education system at all levels will leverage the power of technology to measure what matters and use assessment data for continuous improvement.

Most of the assessment done in schools today is after the fact and designed to indicate only whether students have learned. Little is done to assess students' thinking during learning so we can help them learn better. Nor do we collect and aggregate student-learning data in ways that make the information valuable to and accessible by educators, schools, districts, states, and the nation to support continuous improvement and innovation. We are not using the full flexibility and power of technology to design, develop, and validate new assessment materials and processes for both formative and summative uses.

Just as learning sciences and technology play an essential role in helping us create more effective learning experiences, when combined with assessment theory they also can provide a foundation for much-needed improvements in assessment (Pellegrino, Chudowsky, and Glaser 2001; Tucker 2009). These improvements include finding new and better ways to assess what matters, doing assessment in the course of learning when there is still time to improve student performance, and involving multiple stakeholders in the process of designing, conducting, and using assessment.

Equally important, we now are acutely aware of the need to make data-driven decisions at every level of our education system on the basis of what is best for each and every student—decisions that in aggregate will lead to better performance and greater efficiency across the entire system.

What We Should Be Assessing

> *"I'm calling on our nation's governors and state education chiefs to develop standards and assessments that don't simply measure whether students can fill in a bubble on a test, but whether they possess 21st century skills like problem-solving and critical thinking and entrepreneurship and creativity."*
>
> *—President Barack Obama,*
> *Address to the Hispanic Chamber of Commerce, March 10, 2009*

President Obama issued this challenge to change our thinking about what we should be assessing. Measuring these complex skills requires designing and developing assessments that address the full range of expertise and competencies implied by the standards. Cognitive research and theory provide rich models and representations of how students understand and think about key concepts in the curriculum and how the knowledge structures we want students to have by the time they reach college develop over time. An illustration of the power of combining research and theory with technology is provided by the work of Jim Minstrell, a former high school physics teacher who developed an approach to teaching and assessment that carefully considers learners' thinking.

Minstrell's work began with a compilation of student ideas about force and motion based on both the research literature and the observations of educators. Some of these student ideas, or "facets" in Minstrell's terminology, are considered scientifically correct to the degree one would expect at the stage of introductory physics. Others are partially incorrect, and still others are seriously flawed. Using these facets as a foundation, Minstrell designed a Web-based assessment program with sets of questions that can be used to inform learning about force and motion rather than simply test how much students have learned (Minstrell and Kraus 2005). Minstrell's facet assessments and instructional materials are available on the Web (http://www.diagnoser.com).

Technology Supports Assessing Complex Competencies

As Minstrell's and others' work shows, through multimedia, interactivity, and connectivity it is possible to assess competencies that we believe are important and that are aspects of thinking highlighted in cognitive research. It also is possible to directly assess problem-solving skills, make visible sequences of actions taken by learners in simulated environments, model complex reasoning tasks, and do it all within the contexts of relevant societal issues and problems that people care about in everyday life (Vendlinski and Stevens 2002).

Other technologies enable us to assess how well students communicate for a variety of purposes and in a variety of ways, including in virtual environments. An example of this is River City, a decade-long effort at Harvard University funded by the NSF. River City is a multiuser virtual environment designed by researchers to study how students learn through using it (Dede 2009). This virtual environment was built as a context in which middle school students could acquire concepts in biology, ecology, and epidemiology while planning and implementing scientific investigations in a virtual world.

River City takes students into an industrial city at the time in the 18th century when scientists were just beginning to discover bacteria. Each student is represented as an avatar and communicates with other student avatars through chat and gestures. Students work in teams of three, moving through River City to collect data and run tests in response to the mayor's challenge to find out why River City residents are falling ill. The student teams form and test hypotheses within the virtual city, analyze data, and write up their research in a report they deliver to the mayor.

Student performance in River City can be assessed by analyzing the reports that are the culmination of their experiences and also by looking at the kinds of information each student and each student team chose to examine and their moment-to-moment movements, actions, and utterances. On the basis of student actions in River City, researchers developed measures of students' science inquiry skills, sense of efficacy as a scientist, and science concept knowledge (Dede 2009; Dieterle 2009). Materials and other resources have been developed to support educators in implementing River City in their classrooms.

As the River City example illustrates, just as technology has changed the nature of inquiry among professionals, it can change how the corresponding academic subjects can be taught and tested. Technology allows representation of domains, systems, models, and data and their manipulation in ways that previously were not possible. Technology enables the use of dynamic models of systems, such as an energy-efficient car, a recycling program, or a molecular structure. Technology makes it possible to assess students by asking them to design products or experiments, to manipulate parameters, run tests, record data, and graph and describe their results.

Technology-based Assessment Using a Hot-air Balloon Simulation

The National Assessment of Educational Progress (NAEP) has been exploring the use of more complex assessment tasks enabled by technology. In one technology-based simulation task, for example, eighth-graders are asked to use a hot air balloon simulation to design and conduct an experiment to determine the relationship between payload mass and balloon altitude. After completing the tutorial about the simulation tool interface, students select values for the independent variable payload mass. They can observe the balloon rise in the flight box and note changes in the values of the dependent variables of altitude, balloon volume, and time to final altitude.

In another problem, the amount of helium, another independent variable, is held constant to reduce the task's difficulty. Students can construct tables and graphs and draw conclusions by clicking on the buttons below the heading Interpret Results. As they work with the simulation, students can get help if they need it: A glossary of science terms, science help about the substance of the problem, and computer help about the buttons and functions of the simulation interface are built in to the technology environment. The simulation task takes 60 minutes to complete, and student performance is used to derive measures of the student's computer skills, scientific inquiry exploration skills, and scientific inquiry synthesis skills within the context of physics.

Another advantage to technology-based assessments is we can use them to assess what students learn outside school walls and hours as well as inside. Assuming that we have standards for the competencies students must have and valid, reliable techniques for measuring these competencies, technology can help us assess (and reward) learning regardless of when and where it takes place.

The National Assessment of Educational Progress (NAEP) has designed and fielded several technology-based assessments involving complex tasks and problem situations (Bennett et al. 2007). (See sidebar on technology-based assessment using a hot-air balloon simulation.)

Growing recognition of the need to assess complex competencies also is demonstrated by the Department's Race to the Top Assessment Competition. The 2010 competition challenged teams of states to develop student assessment systems that assess the full range of standards, including students' ability to analyze and solve complex problems, synthesize information, and apply knowledge to new situations. The Department of Education urged participants in this competition to take advantage of the capabilities of technology to provide students with realistic, complex performance tasks; provide immediate scoring and feedback; and incorporate accommodations that make the assessments usable by a diverse array of students (Weiss 2010)

Using Technology to Assess in Ways That Improve Learning

There is a difference between using assessments to determine what students have learned for grading and accountability purposes (summative uses) and using assessments to diagnose and modify the conditions of learning and instruction (formative uses). Both uses are important, but the latter can improve student learning in the moment (Black and Wiliam 1998). Concepts that are widely misunderstood can be explained and demonstrated in a way that directly addresses students' misconceptions. Strategic pairing of students who think about a concept in different ways can lead to conceptual growth for both of them as a result of experiences trying to communicate and support their ideas.

Assessing in the Classroom

Educators routinely try to gather information about their students' learning on the basis of what students do in class. But for any question posed in the classroom, only a few students respond. Educators' insight into what the remaining students do and do not understand is informed only by selected students' facial expressions of interest, boredom, or puzzlement.

To solve this problem, a number of groups are exploring the use of various technologies to "instrument" the classroom in an attempt to find out what students are thinking. One example is the use of simple response devices designed to work with multiple-choice and true-false questions. Useful information can be gained from answers to these types of questions if they are carefully designed and used in meaningful ways. Physics professor Eric Mazur poses multiple-choice physics problems to his college classes, has the students use response devices to answer questions, and then has them discuss the problem with a peer who gave a different answer. Mazur reports much higher levels of engagement and better student learning from this combination of a classroom response system and peer instruction (Mazur 1997).

Science educators in Singapore have adopted a more sophisticated system that supports peer instruction by capturing more complex kinds of student responses. Called Group Scribbles, the system allows every student to contribute to a classroom discussion by placing and arranging sketches or small notes (drawn with a stylus on a tablet or handheld computer) on an electronic whiteboard. One educator using Group Scribbles asked groups of students to sketch different ways of forming an electric circuit with a light bulb and to share them by placing them on a whiteboard. Students learned by explaining their work to others and through providing and receiving feedback (Looi, Chen, and Ng 2010). (See sidebar on networked graphing calculators for another example of how a technology-based assessment can be used to adjust instruction.)

Using Networked Graphing Calculators for Formative Assessment

Over a wireless network, students can contribute mathematical content to the classroom, such as algebraic functions or graphs—content that is much richer than the answer to a multiple-choice question.

Mrs. J, an experienced science teacher in an urban middle school, participated in a large field trial testing the effectiveness of networked graphing calculators. When district-level tests had revealed that her students struggled to interpret graphs, Mrs. J used the graphing calculator-based wireless system to implement weekly practice on graph interpretations, overcoming her initial feeling that "technology is just overwhelming." She reported, "I have taught for 18 years and I have been in seventh-grade science for about 15 of the 18 … and there are things that I have always been really sure that … kids have understood completely. Now I see what they are thinking. And I am like, whoa, I am just amazed."

Mrs. J used the insights into her students' misunderstandings as revealed by the graphs they constructed to guide her instructional decisions.

Mrs. J also found the classroom network technology beneficial for providing specific help for individual students: "We were doing earth and sun relationships … revolution versus rotation … and … I was able to … see who was making those mistakes still…. So it helped me because I could pinpoint [students' weaknesses] without embarrassing them."

Assessing During Online Learning

When students are learning online, there are multiple opportunities to exploit the power of technology for formative assessment. The same technology that supports learning activities gathers data in the course of learning that can be used for assessment (Lovett, Meyer, and Thille 2008). An online system can collect much more and much more detailed information about how students are learning than manual methods. As students work, the system can capture their inputs and collect evidence of their problem-solving sequences, knowledge, and strategy use, as reflected by the information each student selects or inputs, the number of attempts the student makes, the number of hints and type of feedback given, and the time allocation across parts of the problem.

The ASSISTment system, currently used by more than 4,000 students in Worcester County Public Schools in Massachusetts, is an example of a Web-based tutoring system that combines online learning and assessment activities (Feng, Heffernan, and Koedinger 2009). The name ASSISTment is a blend of tutoring "assistance" with "assessment" reporting to educators. The ASSISTment system was designed by researchers at Worcester Polytechnic Institute and Carnegie Mellon University to teach middle school math concepts and to provide educators with a detailed assessment of students' developing math skills and their skills as learners. It gives educators detailed reports of students' mastery of 100 math skills, as well as their accuracy, speed, help-seeking behavior, and number of problem-solving attempts. The ASSISTment system can identify the difficulties that individual students are having and the weaknesses demonstrated by the class as a whole so that educators can tailor the focus of their upcoming instruction.

When students respond to ASSISTment problems, they receive hints and tutoring to the extent they need them. At the same time, how individual students respond to the problems and how much support they need from the system to generate correct responses constitute valuable assessment information. Each week, when students work on the ASSISTment website, the system "learns" more about the students' abilities and thus can provide increasingly appropriate tutoring and can generate increasingly accurate predictions of how well the students will do on the end-of-year standardized test. In fact, the ASSISTment system has been found to be more accurate at predicting students' performance on the state examination than the pen-and-paper benchmark tests developed for that purpose (Feng, Heffernan, and Koedinger 2009).

How Technology Supports Better Assessment

Adaptive Assessment Facilitates Differentiated Learning

As we move to a model where learners have options in terms of how they learn, there is a new role for assessment in diagnosing how best to support an individual learner. This new role should not be confused with computerized adaptive testing, which has been used for years to give examinees different assessment items depending on their responses to previous items on the test in order to get more precise estimates of ability using fewer test items.

Adaptive assessment has a different goal. It is designed to identify the next kind of learning experience that will most benefit the particular learner. The School of One demonstration project (see the sidebar on the School of One in the Learning section) used adaptive assessment to differentiate learning by combining information from inventories that students completed on how they like to learn with information on students' actual learning gains after different types of experiences (working with a tutor, small-group instruction, learning online, learning through games). This information was used to generate individual "playlists" of customized learning activities for every student. (See the sidebar on meshing learning and assessment for an example of adaptive assessment in higher education.)

Universal Design for Learning and Assistive Technology Improve Accessibility

Technology allows the development of assessments using Universal Design for Learning principles that make assessments more accessible, effective, and valid for students with greater diversity in terms of disability and English language capability. (See the sidebar on universal design for textbooks in the Learning section.)

Most traditional tests are written in English and can be taken only by sighted learners who are fluent in English. Technology allows for presentation and assessment using alternative representations of the same concept or skill and can accommodate various student disabilities and strengths. Moreover, having the option of presenting information through multiple modalities enlarges the proportion of the population that can be assessed fairly.

Technology also can support the application of UDL principles to assessment design. For example, the Principled-Assessment Designs for Inquiry (PADI) system developed by Geneva Haertel, Robert Mislevy, and associates (Zhang et al. 2010) is being used to help states develop science assessment items that tap the science concepts the states want to measure and minimize the influence of such extraneous factors as general English vocabulary or vision. Technology can support doing this labor-intensive work more efficiently and provides a record of all the steps taken to make each assessment item accessible and fair for the broadest number of students.

Similarly, assistive technology can make it possible for students who have disabilities that require special interfaces to interact with digital resources to demonstrate what they know and can do in ways that would be impossible with

Meshing Learning and Assessment in Online and Blended Instruction

The online learning systems being developed through the Open Learning Initiative (OLI) at Carnegie Mellon University illustrate the advantages of integrating learning and assessment activities. The OLI R&D team set out to design learning systems incorporating the learning science principle of providing practice with feedback. In the OLI courses, feedback mechanisms are woven into a wide variety of activities. In a biology course, for example, there are

- *Interactive simulations of biological processes that students can manipulate; the student's interaction with the simulation is interspersed with probes to get at his or her understanding of how it works;*
- *"Did I Get This?" quizzes following presentation of new material so that students can check for themselves whether or not they understood, without any risk of hurting their course grade;*
- *Short essay questions embedded throughout the course material that call on students to make connections across concepts; and*
- *"Muddiest Point" requests that ask students what they thought was confusing.*

Tutored problem solving gives students a chance to work through complex problems with the opportunity to get scaffolds and hints to help them. The students receive feedback on their solution success after doing each problem, and the system keeps track of how much assistance students needed for each problem as well as whether or not they successfully solved it.

When OLI courses are implemented in a blended instruction mode that combines online and classroom learning, the instructor can use the data that the learning system collects as students work online to identify the topics students most need help on so that they can focus upcoming classroom activities on those misconceptions and errors (Brown et al. 2006). OLI is now doing R&D on a digital dashboard to give instructors an easy-to-read summary of the online learning data from students taking their course.

The OLI has developed learning systems for engineering statics, statistics, causal reasoning, economics, French, logic and proofs, biology, chemistry, physics, and calculus. A study contrasting the performance of students randomly assigned to the OLI statistics course with those in conventional classroom instruction found that the former led to better student learning outcomes in half the time (Lovett, Meyer, and Thille 2008).

standard print-based assessments. Designing assessments to work with assistive technologies is much more cost-effective than trying to retrofit the assessments after they have been developed.

Technology Speeds Development and Testing of New Assessments

One challenge associated with new technology-based assessments is the time and cost of development, testing for validity and reliability, and implementation. Here, too, technology can help. When an assessment item is developed, it can be field-tested automatically by putting it into a Web-based learning environment with thousands of students responding to it in the course of their online learning. Data collected in this way can help clarify the inferences derived from student performance and can be used to improve features of the assessment task before its large-scale use.

Technology Enables Broader Involvement in Providing Feedback

Some performances are so complex and varied that we do not have automated scoring options at present. In such cases, technology makes it possible for experts located thousands of miles away to provide students with authentic feedback. This is especially useful as educators work to incorporate authentic problems and access to experts into their instruction.

The expectation of having an audience outside the classroom is highly motivating for many students. Students can post their poems to a social networking site or make videotaped public service announcements for posting on video-sharing sites and get comments and critiques. Students who are developing design skills by writing mobile device applications can share their code with others, creating communities of application developers who provide feedback on each other's applications. The number of downloads of their finished applications provides one way of measuring success.

For many academic efforts, the free-for-all of the Internet would not provide a meaningful assessment of student work, but technology can support connections with online communities of individuals who do have the expertise and interest to be judges of students' work. Practicing scientists can respond to student projects in online science fairs. Readers of online literary magazines can review student writing. Professional animators can judge online filmmaking competitions. Especially in contests and competitions, rubrics are useful in communicating expectations to participants and external judges and in helping promote judgment consistency.

Technology also has the potential to make both the assessment process itself and the data resulting from that process more transparent and inclusive. Currently, only average scores and proficiency levels on state assessments are widely available through both public and private systems. Still, parents, policymakers, and the public at large can see schools' and districts' test scores and in some instances test items. This transparency increases public understanding of the current assessment system.

Technology Could Reduce Test Taking for Accountability Only

Many educators, parents, and students are concerned with the amount of class time devoted to taking tests for accountability purposes. Students not only are completing the tests required every year by their states, but they also are taking tests of the same content throughout the year to predict how well they will perform on the end-of-year state assessment (Perie, Marion, and Gong 2009).

When teaching and learning are mediated through technology, it is possible to reduce the number of external assessments needed to audit the education system's quality. Data streams captured by an online learning system can provide the information needed to make judgments about students' competencies. These data-based judgments about individual students could then be aggregated to generate judgments about classes, schools, districts, and states.

West Virginia uses this strategy in its assessment of students' technology skills. (See sidebar on moving assessment data from the classroom to the state.)

Moving Assessment Data From the Classroom to the State

West Virginia's techSteps program is an example of an assessment system coordinated across levels of the education system. techSteps is organized around six technology integration activities per grade level. The activities are sequenced to introduce technology skills developmentally and in a 21st-century context and are largely open-ended and flexible, so they can be integrated into county and school curricula.

Each techSteps activity includes a classroom assessment rubric. After a student completes a techSteps activity, the teacher enters an assessment of his or her performance against the rubric into the techSteps website. techSteps uses the teacher-completed rubric form to identify the target skills demonstrated by that student and uses this information to build the student's Technology Literacy Assessment Profile.

Through techSteps, West Virginia is able to have statewide student data on technology proficiencies at each grade level without requiring a separate "drop-in-from-the-sky" technology test.

Prospects for Electronic Learning Records

Much like electronic medical records in this country, electronic learning records could stay with students throughout their lives, accumulating evidence of growth across courses and across school years. A logical extension of online grade books and other electronic portfolios, electronic learning records would include learning experiences and demonstrated competencies, including samples of student work.

Many schools are using electronic portfolios of students' work as a way to demonstrate what they have learned. (See sidebar on how New Tech High School uses technology to document student accomplishments.) Although students' digital products are often impressive on their face, a portfolio of student work should be linked to an analytic framework if it is to serve assessment purposes. The portfolio reviewer needs to know what competencies the work is intended to demonstrate, what the standard or criteria for competence are in each area, and what aspects of the work provide evidence of meeting those criteria. Definitions of desired outcomes and criteria for levels of accomplishment can be expressed in the form of rubrics.

An advantage of using rubrics is that they can be communicated not only to the people judging students' work, but also to the students themselves. When students receive

New Tech High School: Supporting Student Use of Assessment Results Using Technology

New Tech High School in Napa Valley, Calif., has been using innovative technology-based assessment practices since the school was founded in 1996. Instruction at the school emphasizes project-based learning, with students tackling complex, interdisciplinary problems and typically working in groups. New Tech instructors design these projects around both required content standards and core learning outcomes that cut across academic content areas, including collaboration, critical thinking, oral and written communication, use of technology, and citizenship.

By using this common framework in assessing student's work across classes and grade levels, New Tech teachers provide more useful information than could be obtained from a summary grade alone. Assessments of writing skill, for example, are aggregated across all projects and all courses so that teachers, parents, and the students themselves can get a view of strengths and weaknesses across multiple contexts. In addition, these assessments are made available to students in online grade books that are continually updated so that students can see how they are doing not only in each course, but also on each of the learning outcomes, averaged across all their courses. Electronic learning portfolios contain examples of students' work and associated evaluations also across all classes and grades.

In addition to receiving performance ratings from their teachers and peers, students at New Tech do postproject self-assessments on completion of major projects. These assessments provide feedback for the teacher who designed the project and an opportunity for the student to think about the project experience. The postproject self-assessment template guides the student in reflecting on how successful the project was in terms of the material learned, engagement (interest, relevance), process (for example, how clear project instructions were and whether sufficient scaffolding for student work was available), and self (extent to which the student fulfilled tasks assigned within the group and showed a solid work ethic).

assessment rubrics before doing an assignment—and especially when students participate in developing the rubrics—they can develop an understanding of how quality is judged in the particular field they are working in (for example, an essay of literary criticism, the design of a scientific experiment, or a data analysis).

As with any other kind of assessment score, ratings derived from rubrics should be both valid (demonstrated to measure what they are intended to measure) and reliable (consistent no matter who the rater is). Before rubrics are used on a larger scale for assessments that have consequences for schools and students, their validity and reliability must be established.

Using Assessment Data to Drive Continuous Improvement

Once we have assessments in place that assess the full range of expertise and competencies reflected in standards, we could collect student learning data and use the data to continually improve learning outcomes and productivity. For example, such data could be used to create a system of interconnected feedback for students, educators, parents, school leaders, and district administrators.

The goal of creating an interconnected feedback system would be to ensure that key decisions about learning are informed by data and that data are aggregated and made accessible at all levels of the education system for continuous improvement. The challenge associated with this idea is to make relevant data available to the right people, at the right time, and in the right form.

For example, assessment data should be made available to students so they can play a larger role in directing their own learning, as demonstrated by New Tech High and its use of online grade books. (See the sidebar on New Tech High School).

Assessment data also should be used to support educators' efforts to improve their professional practice. Data from student assessments can enable teachers to become more effective by giving them evidence about the effectiveness of the things they do.

In addition, teams of educators reflecting on student data together can identify colleagues who have the most success teaching particular competencies or types of students, and then all team members can learn from the practices used by their most effective colleagues (Darling-Hammond 2010; U.S. Department of Education Office of Planning, Evaluation, and Policy Development 2010). Using student data in this way also could improve educators' collaboration skills and skills in using data to improve instruction. At times, it might be useful to have educators use common assessments to facilitate this kind of professional learning.

The same student-learning data that guide students and educators in their decision making can inform the work of principals and district administrators. Administrators and policymakers should be able to mine assessment data over time to examine the effectiveness of their programs and interventions.

The need for student data plays out at the district level as well. Districts adopt learning interventions they believe will address specific learning needs, but these interventions often rely on untested assumptions and intuition. In a data-driven continuous improvement process, the district could review data on the intervention's implementation and student-learning outcomes after each cycle of use and then use the data as the basis for refining the learning activities or supports for their implementation to provide a better experience for the next group of students. (See sidebar on using technology to make the link between assessment data and instructional resources in Fairfax County, Va.)

As good as technology-based assessment and data systems might be, educators need support in learning how to use them. An important direction for development and implementation of technology-based assessment systems is the design of technology-based tools that can help educators manage the assessment process, analyze data, and take appropriate action.

Using Technology to Make the Link Between Assessment Data and Instructional Resources

To encourage teachers to make formative use of assessment data, Fairfax County Public Schools (FCPS), Va., developed eCART (Electronic Curriculum Assessment Resource Tool). This Web-based system allows teachers to access everything, from lesson plans to assessment tools, all in one place.

eCART's searchable database provides access to district-approved resources and curriculum correlated to specific standards, benchmarks, and indicators. It allows teachers to create assessments using varied combinations of FCPS common assessment items.

The eCART assessment items were developed by district teachers and designed to provide diagnostic information. The assessments are used to reveal student misconceptions and skills that need to be reinforced.

Using assessment results for their students, Fairfax teachers can follow links to a large library of instructional resources, including supplementary materials, lesson plans, work sheets, and Web links. Students can take eCART assessments online or using pencil and paper.

Student eCART assessment results are stored in the district's data system so that classroom assessment data can be viewed along with benchmark assessment data and results from state tests. Having a common set of formative assessments enables comparisons of student performance across classrooms and schools.

Advancing Technical and Regulatory Practice

Two types of challenges to realizing the vision of sharing data across systems are technical and regulatory. On the technical front, multiple student data systems, the lack of common standards for data formats, and system interoperability pose formidable barriers to the development of multilevel assessment systems. For example, student and program data today are collected at various levels and in various amounts to address different needs in the educational system. State data systems generally provide macro solutions, institution-

FERPA

The Family Educational Rights and Privacy Act *(FERPA) is a federal law that protects student privacy by prohibiting the disclosure of personally identifiable information from education records without prior written consent, except as set forth in 34 CFR § 99.31. FERPA also allows parents and "eligible students" (defined as students who are age 18 or over or who attend post-secondary institutions) to inspect and review their education records and to request that inaccuracies in their records be corrected.*

Advance written consent is generally required to disclose student-level information from education records, such as student grades, if the information would be linked or linkable to a specific student by a reasonable member of the school community. However, schools may non-consensually disclose basic "directory information" such as student names and phone numbers, if schools give public notice to parents and eligible students that they are designating this type of information as "directory information" and provide parents and eligible students a reasonable period of time after such notice has been given to opt out. Another exception to the requirement of prior, written consent permits teachers or administrators within the same school or school district who have a legitimate educational interest in the student's record to access personally identifiable student data.

In 2008, the FERPA regulations were updated to address the conditions under which FERPA permits the non-consensual disclosure of personally identifiable information from education records for research. In this respect, the regulations were amended to permit the release of de-identified records and information, which requires the redaction of all personally identifiable information per 34 CFR § 99.31(b). The 2008 final regulations also specified the conditions under which states or other state educational authorities that have legal authority to enter into agreements for local educational agencies (LEAs) or post-secondary institutions may enter into agreements to non-consensually disclose personally identifiable information from education records to an organization conducting a study for the LEA or institution under 34 CFR § 99.31(a)(6). The updates to the 2008 FERPA regulations also addressed the non-consensual disclosure of personally identifiable information from education records in a health or safety emergency in 34 CFR §§ 99.31(a) (10) and 99.36.

Source: U.S. Department of Education Family Policy Compliance Office 2010

level performance management systems are micro solutions, and student data generated by embedded assessment are nano solutions. Providing meaningful, actionable information that is collected across multiple systems will require building agreement on the technical format for sharing data.

To assist with these efforts, the National Center for Education Statistics at the Department of Education has been leading the Common Data Standards (CDS) Initiative, a national, collaborative effort to develop voluntary, common data standards. The CDS Initiative's objective is to help state and local education agencies and higher education organizations work together to identify a minimal set of key data elements, common across organizations and necessary to meet student, policymaker, and educator needs, and come to agreement on definitions, business rules and technical specifications, when possible, to improve the comparability and share-ability of those elements. (Note: Version 1.0 of CDS was released on Sept. 10, 2010.)

As the reliance on data to inform decisions, the public's demand for transparency and accountability, and the world of technology grow exponentially, we must stay vigilant in our efforts to protect student privacy. On the regulatory front, regulations such as the Family Educational Rights and Privacy Act (FERPA) serve the important purpose of protecting student privacy but also can present challenges, if not properly understood and implemented. Much of the confusion surrounding research and data sharing posed by FERPA in its original form was reduced or eliminated through a 2008 revision of FERPA regulations. Still, varying interpretations of FERPA requirements and differences in district and state policies have made data sharing a complex, time-consuming, and expensive process. (See the sidebar on FERPA.)

Advancing the technical and regulatory practices to ensure privacy is maintained and information is secure while aggregating and sharing data would facilitate efficient use of data that are already being collected to make judgments about students' learning progress and the effectiveness of education programs.

Reaching Our Goal

2.0 Assessment:

Our education system at all levels will leverage the power of technology to measure what matters and use assessment data for continuous improvement.

To meet this goal, we recommend the following actions:

2.1 States, districts, and others should design, develop, and implement assessments that give students, educators, and other stakeholders timely and actionable feedback about student learning to improve achievement and instructional practices.

Learning science and technology combined with assessment theory can provide a foundation for new and better ways to assess students in the course of learning, which is the ideal time to improve performance. This will require involving experts from all three disciplines in the process of designing, developing, and using new technology-based assessments that can increase the quality and quantity of feedback to learners.

2.2 Build the capacity of educators, educational institutions, and developers to use technology to improve assessment materials and processes for both formative and summative uses.

Technology can support measuring performance that cannot be assessed with conventional testing formats, providing our education system with opportunities to design, develop, and validate new and more effective assessment materials. Building this capacity can be accelerated through knowledge exchange, collaboration, and better alignment between educators (practitioners) and the experts.

2.3 Conduct research and development that explores how embedded assessment technologies, such as simulations, collaboration environments, virtual worlds, games and cognitive tutors, can be used to engage and motivate learners while assessing complex skills.

Interactive technologies, especially games, provide immediate performance feedback so that players always know how they are doing. As a result, they are highly engaging to students and have the potential to motivate students to learn. They also enable educators to assess important competencies and aspects of thinking in contexts and through activities that students care about in everyday life. Because interactive technologies hold this promise, assessment and interactive technology experts should collaborate on research to determine ways to use them effectively for assessment.

2.4 Conduct research and development that explores how UDL can enable the best accommodations for all students to ensure we are assessing what we intend to measure rather than extraneous abilities a student needs to respond to the assessment task.

To be valid, an assessment must measure those qualities it is intended to measure, and scores should not be influenced by extraneous factors. An assessment of science, for example, should measure understanding of science concepts and their application, not the ability to see print, to respond to items using a mouse, or to use word processing skills. Test items and tasks should be designed from the outset to measure the knowledge, skills, and abilities that the test intends to assess and not the students' ability to read when assessing mathematics skills or to self-monitor when completing a science task that includes several steps. Assessment and technology experts should collaborate to create assessment design tools and processes that make it possible to develop assessment systems with appropriate features (not just accommodations) so that assessments capture examinees' strengths in terms of the qualities that the assessment is intended to measure.

2.5 Revise practices, policies, and regulations to ensure privacy and information protection while enabling a model of assessment that includes ongoing gathering and sharing of data for continuous improvement.

Every parent of a student under 18 and every student 18 or over should have the right to access the student's own assessment data in the form of an electronic learning record that the student can take with them throughout his or her educational career. At the same time, appropriate safeguards, including stripping records of identifiable information and aggregating data across students, classrooms, and schools, should be used to make it possible to supply education data derived from student records to other legitimate users without compromising student privacy.

Teaching: Prepare and Connect

Goal: Professional educators will be supported individually and in teams by technology that connects them to data, content, resources, expertise, and learning experiences that can empower and inspire them to provide more effective teaching for all learners.

Teaching today is practiced mostly in isolation. Many educators work alone, with little interaction with professional colleagues or experts in the outside world. Professional development typically is provided in short, fragmented, and episodic workshops that offer little opportunity to integrate learning into practice. A classroom educator's primary job is understood to be covering the assigned content and ensuring that students test well. Many educators do not have the information, the time, or the incentives to continuously improve their professional practice from year to year.

Not surprisingly, half of freshly minted teachers leave the profession within the first five years (Ingersoll and Smith 2003). These conditions exist because our education system and the institutions that prepare educators often fail to give educators the tools to do their job well. Our education system holds educators responsible for student achievement but does support them with the latest technology the way professionals in other fields are supported. Although some preservice programs are using technology in innovative ways (Gomez et al. 2008), widespread agreement exists that teachers by and large are not well prepared to use technology in their practice (Kay 2006). As a result, the technology of everyday life has moved well beyond what educators are taught to and regularly use to support student learning.

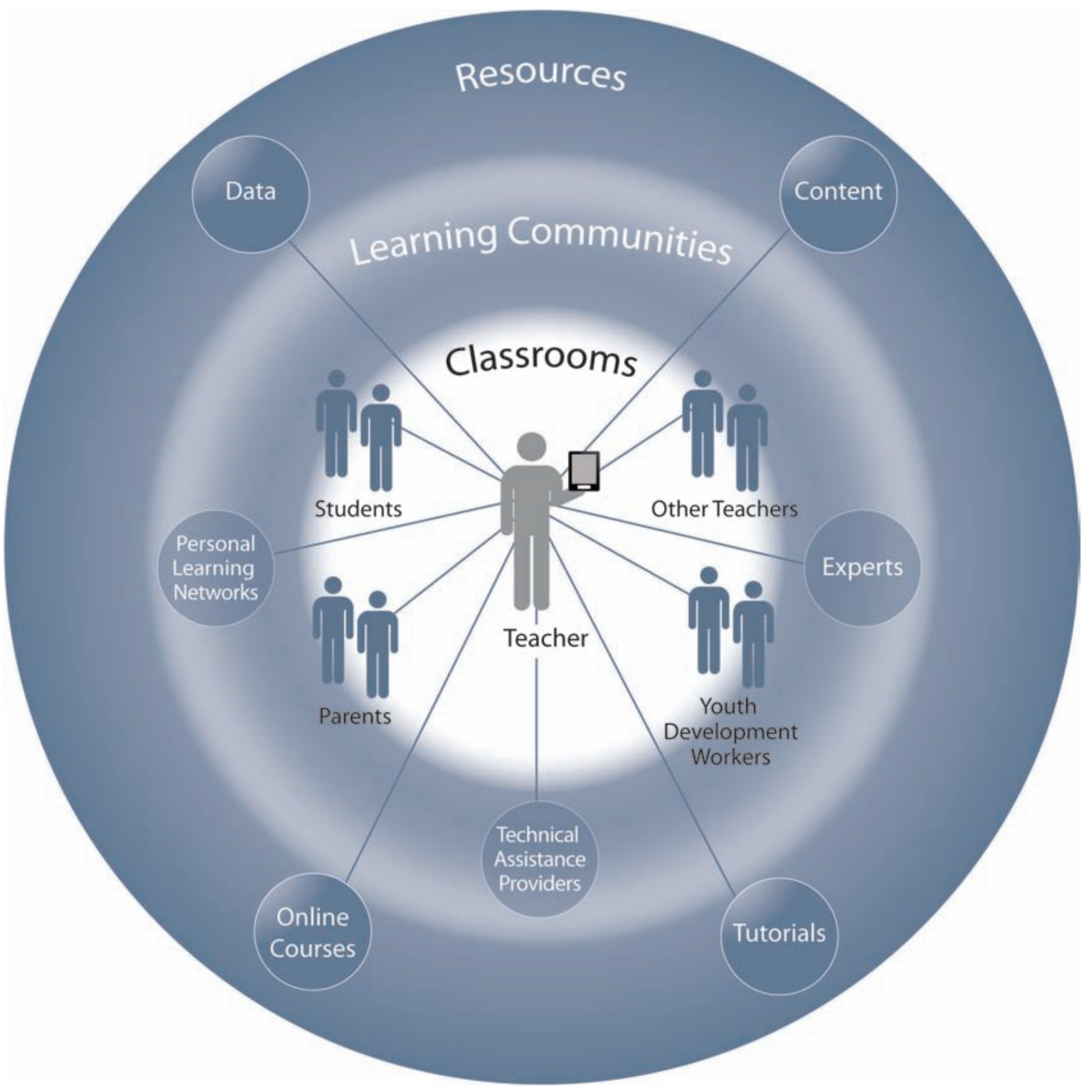
Meanwhile, policymakers and education leaders point to a lack of effective teaching and the need for greater accountability among teachers as the key to fixing education in America. Although the expectation of effective teaching and accountability for professional educators is a critical component of transforming our education system, we also need to recognize that we must strengthen and elevate the teaching profession. This is necessary to attract and retain the most effective educators and achieve the learning outcomes we seek for all learners.

Just as leveraging technology can help us improve learning and assessment, technology can help us better prepare effective educators and increase their competencies throughout their careers while building the capacity of our education system to deliver effective teaching. Technology can do this by enabling a shift to a new model of connected teaching.

The Practice of Connected Teaching

In connected teaching, classroom educators are fully instrumented, with 24/7 access to data about student learning and analytic tools that help them act on the insights the data provide. They are connected to their students and to professional content, resources, and systems that empower them to create, manage, and assess engaging and relevant learning experiences for students both in and out of school. They also are connected to resources and expertise that improve their own instructional practices, continually add to their competencies and expertise, and guide them in becoming facilitators and collaborators in their students' increasingly self-directed learning (Figure 3). Like students in the learning model described earlier, teachers engage in personal learning networks that support their own learning and their ability to serve their students well.

Figure 3. Connected Teaching Builds New Competencies and Expertise



In addition, as learning environments become more complex, connected teaching supports educators in managing the multiple dimensions of curricular instruction. Commercially available and open-source learning management systems are already used widely in universities, and their use is expanding in K–12 settings. Such tools allow educators to coordinate course materials, syllabi, assignments, discussions, and more in a central location for students.

Teachers at George J. Ryan Junior High School in Queens, N.Y., for example, saw improved literacy outcomes in their first year of using an online writing workshop environment. The environment creates virtual classrooms in which educators and students can interact in new ways with course content and with one another. It features a room where students can post writing samples, hold discussions, and find animated content objects linked to quiz data, feedback, and grading. Face-to-face training provided to educators ensured that they could use the environment effectively.

Other online environments also allow broader participation in a student's learning. School administrators can join virtual classrooms for a window on the progress of a given class. Parents or members of other partner institutions can log in for a virtual tour through a class project or contribute materials to the environment.

In connected teaching, individual educators also create their own online learning communities consisting of their students and their students' peers; fellow educators in their schools, libraries, and after-school programs; professional experts in various disciplines around the world; members of community organizations that serve students in the hours they are not in school; and parents who desire greater participation in their children's education.

Episodic and ineffective professional development is replaced by professional learning that is collaborative, coherent, and continuous and that blends more effective in-person courses and workshops with the expanded opportunities, immediacy, and convenience enabled by online learning. For their part, the colleges of education and other institutions that prepare teachers play an ongoing role in the professional growth of their graduates by partnering with schools and organizations that provide engaging and relevant learning experiences throughout the entire course of their careers.

Connected teaching also enables our education system to augment the expertise and competencies of specialized and exceptional educators through online learning systems, online courses, and other self-directed learning opportunities, providing effective teaching where it is not otherwise available.

Connecting With Students to Personalize and Motivate Learning

Connected teaching offers a vast array of opportunities to personalize learning. Many simulations and models for use in science, history, and other subject areas are now available online, including immersive virtual and augmented reality environments that encourage students to explore and make meaning in complex simulated situations (Dede 2009). To deeply engage their students, educators need to know about their students' goals and interests and have knowledge of learning resources and systems that can help students plan sets of learning experiences that are personally meaningful. For a more extensive discussion of personalized learning, see the Learning section of this plan.

Although using technology to personalize learning is a boost to effective teaching, teaching is fundamentally a social and emotional enterprise. The most effective educators connect to young people's developing social and emotional core (Ladson-Billings 2009; Villegas and Lucas 2002) by offering opportunities for creativity and self-expression. Technology provides an assist here as well.

Digital authoring tools for creating multimedia projects and online communities for sharing them with the world offer students outlets for social and emotional connections with educators, peers, communities, and the world at large. Educators can encourage students to do this within the context of learning activities, gaining further insights into what motivates and engages students—information they can use to encourage students to stay in school.

Connecting to Content, Expertise, and Activities Through Online Communities

Many of the technology-based learning resources available today prompt learners to engage with advanced content and authentic activities, which are facilitated when educators orchestrate access to content, experts, and activities of many kinds through online learning communities.

Online learning communities break through educators' traditional isolation, enabling them to collaborate with their peers and leverage world-class experts to improve student learning. Online learning communities also permit the coordination of teams of educators within a school, between a school and homes, and among schools, museums, community centers, and other settings that can support a student's learning. Educators are no longer limited by where they teach or where they lead, nor are they required to deliver teaching as solo practitioners.

For example, through an online learning community, an educator can bring guest speakers located anywhere in the world into student learning. The class can watch the speaker and interact live while the speaker delivers a lecture, demonstrates a scientific experiment or a musical technique, or leads a guided virtual tour of a museum exhibit. A recording of the event can be archived for later viewing or uploaded to a website that hosts free educational content. (For an example of an online learning community built around deep content expertise, see the sidebar on connected teaching in K–12 mathematics.)

Connected Teaching in K–12 Mathematics

The Math Forum (http://mathforum.org) is an online community that supports a connected teaching approach to improving K–12 mathematics education. The Math Forum, based at Drexel University's School of Education, receives between 2 million and 3 million online visits per month.

For educators, the Math Forum website provides valuable instructional resources, including Math Tools, a searchable community library of interactive lessons, activities, and support materials. Educators also can consult a library of articles on current issues in mathematics education and discuss challenges in online forums (Teacher2Teacher). Educators pose questions, which are answered by program associates, who then post the thread for public comment.

Parents can find information about math summer camps and get help explaining concepts. Students can send letters to Dr. Math; between 200 and 300 trained experts are behind the collective identity of Dr. Math.

Problem of the Week, a particularly popular feature on the site, is a subscription-based service. Students around the world submit answers online to the Problem of the Week, annotating their answers with step-by-step explanations. Expert mentors then reply to the submissions, guiding students if necessary to find the right answer.

Math Forum also has been used to support preservice teacher education. In 2004, for example, preservice teachers in two education programs in Oregon used Math Forum's Problem of the Week to practice responding productively to assignments submitted by middle school students. As preservice teachers practiced giving constructive feedback to students, mentors provided guidance and support to improve the feedback. Through this hands-on experience, the preservice teachers learned what kinds of feedback most effectively guided students to the correct answers.

Growth of such online learning communities that foster deep expertise has been limited because they exist outside the formal structure of funding and certifying educator learning. So even though participating in Math Forum may be better for educators than most of the other professional learning experiences they are offered, time spent using online resources like Math Forum does not relieve them of their obligations to attend other programs to meet district and state requirements.

The principle that learning outcomes are more important than where and when the learning takes place should be applied to educator learning just as it should to student learning.

Connecting to Serve the Underserved

Unfortunately, we do not have enough effective educators in many places, including those where we need them most. The shortage of effective educators is especially evident in the STEM areas that are vital to our economic prosperity. A prime example is high school physics: More than 1 million high school students take a physics course each year. Of the educators hired to instruct them, only a third hold a degree in physics or physics education. Many of the other educators who are asked to teach physics (usually in addition to other subjects) have not been trained in how to teach physics concepts and might have limited understanding of those concepts themselves (Hodapp, Hehn, and Hein 2009).

Moreover, the least effective educators are most likely to be teaching in schools serving students from homes that are economically and educationally disadvantaged. Limited access to excellent teaching is a source of inequity in our education system (Darling-Hammond 2010). A recent study found that students in urban and suburban high schools can choose from between three and four times as many advanced mathematics courses (which typically earn extra credit in the college admission process) as students in rural schools (Graham 2009).

Connected teaching can make it possible to extend the reach of specialized and exceptional educators through online learning activities made available to students in every zip code. When a school is unable to attract educators qualified to teach courses that its students need or want, students should be given the option of taking the course online. Many schools have found that K–12 students taking online courses benefit from having an educator on site who keeps track of their progress and provides encouragement, however, that staff member does not need the depth of content expertise of a person solely responsible for teaching a class.

Preparing New Educators and Ongoing Professional Learning

Technology is a powerful enabler of learning, but educators still must teach. They must support their students' engagement with technology resources for learning, highlighting the important subject matter content, pressing students for explanations and higher-order thinking, tracking their students' progress, and encouraging their students to take more responsibility for learning. This requires deep transformations of teaching practices. These transformations must begin in the places where our education system is preparing new professionals: colleges of education and other teacher preparation institutions and organizations.

Young teachers are similar to their students in that they have grown up in a world where laptop computers, cell phones, and handheld gaming devices are commonplace, and homes are filled with computers, TVs, digital video recorders, and game consoles. They are as comfortable interacting with digital devices and accessing the Internet as their students are. Still, this does not mean they understand how to use the technology of their daily lives to improve their teaching practices. Helping them develop this understanding is the job of preservice teacher preparation programs.

The best way to prepare teachers for connected teaching is to have them experience it. All institutions involved in preparing educators should provide technology-supported learning experiences that promote and enable the use of technology to improve learning, assessment, and instructional practices. This will require colleges of education and postsecondary institutions generally to draw from advances in learning science and technology to change what and how they teach when they prepare teachers, keeping in mind that everything we now know about how people learn applies to new teachers as well. (See sidebar on integrating technology into teacher preparation.)

The same imperatives for teacher preparation apply to ongoing professional learning. Professional learning should support and develop educators' identities as fluent users of advanced technology, creative and collaborative problem solvers, and adaptive, socially aware experts throughout their careers.

Research shows that U.S. teachers have less time in their workweek for professional learning than their counterparts in countries where students have the best performance on international examinations (Darling-Hammond 2010). Increasing the time for our educators to engage in professional learning will require processes that cross time and space boundaries.

Educators can be engaged in professional learning not only when attending formal workshops or other activities outside the classroom, but also in the very act of teaching, which can offer a rich source of information to inform professional growth (Ancess 2000; Borko et al. 1997; Kubitskey 2006). When interwoven with daily activities, professional learning allows learning about techniques and materials for teaching that can be directly applied with students. In this process, providing continuous supports for examining, revising, and reflecting on instruction is essential to improving educator practices that affect student outcomes. Technology can help provide continuous supports through models of educator learning that blend face-to-face and online experiences. Technology-supported informal learning communities can connect teachers to university experts in content domains and in pedagogy.

Integrating Technology Into Teacher Preparation

The UTeach program at the University of Texas at Austin is designed to bring more mathematics and science majors into teaching. Participants enter the program in their junior year and graduate with both a bachelor's degree in a STEM field and a teaching certificate. UTeach interweaves technology throughout its course and practicum offerings. Early in their course work, UTeach preservice teachers use technology to find information and to communicate with their professors and with each other. They post lesson plans online and take online assessments. More advanced courses build on these experiences and involve the instructional use of technology within the content areas the preservice teachers will teach. UTeach preservice teachers have multiple opportunities to use technology with students in the field both before and during student teaching.

A different kind of example comes from the alternative teacher certification program at Northwestern University. Northwestern's program uses video and computer technology to capture classroom interactions during interns' summer teaching placements. Peers, mentor teachers, and university faculty review video excerpts with the teaching interns, providing analyses of the teaching and learning and helping to scaffold reflective discourse about classroom practice. In this way, technology helps teaching interns make connections between the language and concepts of the teacher education program and the real practice that occurs in classrooms.

Connecting With Exemplary Practices

Technology can support professional learning by making the practices of exemplary educators accessible to other educators (Fishman 2007; Richardson and Kile 1999). With today's video-sharing tools, for example, outstanding demonstrations of teaching practice can be captured and annotated. Educators can view and analyze their practice and then innovate and customize new ways to refine their craft in light of new insights. Resources such as Teachers.tv can be used to make the act of teaching visible, helping the entire community better understand effective teaching practices. (See sidebar on Teachers.tv.)

Teachers.tv

Teachers.tv is a collection of multimedia resources developed and disseminated in the United Kingdom with the mission of spreading best practices in education as broadly as possible among the entire community involved in student learning—not only those who work in schools, but also parents and district leaders.

The station's programming is available through a variety of media platforms. It is broadcast via Internet all day, everyday and via traditional television for a few hours per day on several stations. Once a program has been broadcast, the content is archived on the site in a searchable library of downloadable videos. Links to the videos can be found on a number of frequently used websites, including that of the Guardian newspaper and both YouTube and iTunes.

Programs ranging in length from 15 minutes to one hour target different members of the educational community. For example, broadcast content in the first week of December 2009 included programs on teaching math, English, and science concepts at the primary or secondary level, a program on effective uses of assessment, a program for district leaders on special needs students, and general-audience programs on Asperger's syndrome, healthy eating, and youth and crime.

Teachers.tv seeks to show, not just tell, how and why best practices work. The regularly scheduled programs "Classroom Observation" and "Great Lesson Ideas" show K–12 teachers' best practice modeled by first-rate teachers in the context of actual classroom instruction. Similarly, a program on special needs students takes viewers inside schools that have been serving that population exceptionally well.

On the Teachers.tv website, users can log in to a community portal where they can find and store the content most relevant for them and discuss their practices with other educators. Teachers also can become "associates" of the station, serving as liaisons between schools and parents and the station. The associates offer suggestions for topics and give first feedback on content.

Connecting With Other Professionals

More than two decades of research has demonstrated the importance of collaboration among teachers. When teachers make their work public and examine each other's work, the quality of their practice and student outcomes improve (Lieberman and Pointer Mace 2010). Social networking technology provides a platform for making teachers' work public, with opportunities for both local and global communities of practice.

Communities of practice provide a strong mechanism for promoting ongoing growth from novice preservice educators through expert master educators and offer opportunities for the engagement of a broad range of participants from outside formal education (Wenger, White, and Smith 2009). Successful learning circles also can bring together educators and students to deepen learning (Riel 1992).

PBS TeacherLine is one example of an online system that engages teachers in collaboration and builds professional community. PBS TeacherLine, long a provider of online courses for teachers, is now focusing on making online courses more interactive to help educators build their own communities of practice. Online courses of 15 or 30 hours are designed as interactive environments in which an expert facilitator communicates best practice approaches and helps educators share ideas. Educators in a course share resources by creating digital portfolios and participating in facilitated discussions.

The Department of Education also is acknowledging the need for communities of practice for educators by funding design research on online communities of practice to learn more about what types of content and interactions will compel people to participate and will provide useful supports for professional educators. This project also includes the development of at least six online communities to leverage the use of educational technology to improve teaching, assessment, learning, and infrastructure in schools. Communities of practice funded by the Department will scaffold best practices, ensuring teachers are highly effective and connected to data, resources, content, and expertise.

Career-long Personal Learning Networks

A transformative idea in the preparation and professional learning of educators and education leaders is to leverage technology to create career-long personal learning networks within and across schools, preservice preparation and in-service educational institutions, and professional organizations. The goal of these career-long personal learning networks would be to make professional learning timely and relevant as well as an ongoing activity that continually improves practices. These networks and other resources would enable educators to take online courses, tap into experts and best practices for just-in-time learning and problem solving, and provide platforms and tools for educators to design and develop resources and share them with their colleagues.

As we move into an era when colleges of education will be held accountable for the effectiveness of their graduates, these institutions can use personal learning networks to provide ongoing support once their graduates enter the workforce. An example of this is TFANet, a website provided by Teach for America (TFA) for all its new educators. TFANet offers valuable resources for educators and opportunities for TFA teachers to connect and share ideas. This resource exchange also enables TFA teachers and alumni to share, rate, and download successful lesson and unit plans, data-tracking tools, and classroom management strategies.

Using technology in these ways for ongoing professional learning for educators will require rethinking the use of time-based measures of attainment rather than competency-based measures. Strictly time-based measures do not allow professional educators to take advantage of the many new opportunities that online learning offers by being able to transcend time and space.

Growing Demand for Skilled Online Instruction

As online learning becomes an increasingly important part of our education system at all levels, this creates both the need and opportunity for educators who are skilled in online instruction and the demand for greater knowledge of the most effective practices. As we implement online learning, we should make sure that students' learning experiences address the full range of expertise and competencies as reflected in standards and use meaningful assessments of the target competencies. Crucial to filling this need while ensuring effective teaching are appropriate standards for online courses and teaching, and a new way of approaching online teacher certification that functions across state lines.

Closing the Technology Gap in Teaching

The technology that enables connected teaching is available now, but not all the conditions necessary to leverage it are. Many of our existing educators do not have the same understanding of and ease with using technology that is part of the daily lives of professionals in other sectors and with this generation of students. The same can be said of many of the education leaders and policymakers in schools, districts, and states and of the higher education institutions that prepare new educators for the field.

This gap in technology understanding influences program and curriculum development, funding and purchase decisions about educational and information technology in schools, and preservice and in-service professional learning. Too often, this gap prevents technology from being used in ways that would improve instructional practices and learning outcomes.

Still, we must introduce connected teaching into our education system rapidly, and for that we must rely on the organizations that support educators in their profession—schools and districts, colleges of education, professional learning providers, librarians and media specialists, and professional organizations. We also must call on education leaders and policymakers to remove barriers to connected teaching and provide incentives and recognition for educators who demonstrate effective teaching in a connected model.

Reaching our Goal

3.0 Teaching:

Professional educators will be supported individually and in teams by technology that connects them to data, content, resources, expertise, and learning experiences that enable and inspire more effective teaching for all learners.

To meet this goal, we recommend the following actions:

3.1 Expand opportunities for educators to have access to technology-based content, resources, and tools where and when they need them.

Today's technology enables educators to tap into resources and orchestrate expertise across a school district or university, a state, the nation, and even around the world. Educators can discuss solutions to problems and exchange information about best practices in minutes, not weeks or months. Today's educators should have access to technology-based resources that inspire them to provide more engaging and effective learning opportunities for each and every student.

3.2 Leverage social networking technologies and platforms to create communities of practice that provide career-long personal learning opportunities for educators within and across schools, preservice preparation and in-service educational institutions, and professional organizations.

Social networks can be used to provide educators with career-long personal learning tools and resources that make professional learning timely and relevant as well as an ongoing activity that continually improves practice and evolves their skills over time. Online communities should enable educators to take online courses, tap into experts and best practices for just-in-time problem solving, and provide platforms and tools for educators to design and develop resources with and for their colleagues.

3.3 Use technology to provide all learners with online access to effective teaching and better learning opportunities and options in places where they are not otherwise available and in blended (online and offline) learning environments.

Many education institutions, particularly those serving the most vulnerable students and those in rural areas, lack educators with competencies in reaching students with special needs and educators with content knowledge and expertise in specialized areas, including STEM. Even in areas where effective teaching is available, students often lack options for high-quality courses in particular disciplines or opportunities for learning that prepare them for the modern world. Online learning options should be provided to enable leveraging the best teaching and make high-quality course options available to all learners.

3.4 Provide preservice and in-service educators with professional learning experiences powered by technology to increase their digital literacy and enable them to create compelling assignments for students that improve learning, assessment, and instructional practices.

Just as technology helps us engage and motivate students to learn, technology should be used in the preparation and ongoing learning of educators to engage and motivate them in what and how they teach. This will require synthesizing core principles and adopting best practices for the use of technology in preparing educators. Technology also should be an integral component of teaching methods courses, and field experiences rather than treated as a discrete skill distinct from pedagogical application.

3.5 Develop a teaching force skilled in online instruction.

As online learning becomes an increasingly important part of our education system, we need to provide online and blended learning experiences that are more participatory and personalized and that embody best practices for engaging all students. This creates both the need and opportunity for educators who are skilled in instructional design combined with knowledge of emerging technologies. Crucial to filling this need while ensuring effective teaching are appropriate standards for online courses and teaching and a new way of approaching online teacher certification.

Infrastructure: Access and Enable

Goal: All students and educators will have access to a comprehensive infrastructure for learning when and where they need it.

Although we have adopted technology in many aspects of education today, a comprehensive infrastructure for learning is necessary to move us beyond the traditional model of educators and students in classrooms to a learning model that brings together teaching teams and students in classrooms, labs, libraries, museums, workplaces, and homes—anywhere in the world where people have access devices and an adequate Internet connection. An infrastructure for learning is necessary to support a learning society in which learning is lifelong and lifewide.

Our infrastructure for learning is modeled on the cyberinfrastructure envisioned and deployed by the National Science Foundation to encourage collaboration among scientists and researchers, which was subsequently broadened to apply to learning in all domains (National Science Foundation 2008b). The term “cyber” tells us that the time and distance barriers of the physical world are reduced by virtual connections between people and between people and technology resources and tools. “Infrastructure” reminds us that even in virtual worlds, physical and organizational structures are needed to run a system.

The essential underlying principle is that the infrastructure includes people, processes, learning resources, and policies and sustainable models for continuous improvement in addition to broadband connectivity, servers, software, management systems, and administrative tools.

Building an infrastructure for learning is a far-reaching project that will require the participation and collaboration of individuals from all disciplines and types of institutions across the entire spectrum of education. It also will require education, business, and government as partners. And it will take leadership and a commitment to a shared understanding of its importance to transforming U.S. education.

Revolutionary Opportunity for Change

Over the past 40 years, we have seen unprecedented advances in computing and communications that have led to powerful technology resources and tools for learning. Today, low-cost Internet access devices, easy-to-use digital authoring tools, and the Web facilitate access to information and multimedia learning content, communication, and collaboration. They also provide the ability to participate in online learning communities that cross disciplines, organizations, international boundaries, and cultures.

Many of these technology resources and tools already are being used within our public education system. We are now, however, at an inflection point for a much bolder transformation of education powered by technology. This revolutionary opportunity for change is driven by the continuing push of emerging technology and the pull of the critical national need for new strategies to turn around a P–12 system that is failing to adequately prepare young Americans for postsecondary education and the workforce and a postsecondary system that is failing to prepare its graduates for success in life and work in a changing world.

Our model of an infrastructure for learning is always on and makes learning opportunities available to learners, educators, and administrators regardless of their location, the time of day, or the type of access devices. It supports not just access to information, but also the creation of content and access to people and participation in online learning communities.

An infrastructure for learning unleashes new ways of capturing and sharing knowledge based on multimedia that integrate text, still and moving images, audio, and applications that run on a variety of devices. It enables seamless integration of in-school and out-of-school learning. It frees learning from a rigid information-transfer model (from book or educator to students) and enables a much more motivating intertwine of learning about, learning to do, and learning to be.

On a more operational level, an infrastructure for learning brings together and enables access to data from multiple sources while ensuring appropriate levels of security and privacy. The infrastructure integrates computer hardware, data and networks, information resources, interoperable software, middleware services and tools, and devices, and it also connects and supports interdisciplinary teams of professionals responsible for its development, maintenance, and management, and its use in transformative approaches to teaching and learning.

Unpacking the Challenge

Given the enormity of the challenge of building an infrastructure for learning, we should approach it step-by-step, designing and implementing individual elements so we can take advantage of their incremental benefits along the way.

Broadband Everywhere

A crucial element of an infrastructure for learning is a broadband network of adequate performance and reach, including abundant wireless coverage in and out of school buildings. “Adequate” means enough bandwidth to support simultaneous use by all students and educators anywhere in the building and the surrounding campus to routinely use the Web, multimedia, and collaboration software. The activities of the FCC (http://www.fcc.gov/broadband) and the Department of Commerce National Telecommunications and Information Administration (NTIA) Broadband Technology Opportunities Program (http://www2.ntia.doc.gov) to bolster the nation's broadband provisioning are essential to learning lifelong and lifewide.

In March 2010, the FCC released the National Broadband Plan to provide a blueprint for connecting all Americans to broadband capability. The National Broadband Plan recognizes the crucial task of improving high-speed Internet access for learners in schools and homes and calls for a number of changes to the E-Rate that would dramatically improve learners' access to broadband-enabled learning experiences. (See the sidebar on the National Broadband Plan. For background information on the E-Rate, see the sidebar on balancing connectivity and student safety on the Internet on p. 56.)

The National Broadband Plan and Education

The National Broadband Plan deals with many aspects of the nation's technology infrastructure, including the infrastructure for education. In the education arena, the plan calls for specific actions in three areas:

Supporting and promoting online learning. *The plan calls for expanded access to educational digital content, increased recognition of credits earned through online learning, refinements of digital data and interoperability standards, digital literacy promotion, and research and development of new broadband-enabled online learning systems.*

Unlocking the value of data and improving transparency. *The plan advocates the adoption of electronic learning records and the modernization of privacy laws to protect student data while allowing its use to improve learning outcomes. The FCC also calls for improved financial data transparency in education, supported by online tools that make school systems' spending visible and connect local education agencies with product and service providers that meet their technology needs more efficiently.*

Modernizing educational broadband infrastructure. *Most critically, the plan calls for several changes to the E-Rate that would increase learners' access to broadband-enabled learning experiences. Proposed changes to the E-Rate include the following:*

- *Raising the E-Rate cap to account for inflation, providing much-needed additional funding to schools and libraries;*
- *Funding wireless connectivity to portable learning devices, allowing students and teachers to continue learning beyond the school day;*
- *Providing more support for internal network connections, allowing greater student and teacher access to high-speed connectivity in the classroom;*
- *Allowing community members to make use of E-Rate-funded connections outside school hours, creating new opportunities for job training and extended learning opportunities for adults;*
- *Encouraging schools and libraries to partner with state, regional, local, and tribal entities to establish networks that increase broadband purchasing power;*
- *Streamlining the E-Rate application process to reduce the burden on schools and libraries that seek funding;*
- *Increasing E-Rate recipients' flexibility to purchase the most cost-effective broadband solutions available in their geographic area;*
- *Setting new minimum service goals for broadband connectivity that take into account the numbers and needs of E-rate network users, providing sufficient bandwidth for learners to take advantage of engaging multimedia tools; and*
- *Awarding some E-Rate funds competitively to promote innovation in technology-supported learning.*

The full text of the National Broadband Plan's recommendations and vision for education are available online at http://www.broadband.gov/plan/11-education.

Access Devices for Every Student and Educator

Because an infrastructure for learning should support learning in and out of the classroom, students and educators need Internet access devices for around-the-clock use from any location. Internet access devices are continually evolving and today include desktop computers, laptops, netbooks, public access kiosks, mobile phones, portable digital players, and wireless readers.

Many districts say they face major challenges in providing access devices for every student and educator. Even with the rise of relatively low-cost mobile devices and netbooks, most devices cost at least several hundred dollars and need to be replaced every few years. In 2002, however, Maine became the first state in the country to give every seventh- and eighth-grade student and educator a laptop for use both at school and at home. Research on the effectiveness of the program shows that student learning has improved (Berry and Wintle 2009; Silvernail and Bluffington 2009; Silvernail and Gritter 2007), and the program is now being expanded to high schools. (See sidebar on building a statewide infrastructure for learning.) Many K–12 students already carry mobile devices for personal use with greater computing power than the supercomputers of a generation ago. K–12 educators routinely own access devices for use in their daily lives. Students at our nation's colleges and universities increasingly are arriving on campus with powerful laptops and mobile devices of their own. The presence of so many access devices and the precedent that has been established at colleges and universities are prompting some K–12 school districts to explore having their students and educators use their own personal access devices as an alternative to purchasing them.

In the past, districts were reluctant to allow students to use their own devices in school because of concerns about the unfair advantage of affluent students who are more likely to have the latest devices and the risk of students accessing inappropriate Internet content or using their connectivity to cheat on tests. However, districts are finding that a combination of acceptable use policies and staff training makes student use of personal digital devices both feasible and safe.

Building a Statewide Infrastructure for Learning

In 2001, Maine kicked off the Maine Learning Technology Initiative (MLTI), the first statewide effort to provide students and educators across multiple grades with 24/7 access to personal learning devices. A joint task force convened by the governor and the state legislature assessed Maine's education needs and the infrastructure that would be required for implementation of one-to-one computing, including hardware, software, internal and external school networks and servers, technical support, and educator professional development.

To be able to provide all aspects of the infrastructure to support worthwhile uses of technology for learning while staying within Maine's budget parameters, the decision was made to focus the first phase of MLTI on middle school students.

After pilot testing and training at "exploration sites" in each of the state's nine regions, Maine's one-to-one program was extended to seventh-graders in all state middle schools in 2002 and to all eighth-graders in 2003. MLTI now equips each of Maine's 243 middle schools with wireless Internet access and provides each school with enough laptops for every seventh- and eighth-grade student and educator to use both in and outside school. Since MLTI's inception, more than 37,000 laptops provided by the program have been used by over 100,000 educators and learners throughout the state. MLTI also provides intensive professional development, implementation assistance, and technical support to educators to ensure that the technology is fully leveraged to support student learning.

Maine believes that its investment in technology for its middle school students has paid off: The state's eighth-grade writing proficiency jumped 12 percent after statewide one-to-one implementation (Silvernail and Gritter 2007). Laptop use also has been linked to gains on statewide mathematics tests and improved retention of science course material (Berry and Wintle 2009; Silvernail and Bluffington 2009).

Inspired by this success, Maine has expanded its laptop initiative to all students in grades 9–12. The state is committed to funding wireless Internet access in all Maine secondary schools and has negotiated discounts for districts to provide their students with laptops.

Middletown Public Schools in New Jersey, for example, brought together elementary, middle, and high school educators to forge an acceptable-use policy that would allow students to use personal cell phones and other computing devices in school. Students then created videos to illustrate acceptable and unacceptable uses for their peers. At Passage Middle School in Newport News, Va., a host of student and educator uses of cell phones to support learning was unleashed when the principal decided to allow the use of cell phones for instructional purposes during class. (See sidebar on using cell phones to support teaching and learning.)

Schools also can solve the equity issue—concern that affluent students will have devices and others will not—by purchasing devices just for the students who need such financial support. This is more cost-effective than purchasing devices for every student. Districts can think about providing an access device and Internet access at home for those students who need them in the same way they provide a free or reduced-price hot lunch for students who could not otherwise afford it. In choosing the devices to provide for students who otherwise would not have them, districts need to make sure that all their students have devices that support writing, analysis, and the creation of digital content related to their courses, not just consumption of content created by others.

Allowing students to bring their own access devices to school has been limited, however, by provisions within the E-Rate, a federal program that supports connectivity in elementary and secondary schools and libraries by providing discounts on Internet access, telecommunications services, internal network connections, and basic maintenance to support them. Schools' eligibility for E-Rate money is contingent on compliance with several federal laws designed to ensure student privacy and safety on the Internet. These include the Children's Internet Protection Act (CIPA), which requires the use of electronic filtering on school networks. In some cases, lack of full understanding of this requirement creates unnecessary barriers to the rich learning experiences that in-school Internet access should afford students.

E-Rate provisions and CIPA requirements should be clarified, and schools and districts should explore the ways that student-owned devices can aid in learning. (See the sidebar on balancing connectivity and student safety on the Internet.)

Using Cell Phones to Support Teaching and Learning

After letting two students use the calculator functions on their cell phones to solve the crisis of being two calculators short for a schoolwide math exam, the principal at Passage Middle School, Va., decided that he might be on to something. Hoping to capitalize on students' excitement when allowed to use their cell phones in school, he instituted Phone Fridays in math class and challenged students to come up with ways to use their phones to enhance learning. Students started using the phones' calendar function to keep track of homework schedules and the camera function to take pictures of the notes on the classroom's whiteboards. They created blogs and podcasts related to their homework and supported their math work both with the phone's calculator and by using the stopwatch function to time their speed at doing calculations.

Positive student reactions led the principal to invite other interested educators to join in the cell phone experiment. Before allowing cell phone usage on a broader scale, each educator had a discussion with his or her students to set ground rules for usage. All the classes came up with similar rules, and a school policy was developed: Cell phones could be used in class only for working on assignments. Text or video could be sent only with the educator's permission. No photographing or video- or audio-recording of people was allowed without their permission, no posting to websites was allowed without permission, and online safety precautions were to be taken when publishing from a mobile phone.

Teachers began using cell phone applications for polling and to set up an online text messaging board to discuss homework. One educator used the cell phones while teaching, asking students to answer questions via text messaging rather than out loud. As student answers came in, they were displayed on a screen at the front of the class, identified by the student's cell phone screen name. English teachers, in particular, found the cell phones useful as they started using blogs to engage students in writing. One class used Twitter to collaborate in generating stories in class.

Balancing Connectivity and Student Safety on the Internet

E-Rate is a federal program that supports connectivity in elementary and secondary schools and libraries by providing discounts on Internet access, telecommunications services, internal network connections, and basic maintenance. Schools, school districts, and consortia can receive discounts on these services ranging from 20 to 90 percent depending on their level of poverty and geographic location.

Schools' eligibility for E-Rate money is contingent on compliance with several federal laws designed to ensure student privacy and safety on the Internet. The Children's Internet Protection Act (CIPA) *requires any school that funds Internet access or internal network connections with E-Rate money to implement filters that block students' access to content that may be harmful to minors, including obscenity and pornography.* CIPA *also requires schools receiving E-Rate discounts to teach online safety to students and to monitor their online activities.*

Ensuring student safety on the Internet is a critical concern, but many filters designed to protect students also block access to legitimate learning content and such tools as blogs, wikis, and social networks that have the potential to support student learning and engagement. More flexible, intelligent filtering systems can give teachers (to whom CIPA *restrictions do not apply) access to educationally valuable content. On the other end of the spectrum, some schools and districts filter students' online activities with proxy servers that meet* CIPA *requirements but are easy to get around, minimizing their utility for managing and monitoring students' online activity.*

CIPA *also has posed challenges to accessing school networks through students' own cell phones, laptop computers, and other Internet access devices to support learning activities when schools cannot afford to purchase devices for each student. Applying* CIPA-*required network filters to a variety of student-owned devices is a technical challenge that may take schools months or years to implement. However, districts such as Florida's Escambia County Schools have created technical solutions and accompanying acceptable use policies (AUPs) that comply with* CIPA *regulations, allowing Web-based learning on student devices to run on networks supported by federal E-Rate funding.*

Source: Universal Service Administrative Company 2008.

Open Educational Resources

Open educational resources (OER) are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits sharing, accessing, repurposing—including for commercial purposes—and collaborating with others. These resources are an important element of an infrastructure for learning. Originating in higher education, OER forms range from podcasts to digital libraries to textbooks, games, and courses, and they are freely available to anyone over the Web.

MIT's decision to launch the OpenCourseWare (OCW) initiative to make the core content from all its courses available online in 2000 gave the OER movement a credible start (Smith 2009). Other universities joined the OCW Consortium, and today there are more than 200 members, each of which has agreed to make at least 10 courses available in open form.

Equally important to the OER movement was the emergence of the Creative Commons, an organization that developed a set of easy-to-use licenses whereby individuals or institutions could maintain ownership of their creative products while giving others selected rights for using OER for noncommercial purposes.

Advances in our understanding of how to design good OER are coming out of the work of the Open Learning Initiative (OLI) at Carnegie Mellon University. OLI has been developing state-of-the-art, high-quality online learning environments that are implemented as part of courses taught not only at Carnegie Mellon, but also at other universities and at community colleges. The OLI learning systems are submitted to rigorous ongoing evaluation and refinement as part of each implementation.

Many OER materials are available not just to individuals enrolled in courses, but to anyone who wants to use them. Nearly half of downloads of MIT's OpenCourseWare, for example, are by individual self-directed learners (Maxwell 2009).

Because OER materials are online, their development, publishing, and consumption have crossed geographic boundaries, enabling the movement to support a global education community. For example, the OER Commons is a well-known global membership network providing access to content that is free to use or share and, in some cases, change and share again. In many cases, these materials also are licensed so they can be incorporated into new courses and in new ways, even within a product that can be sold commercially.

The OER movement could be leveraged more fully throughout the education system and across types of learners. Students in the P–16 systems and adults who are changing careers or who simply have an interest could make use of these materials. Further, as we transition from the static print-based textbook to a more dynamic digital resource network, assets that are published as OER could be integrated into a new kind of "open textbook." For example, the development of a high-quality algebra textbook could be funded by a consortium and then the textbook could made freely available for use, reuse, and continuous improvement. A company could leverage these materials within an even better product for schools to use. Traditionally, textbooks have been a significant portion of the K–12 budget as well as the student-borne cost of higher education, and in budget-conscious times this is one strategy that could be considered.

Interoperability Standards

Not all high-quality technology-based learning resources are open, and ideally individual learners, teachers, schools, districts, and states could bring together an array of digital learning resources from many sources—both open and fee based—to meet their needs. Combining resources in this way, however, requires standards for interoperability so the resources can be catalogued and work together. A number of efforts to develop specifications for learning applications (SIF, SCORM, and IMS) have been underway for years, but no single approach has become the standard.

Next-generation Computing

To help build out an infrastructure for learning, districts and schools should begin a transition to the next generation of computing system architectures. Districts should consider options for reducing the number of servers they run through consolidation using virtualization. Virtualization allows a single server to run multiple applications safely and reliably, so that districts can reduce the number of servers on their networks dramatically, cutting costs and making the networks less complex and easier to manage.

Districts also can consider moving to cloud computing, which involves shifting from the procurement and maintenance of servers in local datacenters to purchasing software as a service (SaaS) and Web applications from datacenters running in the cloud.

Cloud computing is a catchy new name, but its principal outcome—utility computing—is not new. Utility computing is the packaging of computing resources as a metered service similar to how public utilities package and sell electricity through our nation's power grid. What makes cloud computing more desirable and possible is that we are nearing an inflection

North Carolina State University Cloud Computing Services

The Virtual Computing Laboratory (VCL) at North Carolina State University has been a pioneer in delivering secure on-demand computing services for education institutions. VCL was using cloud computing before the term came into popular use: It has been doing research on virtual computing since 2003 and began offering cloud services in 2004.

The VCL academic cloud is based on open-source technology and offers infrastructure as a service, platform as a service, and software as a service, including support of high-performance computing services. The advantages of VCL's cloud computing approach include consolidation of computing resources and technical support services, delivery of applications that would be difficult to install on student computers, and the extension of computing services to education institutions that otherwise would have only limited technology infrastructures.

As of 2009 VCL was serving more than 30,000 faculty and staff members. A typical user accesses VCL through a Web interface, going through a set of authentication and authorization steps and then choosing the desired kind of computing environment and time period from a set of pull-down menus.

VCL can dynamically move resources from one application to another, producing increased efficiency and lower costs. During semester breaks, for example, when most students are not using computing resources, the system assigns those resources to researchers with heavy computing requirements for activities, such as running complex models and simulations.

VCL now offers services on a pilot basis to seven other North Carolina public universities, the North Carolina Community College System, and several out-of-state universities including three in India. Possible extension of these academic cloud services to K-12 schools is being considered.

point driven by technology advances and the need for more powerful and collaborative platforms at lower cost.

Cloud computing can support both the academic and administrative services required for learning and education. It can enable students and educators to access the same learning resources using different Internet devices anytime and anywhere, both in and out of school. This will not happen automatically, however. School systems and other youth-serving organizations—public libraries, public broadcasting, after-school clubs, and so on—will need to engage each other and seek common platforms or at least technical interoperability.

Cloud computing is still in a nascent stage with obstacles to overcome to fully realize its potential. Still, now is the time to move forward with investments that contribute to the shift to cloud computing, with the primary benefits being cost savings and an ability for education institutions to refocus on their core mission, educating students. (See sidebar on North Carolina State University.)

Services Delivered From the Cloud

Figure 4 illustrates the comprehensive nature of integrated software services needed for learning experiences and that can be delivered from the cloud.

At the top are the users of the services—students, educators, administrators, and parents—with a variety of Internet access devices. With these devices, users can find a large and diverse set of digital educational resources from both proprietary and open providers.

Education resources and services could be used directly in a variety of educator- or learner-directed ways. They also could be used as ingredients for derivative products that are authored, built, edited, disseminated, and managed as student projects or educator-author curriculum modules through services indicated in the adjacent cluster. In this model, students and educators are both consumers and producers of educational content, with the role of student and educator sometimes interchanged. The framework of services also includes the administrative services for operating the school and school systems.

Figure 4: Framework for software services in a technology-empowered learning environment

Users of Services: Students, Teachers, Administrators, Parents		
Internet Access Devices		
Resources and Applications		
Education resources & services (open & proprietary)	**Authoring, editing, disseminating & content management**	**Administrative**
digital textbooks • digital libraries • tutoring systems • simulations • augmented reality • interactive visualization • educational	text processing • audio/video capture/edit • programming platforms • blogs• wikis • instructional/course management	scheduling • personnel/HR • plant/facilities management • procurement • attendance • student records
Assessment and Reporting		
Social Networking and Collaboration		
Public and Private Network-connected Clouds – software services, data libraries & repositories		

Below the three types of services are cross-cutting integrated capabilities to support data-driven assessment of individual students, individual educators, and the resources (content) and processes serving teaching and learning. Included here are assessments for formative and summative uses at time scales ranging from real time to decades. Also included are rating, ranking, and recommender services for educational resources.

The resources, authoring, and administrative services all can be used by individuals for solo work and also by teams of people working in various configurations of same and different place and time, perhaps internationally, through social networking and collaboration services. All the above rest critically on networking and middleware, with public and private cloud computing as the underlying platform for computation, data, and digital object management.

Human Talent and Scaling Expertise

Building and nurturing an infrastructure for learning requires providers and users who have knowledge and expertise in emerging technologies and a shared commitment to standards and specialists with experience integrating technology into curriculum development and assessment in meaningful ways.

The challenge of providing this level of expertise on the scale our education system requires should not be underestimated. Already, for example, the number of computers per computer technician in K–12 education is estimated at 612 compared with 150 computers per technician in private industry (CoSN 2009). To an increasing extent, students and educators are handling routine maintenance and troubleshooting of computer equipment themselves.

Using Students as Technical Resources

Generation YES

Generation YES started in 1995 as one of the first 100 federally funded Technology Innovation Challenge Grants. Its founder, Dennis Harper, believed that there was a better way than trying to train teachers in using technology with the expectation that they would then pass these skills to students. His insight was to use students as the technology experts, with each student assigned to a teacher as the technology consultant responsible for helping him or her develop and implement technology-based classroom activities. The learning goals for the student center on such real-world skills as project planning, collaboration, and communication. Since its inception, 1,200 schools and 75,000 students have participated in Generation YES.

MOUSE

Since its start in New York City in 1997, MOUSE has had the dual purpose of providing technical support to help teachers integrate technology into instruction and helping students (Mouse Squad volunteers) acquire the skills and attitudes they need for college. Now operating in more than 200 locations, MOUSE provides student-run technical help desks. MOUSE Corps is a career readiness program that offers professional internships, mentoring, and skill-building workshops to high school students. Citigroup has estimated that MOUSE volunteer labor saves the average school $19,000 a year in technical support costs.

Programs have been developed to make the technical support and troubleshooting a learning experience for students as well as a cost-saving measure. Students can also develop both technical and leadership skills through this experience. (See sidebar on using students as technical resources.)

Another level of support required is a professional educator who can engage with educators on leveraging technology for improving their professional practice. Studies have found that educators are more likely to incorporate technology into their instruction when they have access to this kind of coaching and mentoring (Strudler and Hearrington 2009). School technology coordinators, librarians, and media specialists may play this important role. Innovative approaches to staffing in schools that take advantage of online learning resources may free resources that can be applied to fund on-site mentors and coaches who can help educators make good use of technology resources.

Over time, districts have evolved instructional technology departments concerned with the use of technology in teaching and learning in addition to traditional information technology departments. Some districts have both kinds of IT departments (under any variety of names), and some have combined the two functions under a single leadership.

Even in the latter case, those in charge of IT for a district or state may find they are left out of deliberations on key decisions in such areas as instruction, personnel assignment, or assessment. Those responsible for instruction, personnel, and assessment, on the other hand, are often frustrated by technology that does not meet their needs. Building an infrastructure for learning will require close coordination among all these functions.

Reaching Our Goal

4.0 Infrastructure:

All students and educators will have access to a comprehensive infrastructure for learning when and where they need it.

To meet this goal, we recommend the following actions:

4.1 Ensure students and educators have broadband access to the Internet and adequate wireless connectivity both in and out of school.

Students and educators need adequate broadband bandwidth for accessing the Internet and technology-based learning resources. Adequate should be defined as the ability to use the Internet in school, in the surrounding campus, throughout the community, and at home. It should also include simultaneous use of high-bandwidth resources, such as multimedia, communication and collaboration environments, and communities. Crucial to providing such access are the broadband initiatives being individually and jointly managed by various federal agencies.

4.2 Ensure that every student and educator has at least one Internet access device and appropriate software and resources for research, communication, multimedia content creation, and collaboration for use in and out of school.

Only with 24/7 access to the Internet via devices and technology-based software and resources can we achieve the kind of engagement, student-centered learning, and assessments that can improve learning in the ways this plan proposes. The form of these devices, software, and resources may or may not be standardized and will evolve over time. In addition, these devices may be owned by the student or family, owned by the school, or some combination of the two. The use of devices owned by students will require advances in network filtering and improved support systems.

4.3 Support the development and use of open educational resources to promote innovative and creative opportunities for all learners and accelerate the development and adoption of new open technology-based learning tools and courses.

The value of open educational resources is now recognized around the world, leading to the availability of a vast array of learning, teaching, and research resources that learners of any age can use across all content areas. Realizing this value will require new policies concerning the evaluation and selection of instructional materials so that digital resources are considered and processes are established for keeping educational resource content up to date, appropriate, and tagged according to identified content interoperability standards.

4.4 Build state and local education agency capacity for evolving an infrastructure for learning.

Building an infrastructure for learning is a far-reaching project that will demand concerted and coordinated effort. The effort should start with implementing the next generation of computing system architectures and include transitioning computer systems, software, and services from in-house datacenters to professionally managed datacenters in the cloud for greater efficiency and flexibility. This will require leveraging and scaling up the human talent to build such an infrastructure, which should ultimately save money and enable education IT professionals to focus more on maintaining the local infrastructure and supporting teachers, students, and administrators.

4.5 Develop and use interoperability standards for content and student-learning data to enable collecting and sharing resources and collecting, sharing, and analyzing data to improve decision making at all levels of our education system.

Fragmented content, resources, and student-learning data siloed in different proprietary platforms and systems, along with a lack of common standards for collecting and sharing data, are formidable barriers to leveraging resources for teaching and learning. These barriers exist because we lack common content interoperability standards and tools to enable use of such standards. The lack of common standards affects the quality of tools because developers limit their R&D investments into narrow markets and are not able to leverage overall market advancements in research and development. Interoperability standards are essential to resolving these issues.

4.6 Develop and use interoperability standards for financial data to enable data-driven decision making, productivity advances, and continuous improvement at all levels of our education system.

Just as content, resources, and student-learning data are fragmented in disconnected technology systems and throughout our education system, the same is true for financial data. Therefore, we also need financial data interoperability standards and tools that enable the use of these standards.

Productivity:
Redesign and Transform

Goal: Our education system at all levels will redesign processes and structures to take advantage of the power of technology to improve learning outcomes while making more efficient use of time, money, and staff.

To reach the president's goal of regaining global leadership in college graduation rates by 2020, the United States must increase the percentage of citizens holding college degrees from the current level of just under 40 percent to 60 percent. That is a sizable increase and, considering that college graduation rates in our country have held steady for more than three decades (OECD 2009a), a sizable challenge.

Add to this challenge the projections of most states and the federal government of reduced revenues for the foreseeable future, and it is clear that we will not reach this goal simply by spending more money on education.

In fact, over the last 30 years, the United States has increased its real dollar K–12 education spending per student by more than 70 percent without a commensurate improvement in outcomes (National Center for Education Statistics 2005; 2008). In higher education, tuition costs are on the rise, yet just 21 percent of the increased revenue goes to instruction (Vedder 2004) and spending changes have not resulted in higher degree completion rates (Bound, Lovenheim, and Turner 2009).

More money for education is important, but we must spend education dollars wisely, starting with being clear about the learning outcomes we expect from the investments we make. We also must leverage technology to plan, manage, monitor, and report spending so that we can provide decision-makers with a reliable, accurate, and complete view of the financial performance of our education system at all levels. Such visibility is essential to improving productivity and accountability.

At the same time, we must make a commitment to continuous improvement by continually measuring and improving the productivity of our education system to meet our goals for educational attainment within the budgets we can afford.

The Productivity Paradox

Improving productivity is a daily focus of most American organizations in all sectors—both for-profit and nonprofit—and especially in tight economic times. Education has not, however, incorporated many of the practices other sectors regularly use to improve outcomes and manage costs, nor has it leveraged technology to enable or enhance them. We can learn much from the experience in other sectors.

During the 1970s and 1980s, economists puzzled over what they called the "productivity paradox." Businesses were rapidly deploying technology in the belief that it would help them perform better and more efficiently. But when economists looked for hard data to demonstrate that U.S. economic output per unit of investment was increasing, they turned up empty-handed.

In the 1990s, economists were finally able to find evidence of substantial improvements in productivity related to technology (Brynjolfsson and Hitt 1998). They discovered that when businesses first introduced technology, they tended to use it to automate existing processes and procedures, without regard to whether they might be flawed or inefficient. Such uses may have had some benefit in terms of accuracy or speed, but the cost and complexity of acquiring technology, implementing it, and training staff in its use far outweighed its contributions.

Later still, in the 2000s, economists concluded that dramatic improvements in productivity were the result of structural innovations and a thorough redesign of business processes made possible by technology (Black and Lynch 2003).

What education can learn from the experience of business is that we need to make the fundamental structural changes that technology enables if we are to see dramatic improvements in productivity. As we do so, we should recognize that although the fundamental purpose of our public education system is the same, the roles and processes of schools, educators, and the system itself should change to reflect the times we live in and our goals as a world leader. Such rethinking applies not just to learning, assessment, and teaching processes, but also to the infrastructure and operational and financial sides of running schools and school systems.

A Call to Action for Education Leaders

Redesigning education in America is a complex challenge that will require all 50 states, the thousands of districts and schools across the country, the federal government, and other education stakeholders in the public and private sector to come together to design and implement solutions. It is a challenge for education leaders and policymakers, technologists in both the public and private sectors, and for educators throughout our education system.

An appropriate role for the Department of Education is to identify strategies for improving productivity in education and to work with states and districts to increase their capacity to implement them. This will include encouraging states and local education agencies to make changes to practices, policies, and regulations that prevent or inhibit education from using technology to improve productivity.

In addition, when learning is powered by technology, the role of education leadership changes dramatically. Having leaders throughout our education system who understand the role of technology is essential. For example, every state should assign responsibility for educational technology to a senior-level individual who can provide a new kind of education leadership by ensuring that planning for educational and information technology is connected with the core functions of curriculum and instruction, assessment, professional learning, and administration. A senior-level leader equally knowledgeable about education and technology also would ensure that educational technology purchases are efficient and effective, both in terms of what is purchased and how purchases are made. (For an example of one state that has learned a new way to lead, see sidebar.)

Embracing Continuous Improvement

The underlying principle of continuous improvement is that we are unlikely to improve productivity until we can define and measure it. This starts with identifying what we seek in learning outcomes. It also requires getting a handle on the costs associated with components of our education system and with individual resources and activities so that the ratio of outcomes to costs can be tracked over time.

This plan devotes considerable space to the learning outcomes we seek and measuring what matters in learning. It also considers pragmatic such outcomes as successful high school graduation, readiness for postsecondary education, and college degree completion.

As we establish new and more complete measures of learning and pragmatic outcomes, however, quality matters. A student who successfully completes algebra in one high school may learn more, be better prepared for college-level mathematics, and be more inspired to pursue a career in mathematics than a student who successfully completes algebra at another high school. Even if we cannot accurately measure or easily remedy these qualitative differences, we must consider them as we determine what to measure for continuous improvement.

Leading for Learning

Taking advantage of technology to make transformative changes in learning opportunities requires leadership. The number of aspects of the existing system that need to change make the effort both daunting and complex, but examples of leaders working together to address this challenge are starting to emerge.

In Michigan, Mike Flanagan, the state superintendent of instruction, was motivated to take on educational transformation by the high dropout rate in many school districts. Superintendent Flanagan issued a Dropout Challenge, calling on districts to lower the number of students who leave school without a diploma. One of the first steps in the Dropout Challenge work was to get accurate data on the number of students who had started ninth grade who actually graduated four years later so that Michigan districts knew where they really stood with respect to dropouts. This understanding was hard to come by with the old practice of merely looking at the number of students starting 12th grade who do not earn a diploma.

Next, Superintendent Flanagan reasoned that schools need to measure and use indicators known to predict dropping out—such as poor attendance, earning few course credits in ninth and 10th grades, and failure to progress to the next grade. These data were not part of the state's data system, and many districts did not keep track of them. Michigan used $11.5 million in funding from the American Recovery and Reinvestment Act of 2009 *to fund a Regional Data Initiatives grant program to make these kinds of data available at the school level. More than 97 percent of the states' school districts signed on to the initiative. In addition, an online professional learning community is focusing on best practices in using data for dropout prevention.*

The state legislature supported Superintendent Flanagan's Dropout Challenge initiative by raising the age at which a student can leave school without parental permission from 16 to 18. To provide alternatives for students who have dropped out or who are considering doing so, Michigan also has begun expanding alternative programs, including options for online instruction. Superintendent Flanagan has given waivers to the state's seat time requirements to 21 programs, some of which allow students to take all their instruction online.

Measuring and Managing Costs

The United States spends an average of about $10,000 per student per year on K–12 education. But for too many education leaders and decision-makers, visibility into the costs of specific services our education system delivers to students is nonexistent. This is because education accounting and reporting typically are done across large programs and broad categories, such as instruction or instructional support. These accounting practices are insufficient for tracking, benchmarking, and analyzing the costs of various services individually or compared with one another—all of which are essential to making decisions that lead to better outcomes and productivity.

A better approach to accounting for these purposes is cost accounting, which focuses on recording, tracking, and reporting costs associated with specific functions or services. Cost accounting can provide a complete picture of actual costs today and also serve as the basis for projecting costs in the future. As part of a commitment to continuous improvement, states and districts should adopt common cost-accounting standards for benchmarking and analyzing costs.

Using Data in Decision Making

An essential component of continuous improvement is making decisions based on data, which will require fundamental changes in how we collect and use data and in the processes we currently use for decision making.

For many years, school districts have been developing and using multiple data systems for different purposes. As a result, many districts today have separate systems for finance data, personnel data, required accountability information for special education students, school lunch data, enrollment and attendance, and assessment data. Historically, linking data from these different systems has been cumbersome or impossible.

Advances in technology and a recent policy emphasis on using data in decision making have resulted in much improved data in many districts. Still, although almost all districts have electronic access to such data as student demographics, attendance, grades, and test scores, less than half have the ability to combine data from different types of systems so as to link student outcome data to data about specific instructional programs, teacher characteristics, or school finances (Gray and Lewis 2009; U.S. Department of Education Office of Planning, Evaluation, and Policy Development 2010). Combining data from these different types of systems will require at a minimum the development and use of content, student-learning, and financial data interoperability standards. Over time, it will require designing, developing, and adopting integrated systems for collecting the complex forms of data we need and for deriving meaningful interpretations relative to what we want to measure.

In addition to fragmented data systems, the silos created by funding programs, tradition, and interest groups present a major barrier to improving the productivity of our education system. When those responsible for a given function are isolated from others within the same organization, they tend to develop practices and procedures that are optimal only from their own perspective. In addition, decisions made in one portion of an organization may create tension with decisions made in another.

To ensure better alignment in decision making, states and districts should develop process-redesign teams that cut across functions and follow the process rather than looking at work flow only within a given office (CoSN 2009). In addition, federal and state policies and regulations should be reviewed to identify and remove barriers to more efficient use of resources within schools and districts. Policies also should be reviewed to remove practices that keep technology functions isolated from the functions of teaching, learning, and assessment. These include separate funding streams and restrictions on the use of funds that reinforce the isolation of the educational technology function. (See sidebar on using data to drive improvement.)

Employing Iterative Design and Development

As we embrace continuous improvement, we must respect the complexity of our system and invest the effort needed to evaluate educational practices in different contexts over time. Rather than expecting to find an ideal turnkey solution, states and districts should define, test, and refine new ideas on a trial basis and measure their implementation effectiveness and results. New educational practices should be adopted with the expectation that there will be multiple cycles of implementation and refinement. States and districts also should partner with each other on process redesign pilots and programs to leverage resources and scale up the best ideas.

Moving to Useful Metrics on the Use of Technology

Current data on the use of educational and information technology in our system consist of records of purchases and numbers of computers and Internet connections. Very little information on how technology is actually used to support teaching, learning, and assessment is collected and communicated systematically. Only by shifting our focus to collecting data on how and when technology is used will we be able determine the difference it makes and use that knowledge to improve learning outcomes and the productivity of our education system.

Using Data to Drive Improvement

During the 1980s and 1990s, Maryland's Montgomery County Public Schools (MCPS) saw dramatic changes in their student bodies, with increasing numbers of students living in poverty and coming from immigrant families or historically underserved ethnic groups. When Jerry Weast became superintendent in 1999, he initiated an Integrated Quality Management System (IQMS) as a strategy for identifying and closing achievement gaps. IQMS combines student information, such as enrollment, attendance, grades, scheduling, and test performance, with data on professional development, finances, and human resources. An Instructional Management System (IMS) was added to give teachers online access to curriculum resources, student performance on formative and summative assessments and various screenings, and curriculum guides and lesson plans.

A joint venture with a technology developer produced software for a handheld computing device that allowed teachers to do individual assessments of a student's literacy skills and capture the data for the student's electronic file. The electronic records enabled reading coaches to look at data for individual students, identify students who were not making the expected progress, and seek out the relevant teachers to offer suggestions and support. The result was that district reading achievement rose overall, with especially large gains for African-American, Hispanic, and low-income students (Childress, Doyle, and Thomas 2009).

More recently, MCPS has implemented a collaborative data-focused process it calls M-STAT. Community superintendents come together and use data to examine such issues as differential advanced course enrollment rates within their high schools. The district had long recognized the lower participation of Hispanic and African-American students in advanced courses and had switched from using teacher recommendations to using PSAT scores and other objective indicators to counsel students into honors and AP courses. The M-STAT process revealed that Hispanic and African-American students were less likely than other students to participate in the PSAT. The community superintendents started working with their principals on such actions as meeting with African-American and Hispanic parents to talk about the importance of the PSAT and making the examination more enjoyable by providing snacks. By 2008, 88 percent of African-American and 84 percent of Hispanic students in MCPS took the PSAT; more than 60 percent of African-American and Hispanic high school students were enrolled in at least one honors or AP course (Childress, Doyle, and Thomas 2009).

Employing technology on the scale proposed in this plan is new to education. Findings from evaluations of technological adaptations demonstrate a range of effectiveness, from low to high, depending on not just the specific technology but also the way in which it is used, the training associated with it, and the effort applied to on-going refinement and further development (Campuzano et al. 2009; Kulik 2003). The lessons learned from previous efforts emphasize that the introduction of new or adapted technologies must be accompanied, at a minimum, by a deliberate, often repeating cycle of implementation, observation and assessment, and improvement. To truly build a knowledge base and ensure that we are using our scarce resources wisely, formative research, which might often be quite local in focus, should be accompanied by a more broadly coordinated program of summative research that measures both effectiveness and cost-effectiveness.

Reorganizing Teaching and Learning

We have long known that whatever it is we are trying to teach, whether drawing or quantum mechanics, individual students will vary in how much they know already, how they like to learn, and the speed at which they can learn more. In a time when we have the capability to support learning 24/7 and personalize the way a student interacts with digital content, it no longer makes sense to give every 13-year-old the same set of 45-minute American history lessons.

How much could we save if students who are ready and interested in moving ahead in their studies were allowed to do so instead of marking time until their classmates catch up? How much more efficient would our system be if students who need extra support in reading comprehension strategies had that support at their fingertips whenever they were reading in the content areas? How many more students would pass their courses and not have to repeat them? These are essential questions we must ask as we redesign education, and answering them will require rethinking basic assumptions about how our education system meets our goals.

One of the most basic assumptions in our education system is time-based or seat-time measures of educational attainment. These measures were created in the late 1800s and early 1900s to smooth transitions from K–12 into higher education by translating high school work to college admissions offices (Shedd 2003) and made their way into higher education when institutions began moving away from standardized curricula.

Time-based measures were appropriate in their day, but they are not now when we know more about how people learn and we have access to technology that can help us accommodate different styles and paces of learning. As we move to online learning and learning that combines classroom and online learning, time-based measures will increasingly frustrate our attempts to provide learning experiences that lead to achievement and the pursuit of postsecondary education that our modern world requires.

Another basic assumption is the inflexible way we organize students into age-determined groups, structure separate academic disciplines, organize learning into classes of roughly equal size with all the students in a particular class receiving the same content at the same pace, and keep these groups in place all year. (See sidebar on making a school "not school.")

The last decade has seen the emergence of some radically redesigned schools, demonstrating the range of possibilities for structuring education. For example, organizing education around the demonstration of competence rather than seat time opens up a wide range of possibilities. The first school district to win the Baldrige National Quality Award, Chugach School District in Alaska, achieved remarkable gains in student outcomes after mobilizing its community to identify the competencies it wanted to see in high school graduates and shifting to a performance-based system in which diplomas were awarded on the basis of performance on the district's assessment of those competencies (NIST, Baldrige 2001). Since that time, 15 districts and 200 schools have signed up to replicate this systemic reform (Re-Inventing Schools Coalition n.d.).

Making a School "Not School"

The kind of radical rethinking of the nature of schooling that technology makes possible is illustrated by Westwood Cyber School, located just outside Detroit, Mich. Launched two years ago as a dropout recovery and prevention program, the Cyber School is the first location in the country to implement a British model known as the "Not School."

Like its British prototype, Westwood Cyber does not have traditional classrooms, academic departments, courses, or tests. Students use the Internet to work almost entirely from home, reporting to the brick-and-mortar school building for just two hours a week to check in with school staff. The rest of the time they work interactively with school personnel and the school's learning management system. Learning activities emphasize project-based learning and incorporate multiple subject areas. Student projects result in an individualized portfolio of creative work that is tailored to each student's interests. Experts (state-certified teachers) grade students' portfolio work products using grading rubrics closely tied to state learning standards to ensure that students achieve mastery of required material within their individualized learning programs.

The Westwood school district, which had been losing enrollment, has increased enrollment by 33 percent since starting the Cyber School. The school itself has retained 90 percent of its students.

New Hampshire is now moving to a competency-based approach to secondary education across the entire state. The state's governor asked his school board to come up with the education reforms needed to meet the goal of having zero dropouts by 2012. The board focused on the issue of unproductive requirements that impede student progress: Why, for example, can a student earn a high school credit by attending gym class but not for the hours spent practicing and performing as part of a gymnastics team? Subsequently, the board changed state regulations to give students the option of earning credit for graduation by demonstrating their competence with respect to the standards stipulated by their school districts. New Hampshire districts are still determining how to implement this system, including its implications for funding, teacher training, and assessment practices. But a new high school position—the extended learning opportunity coordinator—is emerging in schools across the state.

Technology can facilitate implementation of such a competency-based approach to education. At the Young Women's Leadership Charter School in Chicago, teachers use a specially designed database to keep track of the proficiency ratings each student has earned. Proficiency ratings are updated daily so that everyone—the student, the parent, teachers, and the school leader—knows exactly where each student stands relative to the competencies required for graduation. (See sidebar on competency-based assessment at the Young Women's Leadership Charter School.)

Competency-based Assessment at Young Women's Leadership Charter School

In 2002, the Young Women's Leadership Charter School (YWLCS) in Chicago instituted a radically new system for awarding course credit that is helping its students master course material, graduate from high school, and enroll in higher education at rates far exceeding those of demographically similar schools. A nonselective public school that serves primarily low-income minority students, YWLCS graduated 79 percent of its students in 2005, a figure 1.5 times higher than Chicago Public Schools' overall 52 percent graduation rate that year.

School leaders have implemented a system for student assessment that moves away from tying credit to seat time. Instead, the school recognizes the continuous nature of student learning by awarding credit for specific competencies demonstrated at any point in a student's high school career.

With a commercial partner, the school developed a data system designed specifically for use in a competency-based program. Throughout the year, YWLCS teachers evaluate student work and go to the system to assign each student a proficiency rating of High Performance, Proficient, or Not Yet Proficient for each key learning objective associated with the class. Students earn credit for classes in which they demonstrate proficiency on at least 70 percent of academic course outcomes.

The data system uses the proficiency data that teachers enter to create a dynamic record of each student's progress that is updated daily and is accessible to teachers, parents, and students. Teachers can use the data system to target their instruction and remediation strategies for current students. In addition, students can use their own data to identify the courses they are not yet proficient in and work with their teachers to develop a plan for mastering unmet standards.

If students demonstrate a competency after the end of the year has passed, future teachers can update students' proficiency ratings in the data system to reflect what they have learned since the conclusion of a course.

YWLCS compiles information from the data system into formal reports of student achievement, converting proficiency ratings into grade point average equivalents, to ensure that its graduates' competencies are recognized by colleges, sources of financial aid, and other external parties. This competency-based approach is producing results: 90 percent of YWLCS students who graduated in 2009 were accepted to college or another postsecondary option.

Another way technology can support the reorganization of teaching and learning is by enabling more flexible student-centered scheduling. At the Huyton Arts and Sports Centre for Learning, a secondary school in the United Kingdom, for example, learning activities are selected and scheduled to fit individual students' needs rather than traditional academic periods and lockstep curriculum pacing.

Extending Learning Time

Another strategy for rethinking how teaching and learning are organized involves extending the learning day, week, or year. American students spend significantly less time in the classroom than students in many other countries, and students—especially low-income students—show a marked drop in their mathematics and reading proficiencies over the summer break. President Obama and other policymakers have questioned the logic of maintaining a three-month summer hiatus originally instituted so that students could provide needed farm labor during the critical summer months.

Since 2006, Massachusetts has had an Expanded Learning Time Initiative under which schools in lower income districts are adding 300 or more instructional hours to the school year. A number of charter school networks share the belief that extending learning time is key to preparing students from low-income communities for college, and they are instituting longer school days and weeks. Yes Prep schools, for example, run from 7:30 in the morning until 4:30 each day with additional sessions every other Saturday. Yes Prep educators also support extending learning time by giving students their cell phone numbers so that students can call them during the evening to ask questions about homework.

As we seek ways to extend learning time, in addition to considering the amount of time students spend in school, we should also look at whether we can provide engaging and powerful learning experiences through other means. For example, we know that students' lives outside school are filled with technology that gives them 24/7 mobile access to information and resources and allows them to participate in online social networks and communities where people from all over the world share ideas, collaborate, and learn new things. Our education system should leverage students' interest in technology and the time they currently spend learning informally outside the regular school hours to extend learning time in a way that motivates them even more.

One way to do that is through online learning, which allows schools to extend learning time by providing students with learning on demand anytime and anywhere, dramatically expanding educational opportunities without increasing time spent in school. With online learning, students can gain access to resources regardless of time of day, geography, or ability; receive personalized instruction from educators and experts anywhere in the world; and learn at their own pace and in ways tailored to their own styles and interests. Moreover, it enables our education system to leverage the talents and expertise of our best educators by making their knowledge and skills available to many more learners.

In addition, all these benefits can be realized through online learning at considerably less cost than providing students with additional in-person, classroom-based instruction by extending the school day or year.

As schools implement online learning, they should ensure that students' learning experiences address the full range of expertise and competencies as reflected in standards and use meaningful assessments of the target competencies. For example, online collaborative environments or virtual worlds can facilitate the participatory nature of learning in addition to providing opportunities for content knowledge. State education agencies can provide leadership and technical assistance in this area, and educators also should look to their peers for best practices.

Removing Barriers to Secondary and Postsecondary Graduation

The United States has a long way to go if we are to see every student complete at least a year of higher education or postsecondary career training. There is no way to achieve this target unless we can dramatically reduce the number of students who leave high school without getting a diploma and/or who are unprepared for postsecondary education. A complex set of personal and academic factors underlie students' decision to leave school or to disengage from learning, and no one strategy will prevent every separation from the education system.

Many students report that dropping out of school is a gradual process of disengagement that can be reversed with more relevant learning experiences and social and emotional interactions at school (Bridgeland, Dilulio, and Morrison 2006; Rumberger and Lim 2008). Technology-based programs and resources, including online learning, tutoring and mentoring, and social networks and participatory communities within and across educational institutions, can provide both. They also can give students guidance and information about their own learning progress and opportunities for the future. Specifically, students need to know what is expected of them

Expanding Opportunities Through Blended Learning

Walled Lake Consolidated School District in Oakland County, Mich., is turning to online learning to offer students a wider range of educational opportunities very cost-effectively.

In 2008, Walled Lake began offering its summer school credit recovery classes online. The district enlisted the help of its teachers to review various offerings and selected an online learning provider whose curriculum was comparable to that of district courses. Walled Lake enrolled 300 students in these online courses and also provided face-to-face meetings with district teachers twice a week to help students with course material and track their progress. This blended strategy lowered the district's costs of providing each summer school course by nearly 50 percent, reducing the cost per student from $194 to about $102.

Inspired by this success and students' positive experiences with online learning, Walled Lake plans to begin allowing high school students to take both online and classroom-based courses during the school year. Students will continue to attend school at least four hours per day, but they may elect to enroll in up to two online courses each semester. As with its summer school courses, Walled Lake students' online learning experiences will be supported by biweekly interactions with local teachers. This blended learning arrangement will accommodate students' diverse learning styles and desire to work before or after school in ways that were not possible with full-time conventional instruction.

Walled Lake is also partnering with a local community college to make postsecondary education a reality for more of its high school students. Under the experimental agreement, 11th- and 12th-grade students may choose to enroll concurrently in high school and college, completing some college coursework online and some on the college campus, facilitated by the flexible scheduling system described above. The district will continue to claim full-time-equivalent funding for each student and will pay students' tuition for courses taken at the community college during their high school years. This arrangement will enable Walled Lake students to complete an associate degree just one year after high school graduation.

as they move from middle school to high school and from high school to postsecondary education. Other practices supported with technology also can help address the problem.

First, there is the issue of identifying students' difficulties early and providing extra support where needed. Support should start as early as possible, before children enter school, and should become intensified for those students who need it as they move through school. From the point of high school entry, every student could have a learning dashboard indicating whether or not his or her course enrollments and performance are on track for high school graduation and qualification for college entry. Such a system could make "smart" suggestions about options for fulfilling requirements, including the possibility of earning credits for courses taken during the summer, in alternative programs, at community colleges, or online.

When prevention fails and students quit attending school for a period of time, we must have multiple options for reconnecting them with the education system. Such students often become discouraged about their prospects for being able to earn the credits needed for graduation or have an aversion to returning to a school where they will be in classes with younger students rather than their original cohort. (See sidebar on adult learning resources in the Learning chapter.)

Increasingly, secondary students are taking courses online to earn credit for courses they initially failed or missed because they were not attending school. Such courses can be taken under any number of arrangements—independently in the evening, during summer sessions, in a night school, or during the school day with a member of the teaching staff, who provides encouragement and support as the student works with the online material.

In Walled Lake Consolidated School District in Michigan, for example, students can recover course credits through online summer school courses. The summer credit recovery program has worked so well that the district is developing a plan that will allow students to stay in high school while working by attending class in their brick-and-mortar school for four hours a day and taking their other two required courses online at their convenience. (See sidebar on expanding learning opportunities through blended learning.)

Another example is provided by Tarrant High School in Alabama. Tarrant students are taking advantage of ACCESS (Alabama Connecting Classrooms, Educators, & Students Statewide), the state's online learning program, to take courses before or after school or in the summer in order to recover credits for courses they failed or to graduate earlier. The school's principal believes that ACCESS has been a significant factor in raising her school's graduation rate from 66 percent in 2006 to 80 percent in 2008. Research conducted in the state of Washington has concluded similarly that online credit recovery can help increase graduation rates (Baker et al. 2006).

Reaching Our Goal

5.0 Productivity:

Our education system at all levels will redesign processes and structures to take advantage of the power of technology to improve learning outcomes while making more efficient use of time, money, and staff.

To meet this goal, we recommend the following actions:

5.1 Develop and adopt a common definition of productivity in education and more relevant and meaningful measures of outcomes, along with improved policies and technologies for managing costs, including those for procurement.

Education has not incorporated many of the practices other sectors regularly use to measure outcomes, manage costs, and improve productivity, a number of which are enabled or enhanced by technology. As other sectors have learned, we are unlikely to improve outcomes and productivity until we define and start measuring them. This starts with identifying what we seek to measure. It also requires identifying costs associated with components of our education system and with individual resources and activities so that the ratio of outcomes to costs can be tracked over time.

5.2 Rethink basic assumptions in our education system that inhibit leveraging technology to improve learning, starting with our current practice of organizing student and educator learning around seat time instead of the demonstration of competencies.

To realize the full potential of technology for improving performance and increasing productivity, we must remove the process and structural barriers to broad adoption. The education system must work to identify and rethink basic assumptions of the education system. Some of these include measurement of educational attainment through seat time, organization of students into age-determined groups, the structure of separate academic disciplines, the organization of learning into classes of roughly equal size, and the use of time blocks.

5.3 Develop useful metrics for the educational use of technology in states and districts.

Current data on the use of educational and information technology in our system consist of records of purchases and numbers of computers and Internet connections. Very little information on how technology is actually used to support teaching, learning, and assessment is collected and communicated systematically. Only by shifting our focus to collecting data on how and when technology is used will we be able to determine the difference it makes and use that knowledge to improve outcomes and the productivity of our education system.

5.4 Design, implement, and evaluate technology-powered programs and interventions to ensure that students progress seamlessly through our P–16 education system and emerge prepared for college and careers.

The United States has a long way to go if we are to see every student complete at least a year of higher education or postsecondary career training. Achieving this target will require dramatically reducing the number of students who leave high school without getting a diploma and/or who are unprepared for postsecondary education. A complex set of personal and academic factors underlie students' decision to leave school or to disengage from learning, and no one strategy will prevent every separation from the education system. Collaboration between P–12 and higher education institutions and practices supported with technology are crucial to addressing the problem.

R&D: Innovate and Scale

The model for learning presented in this plan assumes that we will develop, adopt, and ensure equitable access to a technology-based education system that provides effective learning experiences, assessments, and teaching and a comprehensive infrastructure for learning to support both formal education and all other aspects of learning. It also assumes we will incorporate many of the practices other sectors regularly use to improve productivity and manage costs and will leverage technology to enable or enhance them.

In the past, we have relied on public education entities and private companies to develop technology resources and tools for learning. In both these sectors, however, incentives are provided for developing discrete products and services without regard for how they work as parts of a system or for research on their effectiveness. Public education entities can mandate use of their products and services. Commercial enterprises gain market share through compelling value propositions, effective marketing, and broad distribution channels. But research on the effectiveness of learning technology typically comes after products and services have been deployed—when it is too late to result in major improvements—if it comes at all.

If we are to achieve our goal of leading the world in education, we must be leaders in the design and implementation of a more effective education system. To that end, this plan calls for a new approach to R&D for education that focuses on four areas:

- Continuing to provide competitive grants for scaling up innovative and evidence-based practices through the Department of Education's Investing in Innovation Fund (i3).

The i3 program provides funding for grants that are awarded to schools and nonprofit organizations for scaling innovations that improve K–12 education. There is a particular focus on the identification of evidence and increasing the level of understanding of what strategies and innovations work for what students under what circumstances.

- Transferring existing and emerging technology innovations from such sectors as consumer, business, and entertainment into education.

The Department of Education will promote the inclusion of innovative thinkers in consumer, business, and entertainment technology in federally funded convenings and collaborations with educational technology specialists.

- Supporting and sustaining the education R&D that is currently happening at the National Science Foundation, especially through its cyberlearning initiatives.

In June 2008, the NSF Task Force on Cyberlearning published *Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge*, a comprehensive report on the role technology can and should play in STEM learning. For 2011, the NSF has established a new multidisciplinary research program to fully capture the transformative potential of advanced learning technologies across the education system. The Cyberlearning Transforming Education (CTE) program's investments will focus on anytime, anywhere learning, personalized learning, and using technology to advance our fundamental knowledge of how technology and learning sciences can come together in learning and assessment.

- Creating a new organization with the mission of serving the public good through R&D at the intersection of learning sciences, technology, and education (Pea and Lazowska 2003).

The *Higher Education Opportunity Act* (P.L. 110-315), passed in August 2008, authorizes establishment of the National Center for Research in Advanced Information and Digital Technologies (also called the Digital Promise). The center is authorized as a 501(c)3 that would be able to accept contributions from the public and private sectors to support the R&D needed to transform learning in America.

The National Center for Research in Advanced Information and Digital Technologies would support research at scale, facilitating the participation of educators, schools, and districts as partners in design and research. It would also promote transparency and collaboration, encouraging multiple researchers to work with the same data and interoperable software components and services. Its unique charter is to identify the key research and development challenges in the education field and coordinate the best combination of expertise for addressing them. These characteristics, along with an emphasis on public-private collaboration, distinguish the National Center for Research in Advanced Information and Digital Technologies from existing centers that help state and local education entities identify and implement established best practices in learning technology. The center's work would also be distinct from field-initiated research on the effectiveness of technology-based interventions.

The Defense Advanced Research Projects Agency (DARPA) offers an example of how such a research agency can promote work that builds basic understanding and addresses practical problems. DARPA sponsors high-risk/high-gain research on behalf of Department of Defense agencies, but it is managed and staffed by individuals from both industry and academia who are experts in the relevant research areas. DARPA program officers are given considerable discretion, both in defining the research agenda and making decisions about the funding and structuring of research.

In a similar manner, the National Center for Research in Advanced Information and Digital Technologies should identify key emerging trends and priorities and recruit and bring together the best minds and organizations to collaborate on high-risk/high-gain education R&D projects. It should aim for radical, orders-of-magnitude improvements by envisioning the impact of innovations and then working backward to identify the fundamental breakthroughs required to make them possible.

Through the funding of rapid and iterative cycles of design and trial implementation in educational settings, the national center can demonstrate the feasibility and early-stage potential of innovative tools, content, and pedagogies that leverage knowledge, information, and technology advances at the cutting edge.

The center should also ensure that teams working on each individual project share developments, progress, best practices, and outcomes with each other to take advantage of key findings and economies of scale and to ensure integration and interoperability between projects when desirable. The national center will need to work closely with representatives of private industry to develop clear memoranda of understanding concerning the terms for precompetitive fundamental research.

The national research center can focus on grand challenge problems in education research and development. “Grand challenge problems” are important problems that require establishing a community of scientists and researchers to work toward their solution.

American computer science was advanced by a grand challenge problems strategy when its research community articulated a set of science and social problems whose solutions required a thousand-fold increase in the power and speed of supercomputers and their supporting networks, storage systems, and software. Since that time, grand challenge problems have been used to catalyze advances in genetics (the Human Genome Project), environmental science, and world health.

To qualify as grand challenge problems suitable for this organization, research problems should be

- Understandable and significant, with a clearly stated compelling case for contributing to long-term benefits for society
- Challenging, timely, and achievable with concerted, coordinated efforts
- Clearly useful in terms of impact and scale, if solved, with long-term benefits for many people and international in scope
- Measurable and incremental, with interim milestones that produce useful benefits as they are reached.

This kind of grand challenge problem strategy has driven innovation and knowledge building in science, engineering, and mathematics. The time is right to undertake it to improve our education system (Pea 2007).

The following grand challenge problems illustrate the kinds of ambitious R&D efforts this organization could lead. Notably, although each of these problems is a grand challenge in its own right, they all combine to form the ultimate grand challenge problem in education: establishing an integrated, end-to-end real-time system for managing learning outcomes and costs across our entire education system at all levels.

1.0: Design and validate an integrated system that provides real-time access to learning experiences tuned to the levels of difficulty and assistance that optimize learning for all learners and that incorporates self-improving features that enable it to become increasingly effective through interaction with learners.

Today, we have examples of systems that can recommend learning resources a person might like, learning materials with embedded tutoring functions, software that can provide UDL supports for any technology-based learning materials, and learning management systems that move individuals through sets of learning materials and keep track of their progress and activity. What we do not have is an integrated system that can perform all these functions dynamically while optimizing engagement and learning for all learners. Such an integrated system is essential for implementing the individualized, differentiated, and personalized learning called for in this plan. Specifically, the integrated system should be able to

- Discover appropriate learning resources;
- Configure the resources with forms of representation and expression that are appropriate for the learner's age, language, reading ability, and prior knowledge; and
- Select appropriate paths and scaffolds for moving the learner through the learning resources with the ideal level of challenge and support.

As part of the validation of this system, we need to examine how much leverage is gained by giving learners control over the pace of their learning and whether certain knowledge domains or competencies require educators to retain that control. We also need to better understand where and when we can substitute learner judgment, online peer interactivity and coaching, and technological advances, such as smart tutors and avatars for the educator-led classroom model.

2.0: Design and validate an integrated system for designing and implementing valid, reliable, and cost-effective assessments of complex aspects of 21st-century expertise and competencies across academic disciplines.

The multiple-choice tests used in nearly all large-scale assessment programs fail to meet the challenge of capturing some of the most important aspects of 21st-century expertise and competencies. Past attempts to measure these areas have been expensive and of limited reliability. Technology offers new options for addressing the multiple components of this challenge. For example, technology can support

- Systematic analysis of the claims about student competence (including competence with respect to complex aspects of inquiry, reasoning, design, and communication) intended by academic standards and the kinds of evidence needed to judge whether or not a student has each of those aspects of competence;
- Specifying assessment tasks and situations that would provide the desired evidence;
- Administering complex assessment tasks capable of capturing complex aspects of 21st-century expertise through the use of technology; and

- Developing and applying rules and statistical models for generating reliable inferences about the learner's competencies based on performance on the assessment tasks.

Promising R&D applying technology to each of these components of the grand challenge is ongoing, but the pieces have yet to be integrated into a single system that is applicable across content domains and that is cost-effective to implement. In addition to system development, solving this grand challenge problem will require studies to demonstrate the validity of the new assessments and their usefulness for both making formative instructional decisions to improve learning and summative evaluative decisions for purposes of establishing competency and accountability.

3.0: Design and validate an integrated approach for capturing, aggregating, mining, and sharing content, student-learning, and financial data cost-effectively for multiple purposes across many learning platforms and data systems in near real time.

To meet the education and productivity goals articulated in this plan, learners and their parents, educators, school and district leaders, and state and federal policymakers must use timely information about student-learning and financial data to inform their decisions. Today, these data are maintained in a variety of digital formats in multiple systems at local and state levels. As the processes of learning, assessment, and financial management and accounting move into the digital realm, education data systems and education research have become exceedingly complex in terms of scale, heterogeneity, and requirements for privacy. Still, we must create systems that capture, curate, maintain, and analyze education and financial data in all scales and shapes, in near real time, from all areas where learning occurs: school, home, and community. This must be done in a manner fully consistent with privacy regulations.

Although underlying technologies for exchanging data sets exist, education does not yet have the kind of integrated Web-enabled data-sharing system that has been developed for the health-care, telecommunications, and financial sectors. Such a system must be capable of dealing with both fine-grained data derived from specific interactions with a learning system and global measures built up from that data, and it must be able to collect, back up, archive, and secure data coming from many different systems throughout a state. It must also be capable of integrating the financial data essential for managing costs. Addressing this challenge will require:

- A data format to represent learning and financial data;
- A service to discover and exchange data;
- A data security standard for the service;
- A specification, test suite, and reference implementation of the service to ensure vendor compliance; and
- Best practices to guide the deployment of such services.

4.0: Identify and validate design principles for efficient and effective online learning systems and combined online and offline learning systems that produce content expertise and competencies equal to or better than those produced by the best conventional instruction in half the time at half the cost.

Research labs and commercial entities are hard at work developing online learning systems and combined online and offline learning systems that support the development of expertise within and across academic disciplines. Although we have isolated examples of systems producing improved learning outcomes in half the time, we have yet to see this kind of outcome achieved within the K–12 system and particularly in those schools where students need help the most. In addition, in both K–12 and higher education, we have yet to see highly effective systems that can be brought to scale.

We have evidence that learning can be accelerated through online tutoring, restructuring curricula, and by providing guiding feedback for improvement throughout the learning process. Further, we know that the current “packages” of learning that define semester and yearlong courses are generally arbitrary and a result of long-standing tradition rather than of careful studies. Achieving twice the content expertise and competencies in half the time at half the cost through online learning systems seems very possible, but it will require careful design, development, and testing.

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Appendix A.
How This Plan Was Developed

The U.S. Department of Education initiated the development of *Transforming American Education* in spring 2009 to capitalize on the opportunities created by technological advancements and new research on learning that have emerged since the publication of the last national education technology plan in 2004. The Department's goal was to create a vision for the strategic application of technology throughout the education system in support of student learning and achievement and consistent with the administration's broader education and economic priorities.

In accordance with the White House's Open Government Directive, public participation, transparency, and collaboration were key considerations in developing this plan. Web 2.0 technology greatly accelerated the plan development process and enabled tens of thousands of individuals to learn about and contribute to it through webinars, online forums, and an interactive public website through which all interested parties could contribute resources, statements, and comments.

Plan development began with interviews with a dozen leaders across the Department of Education and at the White House Office of Science & Technology Policy to build a deep understanding of policymakers' priorities, goals, and insights into how to make the next national education technology plan most effective.

Outreach began with an extensive series of events built around the National Educational Computing Conference (NECC) in June 2009. The National Education Technology Plan development team led by SRI International conducted five focus groups with teachers, school administrators, and members of the Consortium on School Networking (CoSN) and the Software & Information Industry Association (SIIA). Fifty chief technology officers and chief information officers from school districts across the country participated in a forum on the new plan.

In addition, more than 300 leading educators and educational technology experts participated in the ISTE Leadership Symposium. Leadership Symposium participants drafted vision statements and action steps that became the basis for the initial Web-based outreach event that generated 263 public comments over a two-week period from June 29 to July 12, 2009, on the National Education Technology Plan temporary website.

The input gathered was presented to a technical working group of educators, researchers, and state and local policymakers who contributed an extraordinary range of expertise to the vision, research, and writing of *Transforming American Education.* The Technical Working Group convened in person at three two-day meetings to craft the plan's vision and recommendations. In addition, technical working group members participated in discussions with guest experts during five two-hour webinars to incorporate additional expertise in critical issue areas for inclusion in the plan.

A second version of the National Education Technology Plan website was launched on Aug. 29, 2009, to give the public a sense of the themes being considered by the technical working group and to allow a wide range of stakeholders to contribute their own resources for consideration. During the three-month input period, 22,876 individuals visited the site and contributed 572 reports, technology tool examples, case studies, and personal or group statements on the plan. The site's 2,582 registered users included classroom teachers (235), students (48), school administrators (48), other school staff (117), district administrators (13), professors and other higher education staff (123), educational technology organization and nonprofit professionals (118), researchers (52), education consultants (116), technology tool and service providers (153), and state and national policymakers (2).

Hundreds of other stakeholders provided valuable input to the national education technology plan team throughout the summer and fall. The plan development team held webinar discussions with the members of educational technology organizations SETDA, CoSN, and NCTET, as well as with education philanthropy leaders. The plan development team presented at several education forums and conferences including iNACOL's Virtual School Symposium, NCTET's Policy Forum, the National Center for Technology Innovation Conference, and the Redefining Teacher Education for Digital Age Learners Invitational Summit. In addition, two technical working group members led a face-to-face open forum at the University of Michigan and a virtual public forum in Second Life.

Finally, to gather perspectives and insights from industry into ways to promote unprecedented innovation in education research and development, Assistant Deputy Secretary for Innovation and Improvement Jim Shelton and the plan development team convened top thinkers from 24 leading technology and educational content providers in a day-long summit in Menlo Park, Calif., on Sept. 21, 2009.

A draft plan was released on March 5, 2010, and posted for online feedback on http://www.ed.gov/technology. After two months of public comment, all input was reviewed by the plan development team and used to inform the final revision of *Transforming American Education.*

The Department extends its thanks to the thousands of individuals who shared their expertise in developing this vision for transforming the future of American education with technology.

Appendix B. Contributors

We extend our deepest thanks to the members of the National Education Technology Plan technical working group for their extensive contributions to the plan's vision for the future of education:

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U.S. Department of Education staff members Jim Shelton, Mike Smith, Karen Cator, and Bernadette Adams provided valuable substantive guidance throughout the design and development of the plan.

Plan development was directed by Barbara Means of SRI International with the support of Marianne Bakia, Kate Borelli, Judy Brooks, Ed Dieterle, Austin Lasseter, Hannah Lesk, Jeremy Roschelle, Linda Shear, Susan Thomas, and Andrew Trotter. Linda G. Roberts served as a senior advisor to the plan development team.

Appendix C. Acknowledgments

We extend our appreciation to the thousands of individuals who participated in the numerous discussions, focus groups, presentations, webinars, public forums, and Web-based comment events that were held throughout the plan development process. A summary of the activities through which stakeholders contributed input is provided below. Our special thanks go to those who organized outreach efforts that helped gather valuable insights from across the field.

Policy Interviews

U.S. Department of Education

Joseph Conaty, Director, Academic Improvement and Teacher Quality Programs

Tom Corwin, Director, Division of Elementary, Secondary, and Vocational Analysis Budget Service

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Dane Linn, Education Division Director, National Governors Association

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Technical Working Group Webinar Discussants

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Open Educational Resources and System Redesign

Michael Horn, Innosight Institute

Elliot Maxwell, Consultant to the Committee for Economic Development

Reconceptualizing Assessment

Robert Kozma, Kozmalone Consulting

Jim Pellegrino, University of Illinois, Chicago

Enhancing Productivity

Rich Kaestner, Consortium on School Networking (CoSN)

Supporting Teachers with Technology

Barry Fishman, University of Michigan

Bill Penuel, SRI International

Ann Renninger, Swarthmore College

Steve Weimar, Math Forum

Outreach Events

State Educational Technology Directors Grantee Meeting

May 5, 2009

142 registered participants

ISTE Leadership Symposium at the National Educational Computing Conference

June 28, 2009

207 registered participants

ISTE CIO/CTO Forum at the National Educational Computing Conference

June 29, 2009

50 participants

Focus Groups at the National Educational Computing Conference

June 29-July 1

59 participants

SETDA Member Webinar

Aug. 24, 2009

Silicon Valley Industry Summit

Sept. 21, 2009

Agile Mind, Linda Chaput
Apple, John Couch
Blackboard, Jessie Woolley-Wilson
Carnegie Learning, Steve Ritter
Cisco, Ned Hooper
Dell, Mark Horan
George Lucas Educational Foundation, Steve Arnold
Google, Maggie Johnson
IBM, James Spohrer
Hewlett-Packard, Phil McKinney
Intel, Eileen Lento
KC Distance Learning, Caprice Young
McGraw-Hill, Randall Reina
Microsoft, Stephen Coller
NeXtAdvisors, Michael Moe
Teachscape, Mark Atkinson
Oracle, Clare Dolan
Pearson, Doug Kubach
Scholastic, Margery Mayer
SMART Technologies, Nancy Knowlton
Sun Microsystems, Scott McNealy
Texas Instruments, Melendy Lovett
VIP Tone, Robert Iskander
Wireless Generation, Larry Berger

NCTET Policy Forum

Sept. 25, 2009
30 participants

CoSN Member Webinar

Oct. 6, 2009
72 registered participants

Webinar with Philanthropy Leaders

Oct. 6, 2009

Cisco 21st Century Schools Initiative, Bill Fowler
HP Global Social Investment, Jim Vanides
Intel Foundation, Wendy Hawkins
MacArthur Foundation, Craig Wacker and Connie Yowell
Microsoft Partners in Learning, James Bernard and Mary Cullinane
National Geographic JASON Project, Caleb Schutz
New Tech Network, Monica Martinez
Oracle Education Foundation, Bernie Trilling
Pearson Foundation, Kathy Hurley and Mark Nieker

Public Forum at the University of Michigan
Oct. 21, 2009
75 participants

NCTET Member Webinar
Oct. 26, 2009

Exploring New Modalities for Learning Conference
Oct. 30, 2009

SETDA Leadership Conference
Nov. 1, 2009

Second Life Public Forum
Nov. 5, 2009
200 participants

ISTE100 Meeting
Nov. 9, 2009
25 participants

iNACOL Virtual School Symposium
Nov. 16, 2009

National Center for Technology Innovation Conference
Nov. 17, 2009

Summit on Redefining Teacher Education for Digital Age Learners
Dec. 8, 2009

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