Transforming American Education:

Learning

Powered by Technology

DRAFT

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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. By 2020,

- We will raise the proportion of college graduates from where it now stands [39%] so that 60% of our population holds a 2-year or 4-year degree.
- We will close the achievement gap so that all students – regardless of race, income, or neighborhood – 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 that success. Our regulations, policies, actions, and investments must be strategic and coherent.

Transforming American Education

To achieve these goals, the National Educational Technology Plan (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.

Just as technology is at the core of virtually every aspect of our daily lives and work, we must leverage it to provide engaging and powerful learning experiences, content, and 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 can learn from other kinds of enterprises that have used technology to improve outcomes while increasing productivity.

A 21st Century Model of Learning Powered by Technology

The NETP presents a model of 21st century 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 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

The model of 21st century 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 instead of a one-size-fits-all curriculum, pace of teaching, and instructional practices.

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, but beyond that students and educators should have options for engaging in learning: large groups, small groups, and work tailored to individual goals, needs, interests, and prior experience of each learner. By supporting student learning in areas that are of real concern or particular interest to them, personalized learning adds to its relevance, inspiring higher levels of motivation and achievement.

In addition, technology provides 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. On-demand learning is now within reach, supporting learning that is life-long and life-wide (Bransford et al., 2006).

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 expertise such 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, and that involves developing deep understanding within specific content areas and making the connections between 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 it 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

The model of 21st century 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.

President Obama has called on our nation's governors and state education chiefs to develop standards and assessments that measure 21st century competencies and expertise – critical thinking, complex problem solving, collaboration, and multimedia communication – 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. And we can do so 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 & William, 1998; Black et al., 2004). 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 assess 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 data, and take appropriate action.

Teaching

Just as leveraging technology can help us improve learning and assessment, the model of 21st century 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 and classrooms are fully connected to provide educators with 24/7 access to data and analytic tools as well as to resources that help them act on the insights the data provide.

The expectation of effective teaching and accountability for professional educators is a critical component of transforming our education system, but equally important is recognizing that we need to strengthen and elevate the teaching profession. This is 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, technology can help us build the capacity of educators by enabling a shift to a model of connected teaching.

In a connected teaching model, connection replaces isolation. 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 inside and outside 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 afterschool 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 provide more options for all learners at all levels. This is accomplished by augmenting the expertise and competencies of specialized and exceptional educators with online learning systems and through on-demand courses and other self-directed learning opportunities. Clearly, more teachers will need to be expert at providing online instruction.

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 pre-service 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

An essential component of the 21st century 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 Resources

Our model of 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 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. It 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

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 K-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 so 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 coming 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

The NETP, 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 NETP. 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 NETP 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, 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.

Postsecondary education institutions – community colleges and 4-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 and there will never be 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

The NETP presents five goals with recommendations for states, districts, the federal government, and other stakeholders in our education system that address learning, assessment, teaching, infrastructure, and productivity. The plan also identifies far-reaching grand challenge problems that should be funded and coordinated at a national level.

1.0 Learning

All learners will have engaging and empowering learning experiences both in and outside 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 actions:

1.1 Revise, create, and adopt standards and learning objectives for all content areas that reflect 21st century expertise and the power of technology to improve learning.

1.2 Develop and adopt learning resources that use technology to embody design principles from the learning sciences.

1.3 Develop and adopt learning resources that exploit the flexibility and power of technology to reach all learners anytime and anywhere.

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

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 Design, develop, and adopt assessments that give students, educators, and other stakeholders timely and actionable feedback about student learning to improve achievement and instructional practices.

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

2.3 Conduct research and development that explore how gaming technology, simulations, collaboration environments, and virtual worlds can be used in assessments to engage and motivate learners and to assess complex skills and performances embedded in standards.

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

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 Design, develop, and adopt technology-based content, resources, and online learning communities that create opportunities for educators to collaborate for more effective teaching, inspire and attract new people into the profession, and encourage our best educators to continue teaching.

3.2 Provide pre-service and in-service educators with preparation and professional learning experiences powered by technology that close the gap between students' and educators' fluencies with technology and promote and enable technology use in ways that improve learning, assessment, and instructional practices.

3.3 Transform the preparation and professional learning of educators and education leaders by leveraging technology to create career-long personal learning networks within and across schools, pre-service preparation and in-service educational institutions, and sprofessional organizations.

3.4 Use technology to provide access to the most effective teaching and learning resources, especially where they are not otherwise available, and to provide more options for all learners at all levels.

3.5 Develop a teaching force skilled in online instruction.

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 that students and educators have adequate broadband access to the Internet and adequate wireless connectivity both inside and outside school.

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

4.3 Leverage 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.

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

4.5 Support "meaningful use" of educational and information technology in states and districts by establishing definitions, goals, and metrics.

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 learning outcomes and costs.

5.2 Improve policies and use technology to manage costs including those for procurement.

5.3 Fund the development and use of interoperability standards for content, student learning data, and financial data to enable collecting, sharing, and analyzing data to improve decision-making at all levels of our education system.

5.4 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.

5.5 Design, implement, and evaluate technology-powered programs and interventions to ensure that students progress through our K-16 education system and emerge prepared for the workplace and citizenship.

A New Kind of R&D for Education

To design and implement more efficient and effective education system, this plan calls for an organization with the mission of serving the public good through research and development at the intersection of learning sciences, technology, and education (Pea & Lazowska, 2003).

The Higher Education 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). Housed in the Department of Education, the center is authorized as a 501(c)3 that would bring together contributions from the public and private sectors to support the R&D needed to transform learning in America. The Digital Promise's intent of involving private sector technology companies in precompetitive R&D with the center can be realized only if the federal government provides the funding that would demonstrate its own commitment to a major program of R&D addressing the complex problems associated with redesigning our education system.

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 independently 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 (Cooke-Deegan, 2007).

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 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.

Grand Challenge Problems

This plan also urges the national research center to focus on grand challenge problems in education research and development. "Grand challenge problems" are important problems that require bringing together a community of scientists and researchers to work toward their solution.

The following grand challenge problems illustrate the kinds of ambitious R&D efforts that should be coordinated at a national level. 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 optimizes learning for all learners and that incorporates self-improving features that enable it to become increasingly effective through interaction with learners.

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.

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.

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.

Introduction

> *"By 2020, America will once again have the highest proportion of college graduates in the world."*
>
> *—President Barack Obama,*
> *Address to Congress, February 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 students with engaging and empowering learning experiences to help them 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 life-long 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 are supportive and safe.

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,

- Twenty-four percent of young people in the United States drop out of high school (OECD, 2007). That number jumps to almost 50% of Latino and African American students (Orfield, Losen, Wald, & Swanson, 2004).

- 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 & Letgers, 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 – 4 out of every 10 new jobs will require some advanced education or training (Dohm & Shnipe, 2007). Fifteen of the thirty fastest growing fields will require a minimum of a bachelor's degree (Bureau of Labor Statistics, 2008).
- Today, just 39% of young people earn a two-year or four-year college degree (National Center for Public Policy and Higher Education, 2008). Enrollment rates are unequal: 69% of qualified White high school graduates enter four-year colleges compared with just 58% of comparable Latino graduates and 56% of African American graduates (National Center for Education Statistics, 2007).

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

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 (39%) so that 60% 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 – regardless of race, income, or neighborhood – graduate from high school ready to succeed in college and careers.

To accomplish these goals, we must embrace a strategy of innovation, prompt implementation, regular evaluation, and continuous improvement. The programs and projects that work must be brought to scale so that every school 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, and retain effective educators, especially in underserved areas where they are needed most.
- States should turn around their lowest achieving schools.

In November 2009, President Obama launched the Educate to Innovate campaign to improve the participation and performance of U.S. students in science, technology, engineering and mathematics (STEM). The campaign brings together the federal government, leading companies, foundations, not-for-profits, and science and engineering societies to work with young people across the country to achieve the following goals:

- Increase STEM literacy so that all students can learn deeply and think critically in STEM subject areas
- Move American students from the middle of the pack internationally to the top in the next decade
- Expand STEM education and career opportunities for underrepresented groups, including girls and women.

Technology is critical to addressing each of these needs.

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 redesign processes, put them in place, and constantly evaluate them for effectiveness, efficiency, and flexibility. We must monitor and measure our performance to improve learning outcomes while managing costs. We must hold ourselves accountable.

We also must apply the advanced technology available in our daily lives to student learning and to our entire education system in innovative ways that improve designs, accelerate adoption, and measure outcomes.

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. 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 many of today's challenges will be solved only by individuals and nations working together. 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. Is this cheating, or 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 that 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 and other important questions. The plan presents goals, recommendations, and actions for a model of 21st century 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.

Our plan is based on the following assumptions:

- Much of the failure of our education system stems from a failure to engage 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 it 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 expand our view of teaching to include extended teams of educators with different roles who collaborate across time and distance and use technology resources and tools that can augment human talent.
- Making engaging learning experiences and resources available to all learners anytime and anywhere will require state-of-the-art technology and specialized people, processes, and tools.
- Education can learn much from industry 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 more far-reaching research and development challenges associated with leveraging technology in education.

Just as technology is at the core of virtually every aspect of our daily lives and work, it is central to implementing the model of 21st century learning in this plan.

The model depends on technology to provide engaging and powerful learning content, resources, and experiences and assessment systems 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. The model depends on technology to execute collaborative teaching strategies combined with professional learning strategies that better prepare and enhance educators' competencies and expertise over the course of their careers.

The model also depends on every student and educator having Internet access devices and broadband Internet connections and every student and educator being comfortable using them. It depends on technology to 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 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, 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 more wisely, with clear expectations about what we expect in terms of learning outcomes and process improvements.

Achievement of the vision set forth in this plan will rely 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 are the Broadband Technology Opportunities Program (BTOP) of the Department of Commerce's National Telecommunications and Information Administration (NTIA), the Rural Development Broadband Program (BOTP) of the Department of Agriculture's USDA Rural Utility Services (RUS), and a cross-agency National Broadband Plan that is being developed by the Federal Communications Commission (FCC).

This 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.

This 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 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 and there will never be a better time to act. In keeping with the appropriate role of the federal government, this National 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.

Learning: A Model for the 21st Century

Goal: All learners will have engaging and empowering learning experiences both in and outside 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 7 hours, 38 minutes to using entertainment media in a typical day – more than 53 hours a week (Kaiser Family Foundation, 2009). The opportunities, access, and information are limitless, borderless, and instantaneous.

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 into 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 life-long, life-wide, and available on demand (Bransford et al., 2006).

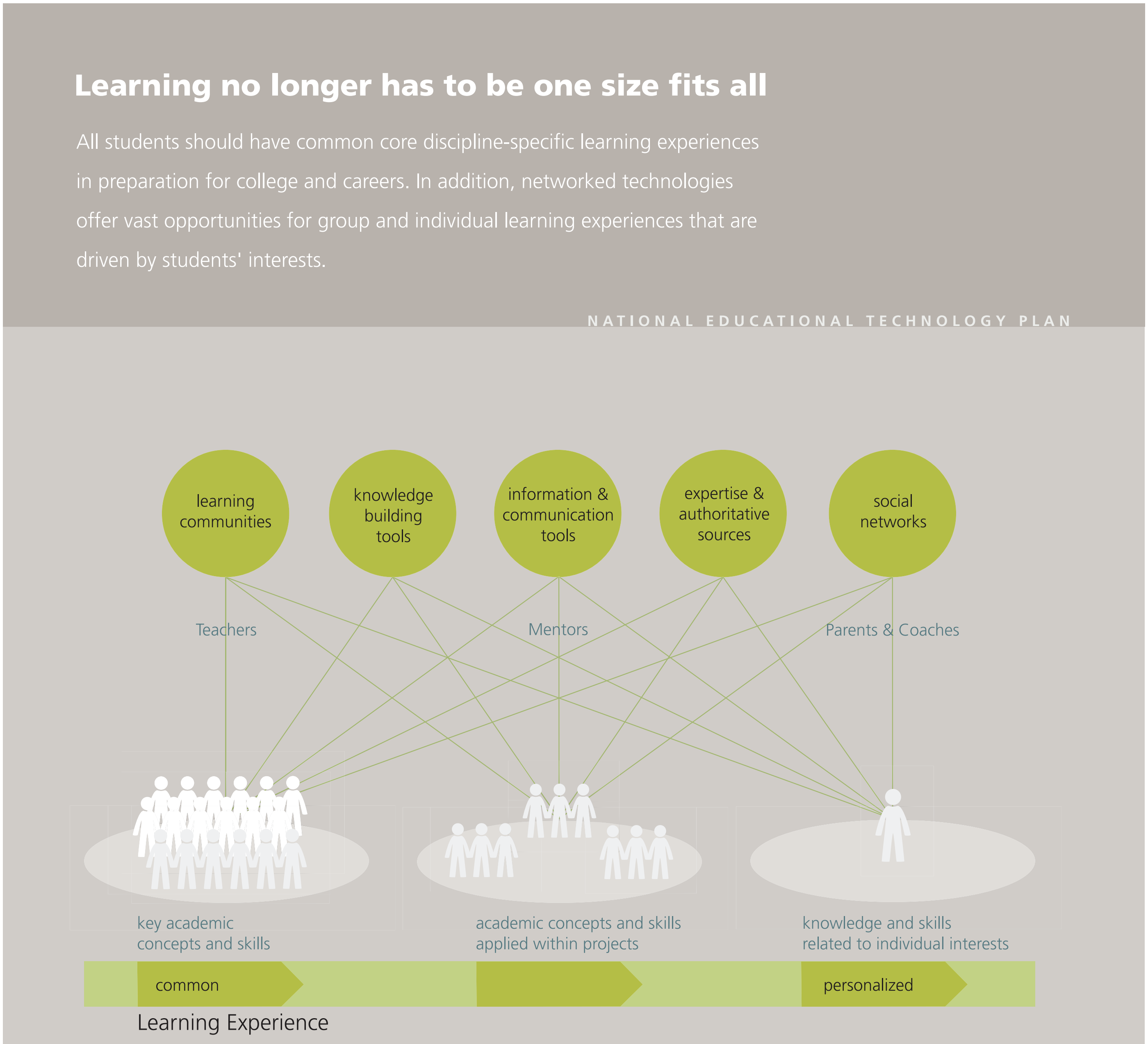
To prepare students to learn throughout their lives and in settings far beyond classrooms, we must change what and how we teach to match what people need to know, how they learn, and where and when they learn and change our perception of who needs to learn. We must bring 21st century technology into 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 21st Century Learning Should Look Like

Figure 1 depicts a model of 21st century 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 work tailored to individual goals, needs, and interests.

Figure 1. A Model of Learning



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 (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 will be expanded throughout 2010 and 2011.

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 & Fadel, 2009).

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.

Individualized, Personalized, and Differentiated Instruction

Words like 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).*

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.

Experts also agree 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 lifetime. 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 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 participatory technology such 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, Kinzer, Coiro, & Cammack, 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.

Individualizing and Differentiating Learning in New York's School of One

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.

The summer pilot included four teachers whose efforts were focused on large-group instruction, four teacher-residents (college students studying to be teachers) who focused on small-group instruction and online instructional support, and two high school students who focused on tutoring and the grading of assessments. The staff met at the end of each day to collectively monitor student growth and prepare for the next day's instruction.

In this model, technology was used to develop a unique learning path for each student based on a database of possible lessons, with supporting instruction on common content that was both individualized and differentiated for each student. The New York City Department of Education expects the School of One program to operate in three middle schools by the spring of 2010 and in 20 schools by 2012.

Source: Submitted to the NETP web-site, edtechfuture.org.

Winona Middle School's Cultural History Project

In 1995, when the Internet was just arriving in schools, students at Winona Middle School 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, the Winona 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.

Source: Submitted to the NETP web-site, edtechfuture.org.

- 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 rather than being content experts we be 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
- As networked learners, with 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 Need to 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 how people learn (National Research Council, 2000, 2003, 2007, 2009; National Science Foundation, 2008b) and can augment all three types of learning.

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.

- 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 gestural expressions such as those that drive interactions in gaming systems.

The Neuroscience of Learning

Three broad types of learning – learning that, learning how, and learning why – each correspond to one of three main human brain divisions.

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, transforming 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, & Clark, 2004).*

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

Source: Submitted to the NETP web-site, edtechfuture.org.

- 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 for different learners. 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 outside school (Brown & Adler, 2008; Collins & Halverson, 2009; National Science Foundation, 2008b). Technology can also be used to create learning resources that provide immediate feedback modeled on games to help engage and motivate learners (Gee, 2004).

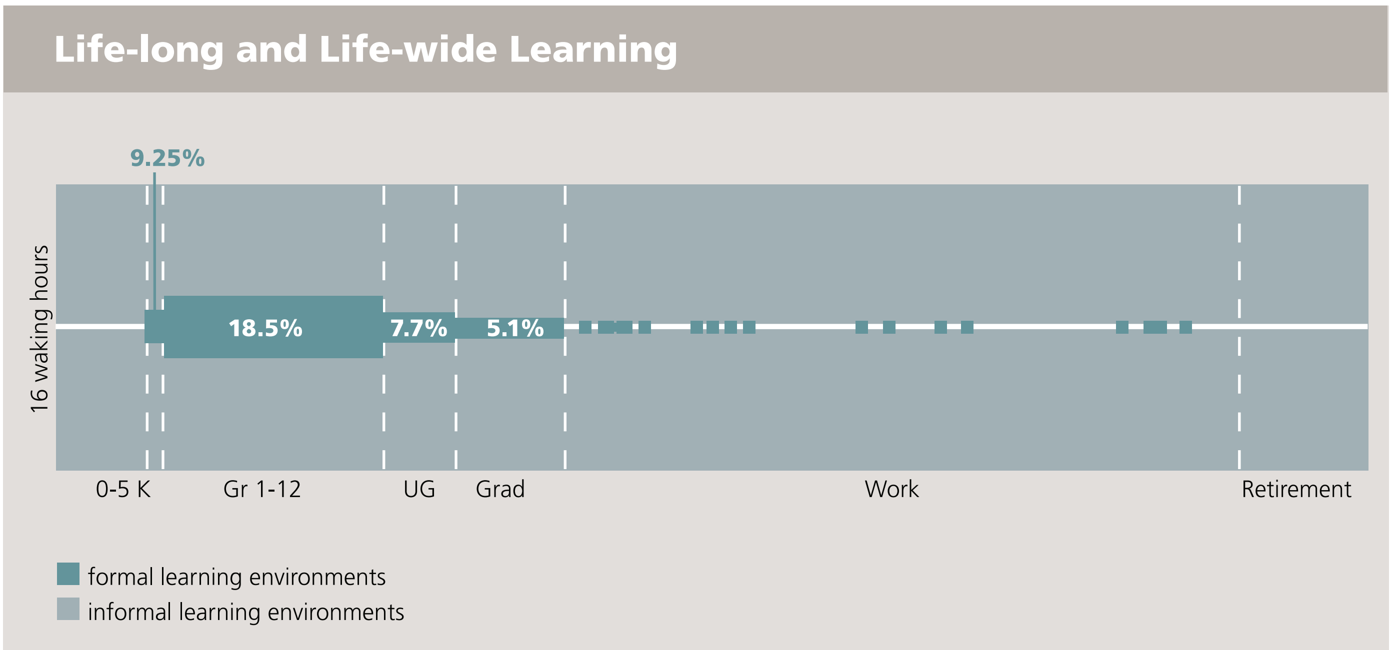
- Sustain effort and academic motivation. Technology-based learning resources can give learners choices that keep them engaged in learning, for example, personally relevant content, a customized interface, options for difficulty level or alternative learning pathways, or choices for support and guidance.

- Develop a positive image as a life-long 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

When the material that knowledge learners require cannot be covered in school or when they are not in school, learners need on-demand opportunities for learning anytime and anywhere. On-demand learning is essential to life-long and life-wide learning (Figure 2), and technology produces a vital bridge, enabling productive use of learning resources across formal and informal learning settings (Barron, 2006).

Figure 2. Life-long and life-wide learning



On-demand learning is facilitated by the vast information and learning resources on the web that are available in an always-on connection to the Internet. This is powerful for individual learners but even more so when accessed by 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, such as developing an entry for Wikipedia or planning the reinvigoration of the environment of their city.

Collaborative environments are enhanced by social and participatory approaches such as wikis, in which learners and teachers regardless of their location – in a classroom or halfway around the world – 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, & Smith, 2009; OECD, 2008, 2009) enrich on-demand learning.

Specific examples of on-demand learning 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, Levine, Smith, & Stone, 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 & 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 in to 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 overcome, because job applications, health information, and many other crucial information resources appear only in the digital realm (http://www.fcc.gov/recovery/broadband/). 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 & Matuchniak, in press). 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).

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

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 a very new and more universally designed approach was mandated by the U.S. Congress. In that year, regulations for NIMAS – the National Instructional Materials Accessibility Standard – 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.

The dramatic effect of the NIMAS legislation is not really in the technology itself, but in the change in how we think about diversity that the technology promotes. The conceptual shift is evident in that Congress calls for schools to provide alternative versions for all students who have "print disabilities." In that remarkable wording shift, "learning disabilities" to "print disabilities," lies a profound alteration in the response to diversity and disability. By recognizing that many learning problems are resident not just in the child but in the medium of instruction, the NIMAS legislation also recognizes that the limits of print are too costly for American education. Printed textbooks cannot adequately meet the challenge of diversity, and we will need to shift our educational practices to new technologies that – through more universal designs – are equitable and effective for all of our learners.

- 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 disabil ities; 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 NIMAS).

- Pre-K. 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 to augment the linguistic, visual, and symbolic worlds that learners experience and seek to emulate. Ready to Learn is an example of technology-based resources that target school readiness skills (Penuel et al., 2009).

- Adult workforce. Many adults in the workforce are underproductive, have no postsecondary credential, and face limited opportunities because they lack fluency in basic 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. Working adults can take online courses at anytime and anywhere. While individual adults benefit with 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 Online Skills Laboratory.)

- 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 life-long learning for seniors requires careful design of learning environments and the use of technology so that sensory weaknesses (in vision or hearing) and mnemonic capacity (in working and associative memory) do not erect insurmountable barriers to continued learning, independence, and socialization.

Online Skills Laboratory

Community colleges are an essential enabler for a wide variety of learners to build the skills necessary for success in the workforce. They serve both college-age students, often those who are academically underprepared for or who lack the financial resources for a four-year college, and adult learners who need to prepare for new jobs or simply desire to continue learning. Both types of learners may be working one or more jobs while they attend school and have other adult responsibilities that make it difficult to attend physical classes on a set schedule.

A new federal program, the Online Skills Laboratory, intends to build a set of open resources for learning, with the help of teams of experts in content, pedagogy, and technology. These courses will be offered free of charge through a network of community colleges and will be openly available to adapt and share to meet the needs of individual teachers or learners. This resource will supplement the resources currently available in physical community college spaces and may become an alternative path to earning a degree. For learners who are raising a family or working a full-time job, this flexibility offers opportunities for learning that would otherwise not be available.

Improving Secondary and Postsecondary Graduation Rates

Among the consequences of our education system's failure to reach all learners is a higher dropout rate than in other developed countries. Overall, 24% of young people in the United States drop out of high school (OECD, 2007), but the dropout rate for Latino and African American students is nearly 50% (Orfield, Losen, Wald, & Swanson, 2004).

The long-term impact of both high school and college dropout rates on our society is catastrophic, both in terms of the success prospects of individuals in life and work and for our nation's ability to compete in a global economy (McKinsey & Company, 2009).

Most 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. 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 can also 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 as they move from middle school to high school and from high school to postsecondary education.

Secondary and postsecondary institutions should work separately and together to support at-risk students in all phases of their education. This support should start early in students' educational career and intensify if they need it.

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 task force initiatives and the President's Council of Advisors on Science and Technology (PCAST) is recommending research and development to guide the restructuring of STEM domains for more effective learning with technology.

Whereas technology has dramatically changed how students learn in all disciplines, perhaps nowhere are its effects more profound than in STEM subjects. New 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

All learners will have engaging and empowering learning experiences both in and outside 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 actions:

1.1 Recommendation: Revise, create, and adopt standards and learning objectives 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 learn. Standard-setting bodies for every academic domain should ensure that their standards reflect 21st century expertise recognizing the role of technology in contemporary practice. Standards should establish that in every content area students have learning experiences that exploit the power and flexibility of technology. The work of revising and disseminating standards should exploit online collaboration tools. The Department of Education should support standards development and revision efforts by connecting the various groups and organizations working on these issues. The Department also should identify and disseminate examples of standards that reflect the transformative power of technology in learning.

1.2 Recommendation: Develop and adopt learning resources that use technology to embody design principles from the learning sciences.

Advances in the learning sciences have improved our understanding of how people learn. The Department of Education should encourage learning science researchers to make their findings broadly available to private and public sector developers of educational technology and ask curriculum developers to draw on advances in the learning sciences as they design and deliver the next generation of technology-based learning content, resources, courses, and tools. Specifically, new resources should give learners choices about how they learn, stimulate active engagement, and provide real-time feedback that fosters learning. Resources also should include self-improving features that enable them to become increasingly effective through interaction with learners. To expand the availability of these resources and ensure their continuous improvement, the Department should fund research and the development of exemplary resources that implement learning science principles. Schools and districts should adopt effective technology-based resources as they become available.

1.3 Recommendation: Develop and adopt learning resources that exploit the flexibility and power of technology to reach all learners anytime and anywhere.

The “always on” nature of the Internet, mobile access devices, and students’ technology fluency give states, districts, and schools opportunities to offer on-demand learning experiences that are available anytime and anywhere. Private and public sector developers of instructional materials should exploit the flexibility and adaptability of technology, paying special attention to 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. Developers should combine technology with design principles for individualized, differentiated, and personalized learning and with Universal Design for Learning (UDL) principles to support multiple options for representing ideas and for embedding supportive structures and processes within both commercially available and open learning resources. States and districts should adopt and implement these resources to the extent possible.

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

New technologies for representing, manipulating, and communicating information and ideas have changed professional practices in STEM fields and what students need to learn to be prepared for STEM professions. The Department of Education should cooperate with the National Science Foundation (NSF), its cyberlearning task force initiatives, and the President's Council of Advisors on Science Technology (PCAST) Subcommittee on Education to restructure instruction in the STEM knowledge domains to mirror contemporary professional practice and reflect the use of technology. States, districts, and schools should use the vast array of online resources in STEM fields and the technology tools and resources currently used by STEM professionals to create relevant and applied curricula that engage students in complex problem solving and collaborative learning with their peers and with experts in the field.

Assessment: Measuring 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, & 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

To change our thinking about what we should be assessing, President Obama has issued the following challenge:

> *"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, March 10, 2009*

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 & Kraus, 2005). Minstrell's facet assessments and instructional materials are available on the web (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 (Vendlenski & 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 multi-user 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, 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.

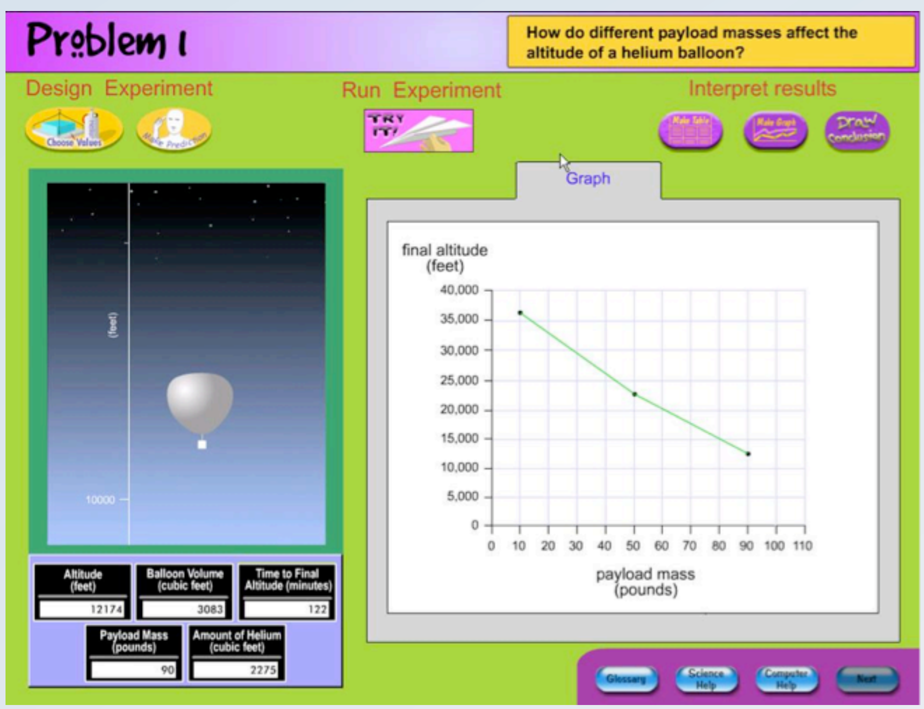
Another advantage to technology-based assessments is we can use them to assess what students learn outside school walls and hours as well as inside. Assuming that we have standards for the competencies students must have and valid, reliable techniques for measuring these competencies, technology can 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, Persky, Weiss, & Jenkins, 2007). One of these calls on students to interact with a simulation of a hot-air balloon (see sidebar).

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 (see screen shot below). 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.



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 & Wiliam, 1998; Black et al., 2004). 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, & Ng, 2010).

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 that "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."

Source: Case study submitted to the NETP web-site, edtechfuture.org.

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, & 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 they make, the number of hints and 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, & 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, & 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 on line, learning through games). This information was used to generate individual "playlists" of customized learning activities for every student.

An example of adaptive assessment in higher education is Carnegie Mellon's Online Learning Initiative (OLI) as described in the sidebar on Meshing Learning and Assessment in Online and Blended Instruction.

Universal Design for Learning improves accessibility

Technology allows the development of assessments designed using Universal Design for Learning (UDL) principles that make them 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 Learning 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 extraneous factors such 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.

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 the kind of integration of learning and assessment activities that is possible with technology-based instruction. The R&D team at Carnegie Mellon set out to both design and study learning systems based on learning science principles. One of those key principles is to provide learners with goal-directed practice and feedback on their performance. In the OLI courses, feedback is 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 their 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*
- *"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, Lovett, Bajzek, & Burnette, 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, & Thille, 2008).

Technology speeds development and testing of new assessments

One challenge associated with developing new technology-based assessments is the time and cost of developing, 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 prior to 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. Ultimately, their success can be measured by the number of downloads of their finished applications.

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 are not only completing the tests required every year by their states, 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, & 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.

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 web site. 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.

Source: Submitted to the NETP web-site, edtechfuture.org.

West Virginia uses this strategy in its assessment of students' technology skills. As this example, described in the sidebar, illustrates, the need for year-end summative tests can be reduced if the student data collected, analyzed, and recorded by formative, embedded assessments are valid, reliable, and of a manageable and actionable level of detail.

Prospects for Electronic Learning Records

Technology provides new options for documenting student accomplishments. At New Tech High School in Napa, California, for example, students are continuously assessed on a set of core competencies as well as on the specific content in their courses. Students receive separate ratings for critical thinking, written and oral communication, technology literacy, and collaboration in addition to their grades on course content. These ratings are posted on an online grade book available to students, their parents, and teachers.

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) 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 (in which case teachers have answer sheets scanned and entered into the system).

According to Mike Foland, project manager for the district's Instructional Technology Support Services, eCART was developed in response to teachers' needs. Foland said, "A need was identified for a single one-stop shop to allow teachers access to resources, standards, assessments, and the results from those assessments, and then the ability based on those results to mine resources and use them to support instruction in the classroom and beyond."

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.

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

The way collaboration skills are assessed at New Tech offers an example. Students learn through interdisciplinary projects, almost all of which they tackle in groups. At the end of each project, each student provides an anonymous online rating of the quality of collaboration of every other member in the group. The collaboration ratings that a student has received across projects and across years at New Tech are part of his or her electronic learning portfolio.

Many schools are using electronic portfolios and other digital records of students' work as a way to demonstrate what they have learned. 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 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. Widely used writing assessments offer one example of how this process works.

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.

Included in this system should be assessment data to support educators' efforts to improve their professional practice. Data from student assessments can enable teachers to become more effective by giving them evidence regarding 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, 2010). Using student data in this way could also 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.

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.

> ***FERPA***
>
> *The Family Educational Rights and Privacy Act (FERPA) is a federal law that protects students' privacy by prohibiting disclosure of education records without adult consent. FERPA also allows parents and students over age 18 to inspect and review education records and request that inaccuracies be corrected.*
>
> *Schools may share basic "directory" information, such as student names and phone numbers, if they give parents the opportunity to opt out. However, advance written permission is required to release all other student-level information, such as student coursework, class discussions, recorded comments, and grades, if they are linked to any information that would enable a member of the school community to identify the student. Several exceptions in the law allow individuals such as teachers and administrators with a legitimate educational interest in the student's record to access personally identifiable student data without prior parent consent.*
>
> *In 2008, FERPA was updated to provide better access to education data for research and accountability. These changes permit the release of student-level data that has been stripped of personally identifying information and allow states to share student information in consolidated education data systems designed to improve student achievement.*
>
> *Clear guidance on how schools can collect and share data without compromising student safety and anonymity would empower educators and learners to take full advantage of emerging technologies and tools without fear of violating FERPA.*
>
> *Source: http://www.ed.gov/policy/gen/guid/fpco/ferpa/index.html*

Removing Technical and Regulatory Barriers

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 multi-level assessment systems.

For example, student and program data today are collected at various levels and in various grain sizes to address different needs in the educational system. State data systems generally provide macro solutions, institution-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.

On the regulatory front, regulations such as the Family Educational Rights and Privacy Act (FERPA) serve the very important purpose of protecting the rights of individuals but also can present barriers to data sharing and the improvement of education through research. Many of the barriers to research and data sharing posed by FERPA in its original form were reduced or eliminated through a 2008 revision of the act. Still, varying interpretations of FERPA requirements and differences in district and state policies have made data sharing a complex, time-consuming, and expensive process.

Reducing the technical and regulatory barriers to data aggregation and sharing 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

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 Recommendation: Design, develop, and adopt assessments that give students, educators, and other stakeholders timely and actionable feedback about student learning to improve achievement and instructional practices.

Assessments can be used formatively to improve students' learning in addition to measuring what they have learned. The Department of Education should urge states and districts to use technology-based assessments in this way and promote partnerships between states and private and public sector organizations to design, develop, validate, and scale up such assessment resources. States and districts should partner in the assessment design and validation process and adopt valid and reliable technology-supported assessment tools as they become available. Districts, schools, and colleges of education should provide educators with professional learning opportunities that teach them to use assessments formatively to improve instructional practices.

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

States and districts should seek objective advice about the quality of available assessment instruments, mechanisms for assessment delivery and scoring, and the timely use of assessment information in monitoring outcomes and continuously improving the processes of teaching and learning. Building the capacity to use technology to measure what matters will not be accomplished overnight, and to accelerate progress the Department of Education should connect assessment and technology experts with education policymakers and practitioners to support the transition. This should include creating forums and resources that enable experts to advise states and districts about using technology to substantially improve the quality of their assessment materials and processes on an ongoing basis.

2.3 Recommendation: Conduct research and development that explore how gaming technology, simulations, collaboration environments, and virtual worlds can be used in assessments to engage and motivate learners and to assess complex skills and performances embedded in standards.

Interactive technologies can support measuring complex performances that cannot be assessed with conventional testing formats. Such technologies, especially games, also have the advantage of being highly engaging because they provide immediate performance feedback so that players always know how they are doing. The Department of Education should provide a clearinghouse of information for states, districts, and schools about current research and evaluation on new forms of technology-based learning and assessment.

Assessment and interactive technology experts should collaborate to explore assessment systems embedded in games and other interactive technologies. States and districts should consider adopting these systems as they become validated and available.

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

Every parent of a student under 18 and every student over 18 should have the right to access the student's assessment data in the form of an electronic learning record that follows the student throughout his or her educational career. At the same time, appropriate safeguards, including stripping records of identifying information and aggregating data across students, classrooms, and schools, can make it possible to supply education data derived from student records to other legitimate users without compromising student privacy. The Department of Education should encourage K-12 and higher education institutions and districts and states to partner with each other to invest in pilot projects that explore new policies and strategies for achieving this. At the national level, the Department should support the development and dissemination of "best practices" that ensure privacy protection while providing access to data that can be used in decision-making, evaluation, and research at the district, state, and national levels.

Teaching:
Improving Learning Through Connected Teaching

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.

In contrast, effective teaching in the 21st century requires innovation, problem solving, creativity, continuous improvement, research, diagnostic use of data, and flexible and personalized approaches to meeting students' diverse needs and strengths. As a result, the most effective educators are professionals with complex knowledge, expertise, and competencies, not merely deliverers of content and managers of well-behaved classrooms.

Unfortunately, our education system often fails to give educators the tools to do their job well. We hold educators responsible for student achievement, but we do not support them with the latest technology the way we do professionals in other fields. The technology of everyday life has moved well beyond what educators regularly use to support student learning

Not surprisingly, half of freshly minted teachers leave the profession within the first five years (Ingersoll & Smith, 2003), and 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, equally important is recognizing that we need to strengthen and elevate the teaching profession. This is 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, technology can help us build the capacity of educators by enabling a shift to a model of connected teaching.

Principles of Connected Teaching

In a connected teaching model, connection replaces isolation. 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. Educators 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 outside school. They also are connected to resources and expertise that improve their own instructional practices and that 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 afterschool 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 provide access to effective teaching and learning resources where they are not otherwise available and provide more options for all learners at all levels. This is accomplished by augmenting the expertise and competencies of specialized and exceptional educators with online learning systems and through on-demand courses and other self-directed learning opportunities.

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 pre-service 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, and professional organizations. We should also 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.

21st Century Resources and Tools for Professional Educators

A cornerstone of connected teaching is the instrumented classroom, which is described in the Assessment section of this plan. A highly instrumented classroom is a place where technology-based systems provide educators with real-time insight into how every student is thinking that, when combined with analytic tools, helps educators make better decisions about how to adapt instruction to students' needs. Also included in the Assessment section are examples of the kinds of tools 21st century educators should have at their fingertips.

In addition, as learning environments become more complex, educators need support in managing the multiple dimensions of curricular instruction. Commercially available and open source learning management systems are already used widely in university settings, 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.

For example, teachers at George J. Ryan Junior High School in Queens, New York, 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.

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 & 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 emotion 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 Connected Teaching in K-12 Mathematics.

Connected Teaching in K-12 Mathematics

Math Forum (http://mathforum.org) is an online community that supports a connected teaching approach to improving K-12 mathematics education. Math Forum began at Swarthmore College in 1992, and Drexel University School of Education took over the project in 1996 and continues to manage it today. Steve Weimer, director of the project, reports that the site supports between 2 and 3 million visits (extended sessions with participants) per month.

The Math Forum website features portals and interactive content for diverse members of the education community. For educators, it provides valuable instructional resources, including "Math Tools," a searchable community library of interactive lessons, activities, and support materials. Educators can also 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. Some conversations continue this way for years, as is the case with a still-active thread begun in 1999 when an educator requested suggestions for interesting ways to use Math Forum as a virtual community (Herrick, 2009).

The activity level on the Teacher2Teacher portion of the Math Forum site speaks to its strength. Between 200 and 300 trained experts are behind the collective identity of Dr. Math, with about 30 very active in a given week. Parents can find information about math summer camps and get help explaining concepts, and students can send letters to Dr. Math. The responses from Dr. Math experts have been collected and published as books.

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. By guiding students to think further about a problem rather than supplying the correct answer, Problem of the Week helps student develop problem-solving skills and promotes inquiry-based learning

Math Forum also has been used to support pre-service teacher education. In 2004, for example, pre-service 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 pre-service teachers practiced giving constructive feedback to students, mentors provided guidance and support to improve the feedback. Through this hands-on experience, the pre-service 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.

Moreover, online communities like Math Forum must compete for resources with institutions such as schools of education that have much more stable sources of funding because it is outside the formal institutional structure of educator preparation. 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.

Preparing New Educators and Ongoing Professional Learning

Technology is a powerful enabler of 21st century 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 pre-service teacher preparation programs.

Today, however, there is tremendous variation in how new teachers are prepared and what they are being prepared to do with technology (Pellegrino, Goldman, Bertenthal, & Lawless, 2007). Although some pre-service programs are using technology in innovative ways (Gomez, Sherin, Griesdorn, & Finn, 2008), widespread agreement exists that teachers are by and large not well prepared to use technology in their practice (Kay, 2006).

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 teacher educators to draw from advances in learning science and technology to change what and how they teach, keeping in mind that everything we now know about how people learn applies to new teachers as well.

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 work week for professional learning than do 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, Mayfield, Marion, Flexer, & Cumbo, 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 to provide continuous supports through models of educator learning that blend face-to-face and online experiences.

Connecting with exemplary practices

Technology can support professional learning by making the practices of exemplary educators accessible to other educators (Fishman 2007; Richardson & 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.

Connecting with other professionals

More than two decades of teacher research demonstrate the importance of collaboration among teachers. When teachers make their work public and examine each others' work, the quality of their practice and student outcomes improve (Lieberman & 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 pre-service educators through expert master educators and offer opportunities for the engagement of a broad range of participants from outside formal education (Wenger, 2009). Successful learning circles also can bring together educators and students to deepen learning (Riel, 1992). PBS TeacherLine is an example of an online system that engages teachers in collaboration and builds professional community.

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 every day 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 other frequently used websites, including that of the Guardian newspaper and both YouTube and iTunes.

Programs ranging in length from 15 minutes to 1 hour target different members of the educational community. Of the programs for teachers, about half present techniques for teaching subject-specific concepts and half address general topics such as career development and classroom management. Some programs are special features, whereas others are regularly scheduled. 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 Disorder, 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 allow K-12 teachers to see 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.

Teachers.tv identifies some of the schools and teachers to feature on the site; in addition, schools and teachers can submit suggestions for vetting by the station. Teachers can also 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.

On the Teachers.tv web site, 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.

Source: Submitted to the NETP web-site, edtechfuture.org.

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.

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, pre-service 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, colleges of education can use personal learning networks to provide ongoing support once their graduates enter the workforce.

An example of this is TFA.net, a website provided by Teach for America for all its new educators. TFA.net offers valuable resources for educators and opportunities for TFA teachers to connect and share ideas. This resource exchange also allows TFA teachers and alumni to share, rate, and download successful lesson and unit plans, data tracking tools, and classroom management strategies.

One barrier to using technology in these ways for ongoing professional learning for educators is 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.

The Role of Connected Teaching in Reaching All Learners

The model of 21st century learning described in this plan depends on effective teaching to provide all learners with equitable access to inspiring and engaging learning experiences. Research shows that consistent access to effective teaching dramatically increases learning, closes achievement gaps, and increases chances for success later in life (Sanders & Rivers, 1996; Wright, Horn, & Sanders, 1997).

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, & 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) than students in rural schools (Graham, 2009).

Technology 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 who keeps track of their progress and provides encouragement, but that staff member does not need the depth of content expertise of a person solely responsible for teaching a class.

Support for a learning society

Not surprisingly, connected teaching quickly moves beyond the walls of the school, immersing all learners in a learning society. The concept of a learning society is not a vision for the future: Examples already exist.

Starting in 2000, a research team in Taiwan developed a network of websites called EduCity that breaks downs the walls of the school to involve broader communities in supporting learning (Chan et al., 2001). As the lead innovator, Tak Wai Chan, describes it, EduCity comprises a hierarchy of communities that have reached more than 1.5 million students and over 1,700 schools.

Support for a Learning Society

Taiwan's online EduCity represents an entire community, consisting of school websites called EduTowns. An EduTown represents a school and consists of the websites of that school's classes, called EduVillages. An EduVillage represents a class and is composed of the personal websites of the students and the educator in that class, called EduCitizens. EduCity provides students with online resources and activities. For example, using Web 2.0 technologies, EduTowns (schools) can adopt online application programs called service items, which are provided by the EduCity. An EduTown can also develop its own service items and share them with other EduTowns. The system also supports teacher collaboration for developing learning materials and lesson plans as open content. Furthermore, every EduCitizen can open an online course in EduCity (Chan, 2009, personal communication).

In one striking story, a 13-year old student named Ah-Chung won the online teacher of the year contest in EduCity in 2000 (Young, Chan, & Lin, 2002) by teaching Visual Basic to other students. The other students did not know that their online educator was a boy younger than all of them. Since that time, EduCity has developed a facility for EduClasses – a system in which any EduCitizen can offer a course on any topic to other students and educators. EduClasses now has more than 1,000 courses in operation and use is spreading from K-12 education to corporate training.

As successful as EduCity is, many participants' experience with the site is more superficial than the original researchers would like. Ultimately, educators should learn how to structure networked learning societies so that they continuously improve and deepen the experiences they provide to participants.

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. To facilitate this, teacher accreditation organizations, colleges of education, and organizations representing online learning providers should work together to develop a set of voluntary national standards for online courses and for online teaching. Leadership organizations and accrediting bodies should collaborate to develop national standards for online teacher certification that would encourage acceptance of online certification across state lines.

Reaching Our Goal

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 Recommendation: Design, develop, and adopt technology-based content, resources, and online learning communities that create opportunities for educators to collaborate for more effective teaching, inspire and attract new people into the profession, and encourage our best educators to continue teaching.

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. Educators should have access to technology-based resources that inspire them to provide more engaging and effective learning opportunities and to do so more efficiently. The Department of Education should provide a clearinghouse of information for states, districts, and schools about available resources. States, districts, universities and other R&D organizations, and the commercial sector should form partnerships to develop commercial and open resources with new capabilities now possible with technology.

3.2 Recommendation: Provide pre-service and in-service educators with preparation and professional learning experiences powered by technology that close the gap between students' and educators' fluencies with technology and promote and enable technology use in ways that improve learning, assessment, and instructional practices.

All institutions involved in the preparation and ongoing learning of educators should combine advances in learning sciences and technology to change what and how they teach. To facilitate adoption of known best approaches across institutions, states, colleges of education, alternative educator and teacher programs, and international organizations should work together to synthesize core principles from best practices for the use of technology in preparing educators, including the rethinking of certification standards. States and national accrediting bodies should require educator preparation programs to leverage technology in preparing teachers, education leaders, and administrators, including incorporation of online courses and resources, embedded and technology-enabled assessments, and data analysis tools and visualizations supporting differentiated instruction. These experiences should be included in all teaching methods courses and field experiences rather than be treated as a discrete set of skills distinct from pedagogical application.

3.3 Recommendation: Transform the preparation and professional learning of educators and education leaders by leveraging technology to create career-long personal learning networks within and across schools, pre-service preparation and in-service educational institutions, and professional organizations.

States, districts, universities and other R&D organizations should work together and with the commercial sector to develop and provide educators with career-long personal learning networks, tools, and resources that make professional learning timely and relevant as well as an ongoing activity that continually improves practices. These networks and other resources should 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. The Department should also encourage colleges of education to use these networks to connect pre-service preparation with in-service professional learning so that as we move into an era in which colleges of education are held accountable for the effectiveness of their graduates, they can participate in providing ongoing support once their graduates enter the workforce.

3.4 Recommendation: Use technology to provide access to the most effective teaching and learning resources, especially where they are not otherwise available, and to provide more options for all learners at all levels.

Many education institutions, particularly those serving the most vulnerable students in the population 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. Similarly, students often lack options for courses in particular disciplines. Online learning options enable leveraging the best teaching. National organizations should support use of online approaches to leverage the best teaching through collaborative efforts to tag and review online learning offerings. High-quality online options are particularly important in cases where qualified teachers are not available. Districts, state institutions, and agencies should have detailed knowledge of where they lack educators with appropriate content knowledge and pedagogical skill and thus where establishing online learning options is a high priority.

3.5 Recommendation: Develop a teaching force skilled in online instruction.

Online learning is becoming an increasingly important part of our education system at all levels, from secondary and postsecondary education to other types of adult learning, including corporate training. This creates both the need and opportunity for educators who are skilled in online instruction and the demand for increased knowledge of the most effective practices. States, teacher accreditation organizations, colleges of education, and organizations representing online learning providers should work together to develop a set of voluntary national standards for online courses and for online teaching. Accrediting bodies and leadership organizations should collaborate to develop national standards for online teacher certification and states should work on reciprocity agreements for certifying online teachers.

Infrastructure:
People, Processes, and Technologies for Learning

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 life-long and life-wide.

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, 2008). 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 K-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, available to students, educators, and administrators regardless of their location, the time of day, and the type of access devices. It supports not just access to information, but also 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 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. While it integrates computer hardware, data and networks, information resources, interoperable software, middleware services and tools, and devices, 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

Because of 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 Federal Communication Commission (www.fcc.gov/broadband/) and the Department of Commerce NTIA Broadband Technology Opportunities Program (www.ntia.doc.gov/broadbandgrants/) to bolster the nation's broadband provisioning are essential to learning life-long and life-wide.

Access devices for every student and educator

Because an infrastructure for learning should support learning in and outside 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 & Wintle, 2009; Silvernail & Bluffington, 2009; Silvernail & Gritter, 2007), and the program is now being expanded to high schools.

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 is 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.

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% after statewide one-to-one implementation (Silvernail & Gritter, 2007). Laptop use has also been linked to gains on statewide mathematics tests and improved retention of science course material (Berry & Wintle, 2009; Silvernail & 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.

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 school-wide math exam, the principal at Passage Middle School, Virginia, decided that he might be on to something. Hoping to capitalize on the excitement expressed by students allowed to use their cell phones, 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 audiorecording 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.

Educators 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 to the educator, they were displayed on a screen at the front of the class, identified by the student's cell phone screen name. Students also used their phones to look up definitions and information. English educators, in particular, found the cell phones useful as they started using blogs to engage their students in writing. Students started using their phones to take photographs outside class for posting to their blogs and then composed blog entries about the photos. One class used Twitter to generate stories in class.

Source: Submitted to the NETP web-site, edtechfuture.org.

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.

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, Virginia, 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.

Schools can also 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.

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 this requirement creates barriers to the rich learning experiences that in-school Internet access should afford students.

E-Rate provisions and CIPA requirements should be clarified and barriers to student-owned devices in schools removed. (See the sidebar on Balancing Connectivity and Student Safety on the Internet for more information.)

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. To apply, schools, school districts, and consortia complete an annual application process that includes a technology needs assessment and a plan for how the connections supported by E-Rate will help the applicant achieve its educational mission. A competitive bidding process is conducted to select a provider to supply the desired infrastructure. Applicants can receive discounts on these services ranging from 20 to 90% depending on their level of poverty and geographic location. Hardware, software, professional development, and other inputs required to take advantage of this connectivity must be purchased by schools and cannot be paid for with E-Rate money.

Under the direction of the FCC, E-Rate has made up to $2.25 billion available each year since its inception in 1998, providing crucial support for the expansion of Internet access in schools. Demand for funding now significantly exceeds the E-Rate cap, particularly as schools seek to provide classrooms with enough bandwidth to support the use of multimedia and interactive applications by many students at the same time (Funds for Learning, 2009). A recent national survey of E-Rate applicants found that the majority of schools could not sustain their current levels of Internet connectivity to classrooms without E-Rate funds.

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 or internal network access with E-Rate money to implement filters that block 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. Schools that do not implement these protections and policies may lose their E-Rate funding and thus their ability to provide online services for their students.

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 tools such as blogs, wikis, and social networks that have the potential to support student learning and engagement. CIPA prohibits educators from disabling filters on the spot when minors are using computers, even to allow students to access erroneously blocked web-sites with legitimate instructional value. 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 has also posed challenges to the in-class use of 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.

Sources: E-Rate Overview: http://www.universalservice.org/sl/about/overview-program.aspx

FCC Order on Community Access: http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-10-33A1.pdf

Open Educational Resources

Open Educational Resources (OER) are an important element of an infrastructure for learning. OER come in forms ranging from podcasts to digital libraries to textbooks, games, and courses. They are freely available to anyone over the web.

Educational organizations started making selected educational materials freely available shortly after the appearance of the web in the mid-1900s. But 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.

Many of these materials are available not just to individuals enrolled in courses, but to anyone who wants to use them. The power of OER is demonstrated by the fact that nearly half the downloads of MIT's OpenCourseWare are by individual self-directed learners, not students taking courses for credit (Maxwell, online presentation for the NETP Technical Working Group, 2009).

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. These rights range from allowing use of a work in its existing form for noncommercial purposes to the right to repurpose, remix, and redistribute for any purpose.

Additional 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. (For more information on OLI, see the Assessment section of this plan.)

The Department of Education has a role in stimulating the development and use of OER in ways that address pressing education issues. The federal government has proposed to invest $50 million per year for the next 10 years in creating an Online Skills Lab to develop exemplary next-generation instructional

Open Textbooks In California

Looking for cost saving measures during a time of severe budgetary pressure, California Governor Schwarzenegger announced in May 2009 that free open-source digital textbooks for high school math and science would be available by fall 2009. In the first-ever statewide initiative to bring open textbooks into classrooms, textbook developers were invited to submit their products for state review. Sixteen submissions in the areas of algebra II, biology/life science, calculus, chemistry, earth science, physics, and trigonometry were scrutinized for coverage of the relevant California content standards. Ten submissions were approved: Four met all relevant content standards and another six met 90% or more.

The governor estimated that the average high school textbook costs $100 and that the state could save $400 million by going to open source for all math and science textbooks for its 2 million high school students. Although the governor's action was stimulated by the need to find innovative ways to save costs, it reflected a conviction that digital materials are of high quality and have important advantages. The governor characterized print textbooks as outdated, heavy, and expensive. "This [digital textbook initiative] represents an important step toward embracing a more interactive learning environment that leverages technology to meet the changing academic needs of California's students," said Schwarzenegger.

Because they are available in digital format, the approved textbooks can be downloaded and used in a variety of ways. Students can view the textbooks on a computer, but the contents can also be projected on a screen, printed chapter by chapter, or bound in their entirety. Several of the approved texts are offered by a nonprofit foundation, whose website gives educators the option to remix or edit textbook components to meet the needs of their class (creating their own "Flexbook"). California's textbook reviews and links to the texts themselves can be found at http://www.clrn.org/fdti/.

Skeptics point to the fact that not all students have computers to view digital text on and that the governor's initiative did not include training for educators in how to use the digital books effectively. But California is pleased enough with its digital textbook initiative that it plans to extend it to other subject areas. Other states, including Virginia, Florida, and Indiana, are launching digital textbook initiatives of their own.

tools and resources for community colleges and workforce development programs. These materials will be available for use or adaptation with the least restrictive Creative Commons license. This work is expected to give further impetus to calls for open standards, system utilities, and competency-based assessments. (For more information on the Online Skills Lab, see the Learning section of this plan.)

The OER movement begun in higher education should be more fully adopted throughout our K-16 public education system. For example, high-quality digital textbooks for standard courses such as algebra can be created by experts and funded by consortia arrangements and then made freely available as a public good. Open textbooks could significantly reduce the cost of education in primary and secondary as well as higher education. Textbooks constitute a significant portion of the government's K-12 budget as well as the student-borne cost of higher education.

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. As a first step, 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. Reducing the number of servers cuts costs and makes school networks less complex and easier to manage, which leads to greater reliability as measured by uptime and availability.

Beyond server consolidation, some school districts are 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 – has been sought after for a long time. 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 point driven by technology advances and the need for more powerful and collaborative platforms at lower cost and with a lower environmental impact than our current datacenter computing model.

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. 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 are being planned.

At the same time that datacenter computing is moving into the cloud, client computing and content have become more multimedia, more intuitive, and more human centered. Applications now span an enormous range of activities in commerce, entertainment, defense, research, and learning.

Cloud computing can serve education in the face of these trends as well. It 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, so that they can learn anytime and anywhere. Thus, it supports our assertion that it is now time for our education system to become part of a learning environment that includes in-school and out-of-school resources. This will not happen automatically; school systems and other youth-serving organizations – public libraries, public broadcasting, afterschool clubs, and so on – will need to engage each other and seek common platforms or at least technical interoperability. Still, cloud computing makes the seamless involvement of multiple organizations in a student's learning more feasible technically and from a cost perspective.

Cloud computing is still in a nascent stage with obstacles to overcome to fully realize its potential. For education, its shortfall in auditability is probably its most serious but by no means irresolvable deficiency. Still, now is the time to move forward with investments in crucial elements of an infrastructure for learning, including platforms for learning, teaching, and assessment that focus on taking advantage of and contribute to the emerging shift to cloud computing.

Software and services that can be delivered from the cloud

Figure 3 illustrates the comprehensive nature of integrated software services needed for 21st century learning experiences and that can be delivered from the cloud.

Figure 3: 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	**Authoring, editing, disseminating & content management**	**Administrative**
(open & proprietary) digital textbooks • digital libraries • tutoring systems • simulations • augmented reality • interactive visualization • educational games • online labs	text processing • audio/video capture/edit • programming platforms • blogs• wikis • instructional/course management	scheduling • person-nel/HR • plant/facilities management • procure-ment • attendance • student records

Assessment and Reporting

Social Networking and Collaboration

Public and Private Network-Connected Clouds – software services, data libraries & repositories

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 applications could be used directly in a variety of educator- or learner-directed ways. They could also 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.

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. We include here assessments for formative and summative uses at time scales from real-time to decades. We also include 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 of 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 require providers and users who have knowledge and expertise in emerging technologies and a shared commitment to standards. We need people capable of developing and nurturing an infrastructure and specialists with experience integrating technology into curriculum development and assessment in meaningful ways. The right people in such positions would give education policymakers, leaders, and educators the courage and confidence to be more innovative – and take more risk – with technology.

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

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.

Source: Submitted to the NETP web-site, edtechfuture.org.

extent, students and educators are handling routine maintenance and troubleshooting of computer equipment themselves. 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.

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 & Hearrington, 2009). Innovative approaches to staffing in schools that take advantage of online learning resources may free resources that can be applied to fund onsite mentors and coaches who can help educators make good use of technology resources.

When districts first began adopting computer systems, the IT department was usually Information Technology. The department's concerns were with the boxes, wires, and software needed to run basic financial, personnel, and reporting systems. As time went on, districts instituted Instructional Technology departments concerned with the use of technology in teaching and learning. 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 information technology for a district or state may find they are left out of deliberations on key decisions in areas such 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. Effective process redesign within school systems will require close coordination among all these functions.

The Role of the Federal Government

The federal government has an important leadership role to play in building a national infrastructure for learning. For example, the Office of Educational Technology should help states and districts build their capacity by providing a clearinghouse that matches expert advice and services with those who need it. This could include consolidating, leveraging, and sharing knowledge, research, and best practices and promoting and enhancing the interactions of partners in alliances focused on solving key challenges.

Another appropriate role is promoting equity in the infrastructure for learning through continuation of the E-Rate.

Reaching Our Goal

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 Recommendation: Ensure that students and educators have adequate broadband access to the Internet and adequate wireless connectivity both inside and outside school.

Students and educators need adequate performance in accessing the Internet and technology-based learning resources. Adequate means enough bandwidth to support simultaneous use of the web, multimedia, communication and collaboration environments, and communities from anywhere in school buildings, on the surrounding campus, and from locations throughout the community and at home. Critical to providing universal access for learning are the broadband initiatives being individually and jointly managed by the Federal Communications Commission (FCC), the Department of Commerce's National Telecommunications and Information Administration (NTIA), and the Department of Agriculture's Rural Utilities Service (RUS). Schools and districts should have up-to-date tools for network analysis to ensure adequate access as usage increases.

4.2 Recommendation: Ensure that every student and educator has at least one Internet access device and 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, including mobile devices, and technology-based software and resources can we achieve the kind of engagement, student-centered learning, and assessments that can improve teaching that this plan proposes. The form of these devices, software, and resources may or may not be standardized and will evolve over time. In addition, states and districts should adopt technologies and develop policies to enable leveraging the technology that students already have. This will require improved security systems, more intelligent filtering systems that allow blocking and enabling access at a more granular level, and personnel capable of providing around-the-clock support for student- and educator-owned devices used for learning in addition to complete support for devices owned by the school. The Department of Education should work with districts, states, and the private sector to articulate effective technology support models.

4.3 Recommendation: Leverage 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 our education system can tap into at all levels and in all content areas, especially STEM. States should reframe and revise policies concerning the evaluation and selection of instructional materials so that digital resources are considered. States should help keep open educational resource content up to date, appropriate, and tagged according to identified content interoperability standards. States should pool resources for identifying, evaluating, designing, and further developing open educational resources. When the Department of Education funds technology-based learning tools and resources, they should give priority to bids that will produce open resources, and the Department should identify and promote new business models that provide for sustaining and maintaining these resources.

4.4 Recommendation: 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. To start, districts and schools should begin a transition to the next generation of computing system architectures. They also should consider moving their technology systems and services from in-house datacenters to professionally managed datacenters in the cloud for greater efficiency and flexibility. To help states and districts make these transitions cost effectively and to leverage the scarce human talent and expertise that will be required, the Office of Educational Technology should support a clearinghouse that matches expert advice and services with those who need them.

4.5 Recommendation: Support "meaningful use" of educational and information technology in states and districts by establishing definitions, goals, and metrics.

The Department of Education should convene education and technology experts to define meaningful use of technology in support of teaching and learning and improved operations. Building on the development of a framework and definitions for meaningful use, the Department should establish and publish goals and metrics for meaningful use. States and districts should use these goals to guide technology purchases. States and districts should consider a percent set-aside of education funds to support the cyberinfrastructure for learning. As state and local educational agencies move to a more integrated use of technology, they should connect planning for educational and information technology with the core functions of curriculum and instruction, assessment, and professional learning. States should assign responsibility for educational technology to cabinet-level individuals who will provide leadership in ensuring that the most efficient and effective purchases are made. The federal government should sustain support for technology use through E-Rate and other means to insure that under-served populations have access to technology for learning.

Productivity:
Improving Learning Outcomes While Managing Costs

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% to 60%. 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% 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% of the increased revenue goes to instruction (Vedder, 2004) and spending changes have not resulted in higher degree completion rates (Bound, Lovenheim, & Turner, 2009).

More money for education is important, but we must spend education dollars more 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 so 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.

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 & 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 & 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.

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 coming together to design and implement solutions. It is a challenge for educators – leaders, teachers, and policymakers committed to learning – as well as technologists, and ideally education leaders and technology experts will come together to lead the effort.

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 should include encouraging changes to practices, policies, and regulations that prevent or inhibit education from using technology to improve productivity.

Embracing Continuous Improvement

The underlying principle of continuous improvement is that we are unlikely to improve learning outcomes and productivity until we define and start measuring them. 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. We also must consider pragmatic outcomes such 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.

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 together data from these different systems was cumbersome or impossible. Just one example of a nearly impossible task in most districts today is calculating the average seniority of educators teaching students who are in free or reduced-price lunch programs versus the average seniority of educators of other students – an important measure when trying to provide equitable access to effective teaching.

Advances in technology and a recent policy emphasis on using data in decision-making have resulted in much improved data in many districts. Still, while almost all districts have electronic access to data such as student demographics, attendance, grades and test scores, less than half have the ability to combine data from different types of systems to be able to link student outcome data to data about specific instructional programs, teacher characteristics, or school finances (Gray & Lewis, 2009; U.S. Department of Education, 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). To make progress toward this goal, technology support and decision-making in the areas of curriculum, instruction, and assessment should be more tightly integrated than they are at present.

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.

Moreover, states can help their districts increase productivity by promoting process redesign and consolidation of technology and services, evaluating innovative models used by districts or regional education service units within their state, and providing technical assistance around successful models that improve outcomes and achieve efficiencies.

Employing iterative design and development

As we take action to improve productivity in education, 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 approach, states and districts should define, test, and refine new ideas on a trial basis and measure both how they are implemented and their results. New educational practices should be adopted with the expectation that there will be multiple cycles of implementation and refinement. States and districts should also partner with each other on pilots and programs to leverage resources and scale up the best ideas.

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 of supporting learning 24/7 and personalizing 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 were 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 it 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.

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% of its students in 2005, a figure 1.5 times higher than Chicago Public Schools' overall 52% 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% 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 in which they are not yet proficient 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% of YWLCS students who graduated in 2009 were accepted to college or another postsecondary option.

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 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 (reinventingschools.org).

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 homed in 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. 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 U.K., 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 do 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, learners 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.

Reducing Barriers to Postsecondary Education

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. But there are practices supported with technology that 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.

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 courses online at their convenience.

Another example is provided by Tarrant High School in Alabama. Tarrant students are taking advantage of ACCESS, 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 have 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% in 2006 to 80% 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).

Moving to Meaningful Use

Current data on the use of educational and information technology in our system consists 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.

To accelerate the transition to collecting and using this type of data, the Department of Education should initiate work on developing a conceptual framework and definitions for meaningful use of technology in education. Clarity about what constitutes meaningful use is a necessary precursor for establishing goals and progress metrics for the use of technology in education.

Expanding Opportunities Through Blended Learning

Walled Lake Consolidated School District in Oakland County, Michigan, 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%, 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.

Source: Submitted to the NETP web-site, edtechfuture.org.

Reaching Our 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 meet this goal, we recommend the following actions:

5.1 Recommendation: Develop and adopt a common definition of productivity in education, and more relevant and meaningful measures of learning outcomes and costs.

The Department of Education should lead 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 cornerstone of this national initiative should be the formation of a commission and the development of an ongoing research agenda dedicated to improving productivity in the education sector.

5.2 Recommendation: Improve policies and use technology to manage costs including those for procurement.

The education sector has not incorporated many of the practices other sectors regularly use to manage costs and improve productivity, a number of which are enabled or enhanced by technology. The Department of Education should encourage states to adopt common cost accounting standards to allow benchmarking and analysis of costs. In the short term, the Department should provide a platform for sharing strategies for cost saving and productivity improvement and highlight policies at the federal, state and local level that may inhibit progress, for example, in procurement.

5.3 Recommendation: Fund the development and use of interoperability standards for content, student learning data, and financial data to enable collecting, sharing, and analyzing data to improve decision-making at all levels of our education system.

Fragmented student learning and financial data siloed in different systems and a lack of common standards for collecting and sharing data are formidable barriers to using data for continuous improvement and cost reduction. A barrier to finding and using content and assessment resources is the lack of common content interoperability standards and the absence of tools to enable usage of standards. The lack of common standards affects the quality of tools because developers must limit their R&D investments in such narrow markets. The Department of Education with the Office of Science and Technology Policy should convene a cross-agency effort to create, publish, and maintain open standards for content, student learning, and financial data interoperability. State and district requests for proposals (RFPs) for assessment and data systems should require appropriate use of these standards.

5.4 Recommendation: 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 at all levels of our education system while increasing productivity, we must remove the process and structural barriers to its broad adoption. States and education leadership organizations should work together 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 age-determined groups, the structure of separate academic disciplines, and the organization of learning into classes of roughly equal size. Educational institutions should explore the use of online learning and combining offline and online learning to provide options for flexibility in restructuring and providing additional learning time. When new processes and structures require policy, legislative, and funding changes, the Department of Education should lead or support the efforts to make those changes.

5.5 Recommendation: Design, implement, and evaluate technology-powered programs and interventions to ensure that students progress through our K-16 education system and emerge prepared for the workplace and citizenship.

Current high school and college dropout rates hinder the ability of the United States to be competitive in a global economy. The Department of Education should promote partnerships between two- and four-year postsecondary education institutions, K-12 schools, and educational technology developers in the private and public sectors to design programs and resources to engage students and motivate them to graduate from high school ready for postsecondary education. Support should start as soon as possible in students' educational careers and intensify for students who need it. States, districts, and schools should experiment with such resources as online learning and online tutoring and mentoring, as well as with participatory communities and social networks both within and across education institutions to give students guidance and information about their own learning progress and their opportunities for the future. Postsecondary education institutions should also experiment with these technologies to devise new approaches to ensure access, quality, and completion. Education institutions should try alternative programs that take advantage of technology to reconnect with students who have dropped out and help them complete learning programs.

R&D: Solving Grand Challenge Problems

The model for 21st century 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. We now have considerable knowledge about the essential components of such a system, but that is not the same as developing and deploying 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 accomplish this, we require an organization with the mission of serving the public good through research and development at the intersection of learning sciences, technology, and education (Pea & Lazowska, 2003). The Higher Education 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). Housed in the Department of Education, the center is authorized as a 501(c)3 that would bring together contributions from the public and private sectors to support the R&D needed to transform learning in America. Federal funding of the center at a level commensurate with its mission should be provided. The Digital Promise's intent of involving private sector technology companies in precompetitive R&D with the center can be realized only if the government provides the funding that would demonstrate its own commitment to a major program of R&D addressing the complex problems associated with redesigning our education system.

A New Kind of R&D for Education

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 currently 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 independently 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 (Cooke-Deegan, 2007).

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 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 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 of what is possible and deploy them incrementally to realize their benefits.

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 with closely with representatives of private industry to develop clear memoranda of understanding concerning the terms for precompetitive fundamental research.

Focus on Grand Challenge Problems

We urge the national research center to focus on grand challenge problems in education research and development. "Grand challenge problems" are important problems that require bringing together 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 optimizes 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
- 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
- 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, educational data systems and educational 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 educational 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 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 healthcare, 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
- 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 year-long 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 educational 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 educational 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 educational 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 Educational 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 Educational Technology Plan website (edtechfuture.org).

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 2-day meetings to craft the plan's vision and recommendations. In addition, Technical Working Group members participated in discussions with guest experts during five 2-hour webinars to incorporate additional expertise in critical issue areas for inclusion in the plan.

A second version of the National Educational Technology Plan website was launched on August 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), educational consultants (116), technology tool and service providers (153), and state and national policymakers (2).

Hundreds of other stakeholders provided valuable input to the national educational 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 Summit on Redefining Teacher Education for Digital Age Learners. 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, 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, California, on September 21, 2009.

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 Educational Technology Plan Technical Working Group for their extensive contributions to the plan's vision for the future of education:

Daniel E. Atkins, University of Michigan
John Bennett, Akron Public Schools
John Seely Brown, Deloitte Center for the Edge
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Chris Dede, Harvard University
Barry Fishman, University of Michigan
Louis Gomez, University of Pittsburgh
Margaret Honey, New York Hall of Science
Yasmin Kafai, University of Pennsylvania
Maribeth Luftglass, Fairfax County Public Schools
Roy Pea, Stanford University
Jim Pellegrino, University of Illinois, Chicago
David Rose, Center for Applied Special Technology (CAST)
Candace Thille, Carnegie Mellon University
Brenda Williams, West Virginia Department of Education

U.S. Department of Education staff members Jim Shelton, Mike Smith, Karen Cator, and Bernadette Adams Yates 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 Lassiter, 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. We extend our special thanks 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, Associate Deputy Under Secretary, Office of Innovation and Improvement

John Easton, Director, Institute of Education Sciences

Cheryl Garnette, Director, Technology in Education Programs, Office of Innovation and Improvement

Alan Ginsburg, Director, Policy and Program Studies Service

Laura Johns, Office of Educational Technology

Jenelle Leonard, Director of School Support & Technology Programs

Martha Kanter, Under Secretary

Ray Myers, Office of Educational Technology

Hugh Walkup, Office of Educational Technology

Joanne Weiss, Director, Race to the Top Fund

White House

Aneesh Chopra, Associate Director and Chief Technology Officer, White House Office of Science and Technology Policy

Kumar Garg, Policy Analyst, White House Office of Science and Technology Policy

Tom Kalil, Deputy Director for Policy, White House Office of Science and Technology Policy

National Organizations

Anne Bryant, Executive Director, National School Boards Association

Michael Cohen, President, Achieve

Dane Linn, Education Division Director, National Governors Association

Gene Wilhoit, Executive Director, Council of Chief State School Officers

Technical Working Group Webinar Discussants

Equity Issues in Technology-Supported Learning

Mark Warschauer, University of California, Irvine

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

August 24, 2009

Silicon Valley Industry Summit

September 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
NeXt Advisors, 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

September 25, 2009
30 participants

CoSN Member Webinar

October 6, 2009
72 registered participants

Webinar with Philanthropy Leaders

October 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
October 21, 2009
75 participants

NCTET Member Webinar
October 26, 2009

Exploring New Modalities for Learning Conference
October 30, 2009

SETDA Leadership Conference
November 1, 2009

Second Life Public Forum
November 5, 2009
200 participants

ISTE100 Meeting
November 9, 2009
25 participants

iNACOL Virtual School Symposium
November 16, 2009

National Center for Technology Innovation Conference
November 17, 2009

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

Technical Working Group members Daniel E. Atkins, Barry Fishman, Roy Pea, and Brenda Williams played an important role in reaching out to various stakeholders. We also extend our deep thanks to those who helped convene and gather input from the community, including Patricia Anderson, Karen Billings, Leslie Connery, Christine Fox, Tracy Gray, Jenelle Leonard, Don Knezek, Keith Krueger, Susan Patrick, Paul Resta, Mark Schneiderman, Irene Spero, and Mary Ann Wolf.

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