1. Executive Summary

Creating The Digital Opportunity Investment Trust

A Proposal to Transform Learning and Training for the 21st Century

A Report to The Congress of The United States

As authorized in P. L. 108-7

Respectfully submitted:

The Digital Promise Project

Lawrence K. Grossman

Newton N. Minow

Co-Chairmen

Anne G. Murphy

Project Director

October 2003

DIGITAL OPPORTUNITY INVESTMENT TRUST (DO IT)

To help transform education, training,
and lifelong learning for the 21st century.

Executive Summary

**“Tell me, and I’ll forget. Show me, and I may not remember.
Involve me, and I’ll understand.”**

Native American Proverb

DIGITALPROMISE
A Century Foundation Project
www.digitalpromise.org

The Honorable Richard B. Cheney
Vice President of the United States
Room S-212 The Capitol
Washington, DC 20510

The Honorable J. Dennis Hastert, M.C.
Speaker of the House of Representatives
Room H-232 The Capitol
Washington, DC 20515

Gentlemen:

Pursuant to Public Law 108-7, we are privileged to submit to Congress this Report, "Creating the Digital Opportunity Trust: A Proposed Transformation of Learning and Training for the 21st Century."

This proposal addresses an issue of profound national concern: how best to use the most advanced new technologies to enhance the ability to learn for men, women and children. It is a roadmap for the education of future generations of Americans. With educators and policy-makers confronting a Niagara of innovations, perhaps the greatest challenge is to establish our objectives and to chart a course for reaching them. Mindful of this, Congress authorized this Report.

We recommend that Congress dedicate a portion of the proceeds from the auctions of the spectrum to create, improve and develop sophisticated new information technologies, which will transform education and training as they have already transformed business, industry and so many other elements of American society. In addition, these funds will enable our nation's libraries, museums, and universities to digitize their collections for the benefit of all, and to move, as they must, into the digital age. More than that, this Report is a Research and Development Plan to harness the power of computer-based technology, including the Internet, in the cause of learning.

No plan is complete without clearly identifying the sources of the funds needed to achieve it. Here, we have modeled the future course of American education after its past: the Morrill Land Grant Colleges Act of 1862, under which proceeds from the sale of public lands during the Westward Expansion were dedicated to providing at least one Land Grant College in each state. Where vast tracts of public land once enabled generations of Americans to obtain a higher education, today it is the public airwaves—the electromagnetic spectrum—that can prepare successive generations for challenges and careers that we cannot even imagine.

The Report before you represents countless thousands of hours of dedicated effort by some of America's best minds and most accomplished and celebrated scientists who, without compensation of any kind, have sought to fulfill the Congressional directive of Public Law 108-7. We are grateful for their service, and for Congress' foresight in authorizing this Report.

Respectfully,

Lawrence K. Grossman Newton N. Minow Anne G. Murphy

Co-Chairmen, Digital Promise Project Project Director

Digital Promise Leadership Council

Digital Promise Coalition: Organizations actively engaged in the support of DO IT

Academic Advanced Distributed Learning (ADL) Co-Laboratory

American Arts Alliance

American Association of Museums

American Council on Education

American Federation of Teachers, AFL-CIO

Americans for the Arts

American Library Association

American Society for Training & Development

AppleTree Institute for Education Innovation

Association of American Universities

Association of Art Museum Directors

Association of Independent Technological Universities

Association of Public Television Stations

Association of Research Libraries

Communication Workers of America, AFL-CIO

Computing Research Association

Consortium for School Networking

Digital Library Federation

EDUCAUSE

e-thepeople

Federation of American Scientists

George Lucas Educational Foundation

International Longevity Center

Libraries for the Future

National Association of State Universities and Land Grant Colleges

National Education Association

National Humanities Alliance

National Initiative for a Networked Cultural Heritage (NINCH)

New America Foundation

National School Boards Association

U.S. Conference of Mayors

Digital Promise Leadership Forum

Ruzena Bajcsy, Director, The Center for Information Technology Research in the Interest of Society

Eric Benhamou, Chairman, 3Com

John Brademas, President Emeritus, New York University

Cathy Davidson, Vice Provost for Interdisciplinary Studies, Duke University

John Diebold, Chairman, Diebold, Inc.

William W. Fisher III, Professor, Harvard Law School

Rob Glaser, Chairman and CEO, RealNetworks

Garrett Gruener, Co-founder of AskJeeves.com and General Partner, Alta Partners

Nick Grouf, Chairman and CEO, PeoplePC

Frances Degen Horowitz, President, CUNY Graduate Center

Bill Janeway, Vice Chairman, Warburg Pincus

Brewster Kahle, Founder, Internet Archive

Thomas Kalil, Special Assistant to the Chancellor for Science and Technology, University of California at Berkeley

Henry Kelly, President, Federation of American Scientists

Bill Kovach, Former Curator, Nieman Foundation at Harvard University

Wendy Lazarus, Director, The Children's Partnership

S. Robert Lichter, President, Center for Media and Public Affairs

Stephanie P. Marshall, Executive Director, Illinois Science and Math Academy

Thomas R. Martin, Professor of Classics, College of the Holy Cross

John W. McCarter, Jr., President, The Field Museum

Anne Mendelsohn, Community Activist, Houston, TX

Ellen Mickiewicz, Professor of Public Policy, Duke University

Mary Minow, Past President, California Association of Library Trustees and Commissioners

Lloyd Morrisett, Former Chairman, Children's Television Workshop

Catherine J. Penprase, President, California Association of Library Trustees and Commissioners

Joel Poznansky, President, Apex ePublishing, Data Services, LLC

Gregory S. Prince, Jr., President, Hampshire College

Barbara Roberts, President, Acoustiguide Corp.

George Rupp, Former President, Columbia University

Eric Schmidt, Chairman and CEO, Google

Paul Taylor, Executive Director, Alliance for Better Campaigns

J. M. Tenenbaum, Senior Vice President, CommerceOne

Andries Van Dam, Vice President, Research, Brown University

Mary L. Walshok, Associate Vice Chancellor, University of California at San Diego

Margaret C. Whitman, President and CEO, Ebay

William Wulf, President, National Academy of Engineering

Congress's Opportunity to Build on Its Historic Legacy in Education

In a knowledge-based global economy, America's prosperity, its democracy, its culture, and, indeed, its future depend more than ever on the skills and ideas of our citizens. Many leaders in government and business already recognize that the people's access to learning across a lifetime in rural and urban America must move to the top of the nation's priorities.

In each of the past three centuries, Congress made a bold, farsighted investment in educating all our citizens. The Northwest Ordinance of 1787 set aside public land to support public schools in every state. The Land-Grant Colleges Act of 1862 established 105 land-grant colleges that made America's agriculture and industry the most advanced in the world. The GI Bill of 1944 profoundly expanded educational opportunities for veterans of World War II.

Now it is time for the fourth major educational initiative to advance those great legacies into the 21st century. Congress should create the **Digital Opportunity Investment Trust** (DO IT) to open the door to a knowledge-based future for Americans of all ages.

Like Congress's three bold educational initiatives of past centuries, the Digital Opportunity Investment Trust (DO IT), will be the catalyst for a transformation of learning. The Trust will stimulate and fund development of new educational software and content for learning, skills training, and lifelong use by generations to come. The United States is the world leader in technology and science, yet our educational system remains virtually untouched by the remarkable advances information technology now offers. DO IT will do for education and training what NSF does for science, NIH does for health, and DARPA does for national defense.

The Trust would be funded by revenues from a publicly owned asset, the electromagnetic spectrum, the 21st century equivalent of the publicly-owned land that earlier financed America's public schools and public higher education. Within the next decade, Congressionally-mandated federal auctions and fees for the commercial exploitation of these spectrum frequencies are expected to produce tens of billions of dollars. Over the years, DO IT will accumulate approximately $20 billion of this revenue. Conservatively invested, this would back the Trust with an annual budget of approximately $1 billion.

What Will Be DO IT's Priorities?

- **Develop learning models:** Schools and colleges have hardware and connections, but need far better software and content. DO IT will develop learning models to give teachers and students tools as basic as interactive digital aids to reading, writing, math, and languages, and as sophisticated as simulations and visualizations impossible to create in the 'real' world—a virtual solar system; a working 3-D model of the human body; a realistic trip to Mars; a recreation of Mark Twain's America; an historically accurate interactive recreation of the Constitutional Convention.

- **Digitize the collections of universities, museums, libraries, and cultural institutions:** America's heritage is stored there. DO IT will help to digitize these collections and set standards to conserve "born digital" materials, ensuring their accessibility to all. It will assist in the development of content and software to integrate the riches of our cultural institutions into classroom curricula and stimulate research in the humanities. It will help move our not-for-profit educational, cultural, and scientific institutions into the digital age and enable them to reach beyond their walls into even the most remote schools, homes, and workplaces.

- **Intensify research in using technology to improve learning:** DO IT will fund needed research on the little-understood interaction of cognitive and computerized processes. Cognitive scientists have made tremendous gains in understanding how people learn, but these advances have not been incorporated into teaching and training. A landmark series of studies has already shown that one-on-one tutoring improved student achievement by two standard deviations over group instruction—the equivalent of raising the performance level of 50th percentile students to the 98th percentile, an astonishing jump. Imagine the benefit if we could replicate this across the educational horizon through virtual one-on-one tutoring using advanced, interactive information technologies.

- **Develop far better assessment methods.** Student progress depends on regular assessment. DO IT will investigate and develop prototypes for embedded assessment and testing to give students, teachers, and parents continuous, real-time measures of each learner's progress.

- **Improve training tools for America's workers.** To ground our workers in 21st century skills, which require constant updating, the Trust will finance and encourage public-private partnerships to develop experiential ways in which workers can learn what they need to know on the job. DO IT will create content and software that make available anyplace, anywhere, anytime proto-type training and retraining materials for workforce development, skills improvement, certification, and further education.

- **Transform and expand lifelong learning for our aging population.** DO IT will encourage lifelong learning that enables people to continue to be productive citizens who participate effectively in our democratic society, learn about responsible health practices and developments, and enjoy stimulating, healthy lives.

- **Develop just-in-time training and public information for safety, resilience, and homeland security.** DO IT will fund research into instant training and information materials designed for first-responders, emergency workers, police and fire departments, as well as for the general public, to help deal with terrorist and other man-made and natural disasters.

Examples of What Can Be Done

- Help third graders master basic arithmetic.

- Allow high school students to participate, through simulations, in the political debates in Philadelphia that led to ratification of the U.S. Constitution.

- Let college students experience the inner workings of the brain or learn Chinese interactively.

- Help laid-off machinists master the skills needed to learn computer-assisted design.

- Allow a school superintendent in Alaska to tailor curricula to the special needs of his widely dispersed students.

- Enable a marginally employed 40-year-old immigrant to become proficient in English at her own pace.

- Teach emergency medical personnel how to take the pulse of a virtually "real" 3-D patient and apply first aid to her wounds, through virtual reality and simulation projects.

- Make it possible for first-responders of all kinds to acquire skills quickly, obtain regular refresher sessions, and receive just-in-time training during actual events.

- Quickly provide clear, authoritative information directly to all Americans during any major threat to security or safety.

The Trust's Structure

DO IT is envisioned as an independent trust fund, a Congressionally mandated non-

governmental organization with a creative, lean management structure. It will stimulate research and development of innovative learning systems and content. In partnership with corporate, foundation, and other sponsors, its funding will support public service projects, the vast majority of which will be carried out by qualified outside organizations such as universities, libraries, museums, and research centers, as well as by software and educational companies.

A small staff will serve under a highly qualified, independent, nonpartisan board of directors. (See Section 2, "Structure and Governance.") Like NSF and NIH, DO IT will set priorities through consultation with expert advisory panels based on local and national needs. It will solicit proposals from both public and private sectors, using peer review and other established procedures to select the most promising ideas for funding by grants and contracts.

To enable Congress to examine and evaluate the Trust Fund's performance each year and approve its budget, the Trust will send Congress an annual report, not unlike that required by the Land-Grant Colleges Act of 1862, "recording any improvements and experiments made, with their cost and results." This comprehensive, detailed report of DO IT's policies, priorities, and operations during the preceding fiscal year will be submitted to the President and the Congress through the Director of the National Telecommunications and Information Agency (NTIA).

The Rationale for Change

Education Must Not Lag in the Digital Age

Information technology has already transformed many aspects of American society—science, engineering, industry, business, finance, entertainment, national defense, the media, and personal communications. The computer, the Internet, digital telecommunications, virtual reality, 3-D simulations, and other advanced interactive information technologies offer unprecedented opportunities to transform the ways we learn and teach.

Many studies have highlighted the fact that the knowledge and skill levels of Americans have fallen behind those of other countries. A recent study revealed that a higher percentage of adults in the United States scored the lowest literacy level in writing and math compared to the other industrialized countries tested. According to the National Assessment of Educational Progress, only 18 percent of high school seniors are proficient in science, and half do not know the basics of the subject.[1]

Education and training, learning and teaching—the industry on which all others depend, arguably the most important industry in our knowledge-based economy—must not lag behind. That was the "overarching" finding of the *President's Information*

Technology Advisory Commission,[2] the influential *U.S. Commission on National Security in the 21st Century*, Congress's bipartisan *Web-Based Education Commission*, the Department of Commerce's "*2020 Visions*," the *Business-Higher Education Forum*, and others.

A Solution on the Horizon

Last July, in an article in *The Hill*, former House Commerce Committee Chair Thomas J. Bliley (R, VA) urged his colleagues in Congress and the White House to fulfill the "largely unfulfilled promise" of the Telecommunications Reform Act of 1996, which he shepherded. "Happily, there's a solution on the horizon," the Chairman concluded, a "rightful investment of government … one that'll allow us to keep our word and fulfill the promise of the Telecommunications Act. It's called the 'Digital Opportunity Investment Trust'—DO IT."[3]

The resources of the nation's great educational and cultural institutions—schools, universities, libraries, museums, health centers, and arts, cultural and civic centers—repositories of what Carnegie Corporation president Vartan Gregorian calls "the DNA of our civilization," can soon be made accessible to all. Now we can bring these riches to all—at home, on the job, or in school.

Advanced information technologies can bring new skills and continuous learning to every American. As Chairman Bliley predicted, "That same technology could teach unemployed workers new job skills—on their own time, at their own pace, in their own homes." Properly developed and distributed, new learning applications will keep our country up-to-date and competitive in a global economy.

The prescient report of the *U.S. Commission on National Security in the 21st Century*, chaired by former Senators Warren Rudman (R. NH) and Gary Hart (D. CO), warned that, "the inadequacies of our systems of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine. American national leadership must understand these deficiencies as threats to national security. If we do not invest heavily and wisely in rebuilding these two core strengths, America will be incapable of maintaining its global position long into the 21st century."[4] (See Section 3, "The Rationale")

The Benefits of DO IT

Further urgent reasons to enact the Digital Investment Trust include:

- Despite colossal strides in providing hardware and broadband connections in schools, very little has been done to capitalize on the remarkable emerging information technologies, to equip learners, teachers, and trainers with the software and content to take advantage of this.

- Federal agencies have sponsored some education technology research, but they have never been able to operate at the scale now required, or adopt the management needed to ensure that basic research gains are transferred to applied research and development.

- Massive numbers of educational users are ready and waiting. Ninety percent of all American school children between the ages of five and 17 already use computers, and very nearly 60 percent use the Internet. Americans who do not have Internet access at home often have access through public facilities. A great many children use public access—just over 80 percent of ten to 17-year-olds in the lowest income groups use computers at school, while the figure is only a few points higher (89 percent) for children in the highest income groups.[5]

- DO IT will enable the nation's multi-billion dollar investment in its public broadcasting system to fully, efficiently contribute to education. With local public television and radio station access to virtually every home and school in the nation, interactive software and content can be distributed using the stations' new digital capacity. Public broadcasting's distinctive creative skills and production facilities can be used to produce essential new educational, public service, and training initiatives.

- DO IT will improve workplace skills. A recent Hudson Institute study found that 60 percent of all future jobs will require skills that only 30 percent of today's workers possess.[6] Business leaders point with alarm to the widening skills gap between traditional training and the skills actually required to do today's jobs, let alone those of tomorrow.

- America is an aging society. The easy access digital technology offers can, through DO IT, allow "lifelong learning" and "senior quality of life" to become more than catchphrases.

- Americans who live in rural or remote communities stand to gain most obviously from the DO IT initiative. Where distances are great, specialized teachers scarce, and advanced courses hard to finance, interactive digital technologies, with their reach, accessibility, and low distribution costs, will bring huge improvements.

Getting There from Here: DO IT Research and Development Roadmap

Congress's bipartisan *Web-Based Education Commission*, in its groundbreaking report of 2001, called for "a comprehensive research, development and innovation framework for learning technology."[7] The Learning Federation, a coalition of distinguished experts from the public and private sectors, organized by the Federation

of American Scientists, has drafted a research and development roadmap of what needs to be done, what is possible, and what already exists. A full summary is included with this Report to Congress (Section 4). The complete document is available at *www.thelearningfederation,org.*

The Roadmap received guidance from national leaders in learning science and information technology, and advice by experts from companies, universities, government research facilities, and educational experts. It charts a course toward exciting new learning environments and offers a practical vision of how we should get there. It focuses on instructional design of the new digital learning directions, as well as on question generation and answering systems for classroom and other use. It discusses building simulations and virtual environments, learner modeling and assessment, and the tools we will need to build and maintain advanced learning systems. The Roadmap concludes that, for the first time in history, technology is available to make advanced learning concepts routine and affordable.

Conclusion

Like the Northwest Ordinance in the 18th century, the Land-Grant Colleges Act in the 19th century, and the GI Bill in the 20th, the Digital Opportunity Investment Trust in our century will be a farsighted federal investment that will repay future generations of Americans many times over. It asks merely that the Congress return to the public, the owner of the electromagnetic spectrum, a small portion of the revenue to be reaped from it under provisions of the Telecommunications Act of 1996.

Over the past four years, this DO IT proposal has been thoroughly studied and rigorously developed. It has benefited from extensive discussions and workshops throughout the country; more than one thousand leaders have contributed their best insights: leaders from nonprofit and for-profit companies and institutions, experts in cognitive and computer sciences, and software development, as well as from education, libraries, museums, the humanities, and government.

This Report to Congress itself has been shaped with the assistance of a wide range of prominent national organizations representing the academic, educational, museum, library, scientific, labor, public broadcasting, and political communities—all of which have endorsed DO IT. The Report has also benefited from the participation of representatives of the U.S. Conference of Mayors, the National Science Board, labor unions, senior citizens' groups, and corporate executives, all of whom have also endorsed DO IT.

Respectfully submitted,

Lawrence K. Grossman
Co-Chair

Lawrence K. Grossman is former president of NBC News and PBS, advertising agency owner, holder of the Frank Stanton First Amendment Chair at the Kennedy School of Government, and senior fellow and visiting scholar at Columbia University. He currently serves as a trustee of Connecticut Public Broadcasting and various nonprofit health organizations, and as a Dupont-Columbia Journalism Award juror. He is the author of *The Electronic Republic: Reshaping Democracy in the Information Age*. (Viking/Penguin and The Twentieth Century Fund, 1996).

Newton N. Minow
Co-Chair

Newton N. Minow is former Chairman of the Federal Communications Commission, PBS, the RAND Corporation, and the Carnegie Corporation of New York. He was a board member of CBS and the Tribune Company, and is a life trustee of Notre Dame and Northwestern Universities. He is co-author (with Craig L. LaMay) of *Abandoned in the Wasteland*, an influential book on television and children. Senior Counsel to Sidley & Austin, Mr. Minow is also the Annenberg Professor of Communications Law and Policy at Northwestern University.

Anne G. Murphy
Project Director

Anne G. Murphy is President of Linkages, a consulting firm specializing in public policy and the arts and humanities. Clients have included the National Cultural Alliance and OVATION, a cable network dedicated to the arts. She was Director of the American Arts Alliance, managing matters of public policy, legislation, and public relations. Earlier in her career she held senior positions at the Public Broadcasting Service and the National Endowment for the Arts. Ms. Murphy serves on the Board of Overseers for the Corcoran Museum of Art.

End Notes

[1] U.S. Department of Education, Office of Educational Research and Improvement. National Center for Education Statistics Science Highlights: *The Nation's Report Card: Science Highlights 2000 US* (November 2001)

[2] *Using Information Technology to Transform The Way We Learn*, PITAC Panel on Transforming Learning, Report to President George W. Bush, February 2001

[3] Thomas J. Bliley, *Seeking to Fulfill the Promise of Telecommunications*, The Hill, July 19, 2003, p. 16

[4] *Road Map for National Security: Imperative for Change*, Phase III report of the United States Commission on National Security in the 21st Century, February 2001, p. ix.

[5] U.S. Department of Commerce, National Telecommunications and Information Administration, *A Nation Online: How Americans are Expanding Their Use of the Internet* (February 2002) p. 1

[6] *Building a Nation of Learners: The Need for Changes in Teaching and Learning to Meet Global Challenges*, Business-Higher Education Forum, 2003, p. 13

[7] *The Power of the Internet for Learning: Moving from Promise to Practice*, The Web-Based Education Commission, December 2000, p. v

Acknowledgments

A number of individuals deserve special recognition for their contributions to this Report to Congress:

Richard Somerset-Ward for organizing and writing the first draft.

Henry Kelly, Kay Howell, Michelle Roper, Marianne Bakia and Kendra Bodnar at the Federation of American Scientists for their dedicated advice and assistance in its preparation.

Henry Geller, Rayne Guilford, Marion Fremont-Smith, Tom Kalil, and Eamon Kelly for their expert advice and counsel.

The Carnegie Corporation of New York, Century Foundation, John S. and James L. Knight Foundation, John D. and Catherine T. MacArthur Foundation, and the Open Society Institute, for launching and supporting the Digital Promise Project.

This Report is the product of many thousands of hours of dedicated effort by literally thousands of America's most thoughtful leaders, best minds, and most accomplished and celebrated educators and scientists who, without compensation of any kind, gave generously of their time, energy, and ideas. Those who contributed to the Learning Federation's Learning Sciences Research and Development Roadmap included in this Report are recognized in that section.

Congress authorized this project through PL 108-7, which provided an appropriation through the Department of Education to the Federation of American Scientists for the Digital Opportunity Investment Trust. We express our appreciation to the Members of the Congress of the United States and to the Department of Education for their support of this effort.

Digital Promise Project

1717 K St. NW Suite 209
Washington, DC 20036
T (202) 454-4683
F (202) 675-1010

www.digitalpromise.org
digitalpromise@fas.org

Design/Edit: Reingold, Inc.

CREATING THE DIGITAL OPPORTUNITY INVESTMENT TRUST

A Proposal to Transform Learning and Training for the 21st Century

A Report to The Congress of The United States

As authorized in P. L. 108-7

Respectfully submitted:

The Digital Promise Project
Lawrence K. Grossman
Newton N. Minow
Co-Chairmen

Anne G. Murphy
Project Director

October 2003

DIGITALPROMISE *www.digitalpromise.org*

DIGITAL OPPORTUNITY INVESTMENT TRUST (DO IT)

To help transform education, training,
and lifelong learning for the 21st century.

Structure & Governance

Structure and Governance of the DO IT

The Digital Opportunity Investment Trust (DO IT) will be established by the U.S. Congress as a Congressionally created non-governmental Trust Fund. It will be funded by receipt of thirty (30) percent of the revenues deposited in the U.S. Treasury from auctions of the electromagnetic spectrum, as well as licenses and other fees derived from spectrum uses until 2020, other than those assessed to defray the administrative costs of the Federal Communications Commission.

Purposes and Activities

The Digital Opportunity Investment Trust will:

- Help underwrite the digitization of collections in the nation's museums, libraries, and cultural institutions so that these become available for widespread public use, including education, training, research, and other public purposes.

- Provide grants and contracts to competent people, companies, and not-for-profit organizations to support research and development of innovative digital and information technologies. Grants and contracts will also develop applications of research, including the creation of prototypes, models, and pilot projects, as well as initial production (though not publication or manufacture) of content and software approved for use in educational curricula of many types including classroom use, job retraining, skills training, public safety preparedness, and lifelong learning.

- Serve as a national clearinghouse for in-depth examination of issues arising from the public-interest, educational, training, and similar uses of new information technologies. The Trust will support the development of common platforms and open standards.

Establishment of the Board of Directors

DO IT will be overseen by a nine-member Board of Directors. All members of the Board will serve with the advice and consent of the Senate. Members of the Board will elect the Chairman and Vice Chairman of the Board. The Board shall reflect equal representation from the public and private sectors and include eminent individuals in the disciplines the Trust Fund serves, such as education, information technology, telecommunications, labor and workforce development, cultural and civic affairs, and the arts and humanities.

As often as practicable, members of the Board will represent various regions of the United States, diverse professions and occupations, and various kinds of talent and experience that are appropriate to the functions and responsibilities of the Trust. No member of the Board of Directors may be a regular, full-time employee of the Federal Government. Expenses, following federal per diem guidelines, will be paid, but no member shall receive stipends, fees, or honoraria for his or her Board service.

Selection of the Board Members

Of the Board's nine members, five shall be appointed by the President; one by the Majority Leader of the Senate; one by the Minority Leader of the Senate; one by the Speaker of the House of Representatives, and one by the Minority Leader of the House of Representatives. Board members shall be chosen from lists of distinguished nominees submitted by relevant professional bodies at the request of the President and Majority and Minority Leaders.

Terms of Appointment to the Board

Each member of the Board will serve for six years, with one-third of the Board members appointed every two years. Terms will not coincide with federal election years. Three members of the first Board, selected from among those appointed by the President, shall serve for six years. Three members of the first Board, those appointed by the Majority and Minority Leaders of the Senate and the Majority Leader of the House, shall serve for four years, and the remaining three members of the first Board, two appointed by the President and one appointed by the Minority Leader of the House,

shall serve for two years. The Board Chair and Vice Chair shall serve a two-year term in those offices. The Board Chair may serve no more than two consecutive terms in that office. Members of the Board shall be appointed not later than 30 days after the date of enactment of this Act. Vacancies shall not affect the Board's powers and shall be filled in the same manner as the original member was chosen and subject to the same terms.

Appointment of the Director

The Digital Opportunity Investment Trust will have a Director. The Director of the DO IT shall be selected by, and serve at the discretion of, the Board of Directors. The Director will be responsible for hiring all other DO IT personnel and instituting procedures to carry out policies and priorities established by the Board.

Accountability and Reporting

DO IT will submit a report annually for the preceding fiscal year to the President and the Congress of the United States. This shall be a comprehensive, detailed report of all receipts and expenditures of DO IT during the preceding fiscal year. The annual report will be submitted through the Director of the National Telecommunications and Information Agency (NTIA). The Chairman of the Board of the Trust, other Board members, and principal officers of DO IT will be available to testify before appropriate Committees of the Congress on these reports or on any other matters relevant to DO IT.

Procedures and Guidelines

In general, in order to carry out the activities described above, the Director of the Trust, after consultation with the members of the DO IT Board, may award contracts and grants to nonprofit public institutions (with or without private partners), as well as to competent companies and individuals. To the extent practicable, proposals for such contracts or grants will be evaluated according to comparative merit by panels of experts who will represent diverse interests and perspectives, and who will be appointed by the Director of the Trust.

The underlying content of projects for which DO IT provides majority funding should be declared in the public domain—i.e., their R&D properties and materials should be

made freely and non-exclusively available to the general public. Although underlying content would be in the public domain, commercial firms will have the ability to make enhancements to this content, develop future alterations, and provide distribution and customer support. The possibility of exempting specific projects from the above terms should be open to DO IT—including projects involving majority funding, if it can be shown that the American people will benefit significantly in the long run by the project's being outside the public domain.

Source of Funds for the Trust

The Trust shall consist of the amounts that are transferred to it, as described below, and any interest earned on the investment of amounts in the Trust, as described in the section on investment of Trust funds.

The Secretary of the Treasury shall transfer to the Trust each fiscal year quarter, through fiscal year 2020, an amount equal to thirty percent of the cash payment received by the Federal Government during the preceding fiscal year quarter from—a) auctions of the publicly-owned electromagnetic spectrum and b) fees authorized by Congress to be derived from use of the publicly-owned electromagnetic spectrum, excluding those fees imposed by the FCC to defray the costs of that agency's operations.

Investment of Trust Funds

In general, these funds should be invested in the name of the Trust in interest bearing, obligations of the United States or in obligations guaranteed as to both principal and interest by the United States.

Expenditures: The Director of the Trust shall not undertake any outside grant or contract activities until the Trust has received the interest or other proceeds from the investment of the Trust funds for at least one year's duration. Thereafter, grants and contract activities may commence after an annual budget is approved by the Board, based on the amount earned by the Trust in the prior fiscal year. No obligations from the Trust shall exceed the proceeds received from the investment of funds during the preceding fiscal year.

1717 K St. NW Suite 209
Washington, DC 20036
T (202) 454-4683
F (202) 675-1010

www.digitalpromise.org
digitalpromise@fas.org

Design/Edit: Reingold, Inc.

CREATING THE DIGITAL OPPORTUNITY INVESTMENT TRUST

A Proposal to Transform Learning and Training for the 21st Century

A Report to The Congress of The United States

As authorized in P. L. 108-7

Respectfully submitted:

The Digital Promise Project
Lawrence K. Grossman
Newton N. Minow
Co-Chairmen

Anne G. Murphy
Project Director

October 2003

DIGITALPROMISE www.digitalpromise.org

DIGITAL OPPORTUNITY INVESTMENT TRUST (DO IT)

To help transform education, training,
and lifelong learning for the 21st century.

The Rationale

**“Tell me, and I’ll forget. Show me, and I may not remember.
Involve me, and I’ll understand.”**

Native American Proverb

Introduction

In today's knowledge-based global economy, "No Adult Left Behind" must augment the goal of "No Child Left Behind." All need the opportunity to learn effectively, to master fast-changing workforce skills, to carry out their responsibilities as citizens of a democracy, and to enjoy lifelong learning and personal improvement.

This nation has begun to recognize the urgent need to provide education, lifelong learning, and skills training for its citizens of all ages. More and more, education drives economic growth, and the bar of qualifications is rising.

Secretary of Commerce Donald L. Evans calls for the "successful development and deployment … in education and training" of powerful new information technologies that "promise to transform virtually every industry and many human endeavors." These technologies "could have a profound effect on American competitiveness and our standard of living … The technologies that are coming could create rich and compelling learning opportunities that meet all learners' needs, and provide knowledge and training when and where it is needed, while boosting the productivity of learning and lowering its cost."[1]

The Business and Higher Education Forum echoes Secretary Evans. Its report, *Building a Nation of Learners*, said, "Few people would disagree that knowledge, innovation, and an educated workforce represent the critical components for sustainable advantage in the fast paced global economy."[2] Good jobs now require a solid educational background and an ability to keep up with change. By contrast to former times, today's economy contains almost no jobs paying middle-class wages to people with poor educations. Increasing the education level of workers in an establishment by one year is associated with an 8.6 percent increase in output for all industries, according to the 1994 Educational Quality of the Workforce-National Employer Survey. The increase is 11 percent for the nonmanufacturing sector.[3] In 2002, high school dropouts were three times more likely to be unemployed than college graduates.

We have a unique opportunity to take the next great leap forward in education. As Secretary Evans pointed out, remarkable new information technologies now offer realistic means to achieve universal education. New learning environments using 3-D simulations, visualizations, immersive education, virtual reality, game playing, intelligent tutoring, networks of learners, reusable building blocks of content, and

more, will revolutionize learning and training. We can make emerging information technologies available in many kinds of public places, and in every home. This century's goal must be to make effective learning readily available to all in rural, urban, and suburban America.

For our nation to flourish, Americans must have greater and more effective access to the knowledge they need. U.S. security depends increasingly on sophisticated technology. The Defense Science Board notes that "We need training superiority as much as we need technical superiority."[4] Training is also essential for homeland security. Fire, police, medical, and other first responder personnel must prepare not only for natural disasters but also for an increasingly difficult set of terrorist and other threats. These challenges require an extraordinary repertoire of expertise and create extraordinary new demands for learning outside the classroom.[5]

It wasn't always thus. The start of the nineteenth century produced "horrified outcries over the revolutionary, poisonous idea of teaching all children to read and write." In 1830, a Philadelphia newspaper, in an "Argument Against Public Schools," explained why: "The 'peasant' must labor during those hours of the day which his wealthy neighbor can give to the abstract culture of his mind; otherwise, the earth would not yield enough for the subsistence of all: the mechanic cannot abandon the operations of his trade for general studies; if he could … languor, decay, poverty [and] discontent would soon be visible among all classes."[6]

As this **Rationale for the Digital Opportunity Investment Trust** shows, the new digital landscape is only just beginning to unfold. We have much to do to understand how to use emerging digital technologies to meet the nation's learning challenges. We are still in the very earliest stages of the revolution in learning, the most important revolution of our time. New learning tools need to be carefully researched, effectively designed, and widely deployed. As numerous national commissions have pointed out, this must become one of the nation's most important priorities.

Digital Technologies and Their Capabilities

The Need for Research

Centuries ago, before universal classroom education was considered a cornerstone of Western society, only a tiny privileged minority, the aristocratic, affluent few, received decent educations. Education rested on one-on-one tutoring; a curriculum tailored to the individual needs of each upper-class student. It was elitist, exclusive, and, in most ways, anti-democratic. For artisans, the apprenticeship system had similar one-on-one training characteristics. Others learned only by trial and error, by doing and experiencing.

Today, many cognitive scientists have come to believe we should revive these old-fashioned but demonstrably effective learning methods—provided, of course, that they can be made to work for everyone, in an environment of universal public education. Those scientists and educational theorists are turning to today's computer scientists to discover if this is feasible. Can online and other emerging, interactive digital technologies bring to learners and teachers affordable, practical methods that would be discrete, individually focused, and highly motivating even in modern classrooms?

Clearly, the answer is Yes. The enormous potential of new information technologies, which have transformed so many other elements of our society, can be put to work to transform education and learning. It will require the collaboration of cognitive scientists, computer scientists, and educators with practical classroom experience to work out theoretical and realistic solutions. Then scientists, teachers, and curriculum experts will need to interact—to research and design prototypes, develop models, experiment with pilot programs, and try them in experimental groups—before any of these ideas evolves into applications used in schools and elsewhere.

All this will require time for major research and development. Yet even the most skeptical critics of technology would be hard pressed to deny the revolutionary progress that digital technologies have already brought about in the worlds of business, industry, communication, entertainment, science, engineering, and national defense. Even skeptics must now ask what digital technologies can do to help transform education, learning, teaching, and training in all fields.

Techniques and Tools

Educational experts will find a considerable array of advanced computer and digital technologies and tools already developed and used in many disciplines. Some will be directly transferable to education and teaching. Now, we could implement the kinds of learning processes that teachers have recommended for years, but which were far too costly without new information technology. Many are based on traditional, proven learning methods—learning by trying to do something is inherently motivating and requires expertise to succeed, and learning by asking questions. The new learning tools make it possible to shape instruction for people with disparate educational backgrounds, cultural backgrounds, and language skills, and for people with disabilities. These systems all shape learning by building upon what the individual already knows. They demand constant attention and response from students.

- **Virtual Reality (VR) and simulation:** For more than a quarter of a century, research teams have used computer models to design, test, and visualize new products ranging from aircraft to toothbrushes. The entertainment industry creates breath-taking animations in extraordinarily plausible landscapes, from dinosaurs to Roman gladiators. Equipment for such simulations once cost millions, but now is used to produce animated video games played in nearly a third of American

households.[7] These systems can create highly motivating challenges; kids who find schoolwork boring spend hours mastering the obscure knowledge needed to advance in these games. For years, the US military has used immersive simulations and games in training and recruiting, to teach everything from piloting aircraft to repairing damaged equipment. Doctors, nurses, and first responders are using simulations to practice procedures—including the skills that they may need in the event of a terrorist attack. Such simulations can close the gap between formal instruction and the kinds of practical field experience, apprenticeships, and discovery that make learning compelling and lasting.

VR's chief educational value will be to make learning and training far more individualized and experiential than in traditional classrooms and laboratories. It will enable people to learn at their own speed, in their own time, in their chosen place, and at their appropriate skill level. As a learning tool, virtual reality can be as useful to the remedial student as to the advanced scholar, and as available to the remote rural learner and inner-city student as to the children of suburbia.

- **Intelligent tutors and computer dialogue:** One frustration teachers face in modern classrooms is lack of time to work with students or small groups of students as individuals. With thirty students in a room, lots of questions go unanswered (usually because students don't even try to ask them), and the teacher must move to a new topic as soon as most of the students master most of the material.

  While the kinds of "artificial intelligence" systems needed to provide a computer that can really answer questions or hold a conversation are not available in classrooms, systems capable of reacting to many kinds of questions are gaining power. All of us are probably familiar with using a help desk, using Frequently Asked Question lists, "Googling" for an answer, or trying to follow instructions on what may be wrong with an office copier that has stopped working. These systems are usually flawed, but they are starting to improve. At a minimum they can be used to build systems that respond to students as individuals and free teachers to spend more time with students who have a particularly interesting or difficult question or who need more help.

  Encouraging demonstrations are at hand. Students using Carnegie Learning's mathematics *CognitiveTutor* "perform 30 percent better on questions from the TIMSS assessment, 15-25 percent better on standardized tests, and demonstrate an 85 percent better performance on assessments of mathematical problem-solving and thinking."[8] Among the tasks an intelligent tutoring system can perform are: assessing the individual learner's strengths, weaknesses, and mastery of subject material; generating instruction material tailored to the progress of an individual student; serving as an 'expert' in subject matter areas; providing helpful series of

questions and answers; and using a variety of pedagogical approaches—including explanations, guided learning, and coaching,

- **Testing and assessment:** A central premise of the "leave no child behind" legislation is to employ tests that will give students, teachers, and parents the information they need to improve students' performance. Interactive computer and digital technologies can help in at least two ways. First, they introduce the possibility of measuring much more complex forms of knowledge and understanding than standardized written questions. The simulations can, for example, give problems such as "fish are dying in this lake, see if you can figure out why." Second, the new technologies can continuously monitor a student's state of understanding as he or she moves through assignments. Each individual has different strengths and weaknesses, each of us has bad days. The new technologies can be embedded in learning systems to keep a close watch on each student's work. They can build a record of performance that will help students understand their own progress, and provide continuous information to teachers and parents. No one will need to be surprised at the results on a student's final performance test since, with embedded assessments, performance information will become available daily.

  Rolled out in 2002, *MyBPS (My Boston Public Schools)* offers schools a "statistical snapshot" of each student's performance on state curriculum standards as measured by the Massachusetts Comprehensive Assessment System. It enables teachers to address individual students' weaknesses and is already a useful tool. But with further research, it should be able to give teachers *daily* evaluations of students' work, as well as enabling students to complete "homework modules" online. By 2007, its goal is to be a complete system—for teachers' professional development and collaboration, for students taking online courses, for instant assessment, for accessing electronic textbooks and compiling student portfolios, and for fully informing students, teachers, administrators, and parents.[9]

An Overview of Digitization

The dream of a universal library of human knowledge that is globally accessible is now within our grasp. But a number of practical technical and non-technical issues must be addressed first. Computer technology can radically improve upon the often fragile, hard-to-access physical records we've used for centuries; now we can record text, images, video, music, and three dimensional materials, using a single efficient, underlying digital language—strings of ones and zeros. Captured in digital form, all these materials can be stored and communicated in the same way. Over the Internet, the riches of American culture and science can be made instantly available in schools, libraries, homes, hospitals, and even prisons. These materials put superb research tools in the hands of students of all ages, and they are the raw material from which we can build more sophisticated educational tools.

An expanded digital library could mean that performances at the Spoleto Festival in North Carolina, sound recordings from the annual National Cowboy Poetry Gathering in Elko, Nevada, or landscapes that inspired the paintings in the Sid Richardson Collection of Western Art in Texas, would be available not just to people fortunate enough to be able to visit these places, but to everyone with access to the Internet. Students can examine geology collections in Minnesota and antique buffs can examine period rooms and furnishings from Oregon to Maine. Parents wanting more material on their children's health care can access everything from introductory guides to the latest medical research paper.

Searching with Librarians as Guides

New tools will make it much easier to locate needed material in the enormous collections becoming available. Google and similar search engines have enabled even the most naive user to explore millions of pages of text and images. But search engines are limited to text and images rather than three-dimensional objects. Also, much content is stored within databases that make these materials invisible to Internet search engines.[10] With the commercial market weighing in as a leading provider of digitized content, we may increasingly encounter subscription services or gated access to materials.[11] Future search engines should be able to answer questions presented in more natural language (such as "Who painted the Sistine Chapel ceiling?"), search the content of images or videos ("Find the painting where a Cowboy on a Palomino is staring at sunset over the Yellowstone"), or find information in charts, graphs, and illustrations.

The librarians' essential role will change to that of skilled research advisors. Librarians recognize that "Developments in digital technology, the introduction of the Web and the Internet, and new methods of creating, sharing, and using knowledge have changed dramatically the traditionally understood definitions of library collections and access services. Building collections and generating access to them are no longer achieved just within the walls of the library. Broadly defined, collections and access responsibilities … are inextricably linked—with each other, with other functions in the parent institutions, and, indeed, they reach into other institutions"[12]

These tools will also make it easier to combine information available from many different on-line collections to create an experience tailored to each individual. Imagine not only being able to consult the original manuscript of *Huckleberry Finn*, complete with Mark Twain's revisions, but also to hear it read. Imagine touring the Mississippi through historical photographs or a fly-over, listening to music Twain would have heard played on the riverbanks, consulting contemporary newspapers and letters he wrote and received, and being able to access scholarly material about the book.

Spreading Digitization

While some work is underway, particularly at large institutions such as the Library of Congress, much remains to be done—especially in collecting the unique materials available in the nation's multitude of museums, libraries, and schools. Technical advances are rapidly driving down the cost of storing vast amounts of digital data. Broadband communication opens the possibility of near universal access to rich libraries of images, video, and other materials difficult to transmit using today's technology. Software can compress bulky files making them easier to store and transmit. Image enhancement techniques can bring out details in poorly preserved texts. The cost of scanning text and images can be cut through automation, and new tools will soon capture 3D representations of sculpture and other solid objects. DO IT will concentrate on finding ways to collect information in digital form that would not otherwise be captured. The Trust will also address issues of intellectual property rights, and find financial models that encourage content providers to enable greater public access.

Digitization can give anyone with access to the Internet access to the precious raw materials of American history while preserving the materials themselves. In many cases the original materials are fragile and cannot be handled by anyone except specialists. In addition, we need to build trusted digital repositories where these sources will persist, where they will be unaltered in form or content by hackers and others, where their provenance is known, and where they can be easily located using sophisticated user interfaces.

Model Projects

Perhaps the most ambitious digitization project under way is the *American Memory Project* at the Library of Congress. Begun in 1994, with funding from the US Congress and the private sector, the project includes text, sound, and image files. One of its first priorities was to take advantage of the Internet to reposition its four-year-old CD-ROM project as a web-based project. The grand success of the *American Memory Project* demonstrates what is possible.

Many of the most interesting collections, however, remain in regional museums, libraries, and archives—or in private hands. While a very few institutions have found resources to digitize portions of their collections, vast amounts of material remain unavailable in digital form. Digitizing their holdings offers tantalizing possibilities that could hasten discoveries, aid scholarship, and stimulate interest in local history. These successes show what can be done:

- **Documenting the American South (DAS):** (*www.docsouth.unc.edu/*) offers digitized primary sources in the history and culture of the American South and supplies teachers, students, and researchers with a wide array of titles. Currently, DAS includes six digitization projects: slave narratives, first-person narratives, Southern

literature, Confederate imprints, materials related to the church in the black community, and the history and culture of North Carolina.

As of August 1, 2003, DAS included 1,244 books and manuscripts in electronic formats. The program points out that "Prior to digitization of this material, these types of documents would be accessed by perhaps a half dozen people per year. These unique documents are accessed now by an estimated fifteen to twenty people per day (i.e., well over 5,000 people per year) via the Internet."[13] The resource has influenced graduate students' research questions and methodologies, the kinds of sources K-12 teachers use, and novelists' approaches to character and plot. According to Joe Hewitt of the University of North Carolina Libraries, "Somehow, the primary sources in *DocSouth* seem to help people from different backgrounds to find their way back to a common culture."

- **Classical Chinese Texts:** Available at the University of Hawaii, are online at *http://www.shuhai.hawaii.edu/*

- **Hispanic Oral History (including the records of Sephardic Jews):** Available from collections at the University of California at Davis.[14] *flsj.ucdavis.edu/home/sjjs/lecture/lecture1*

- **Collections of Historic Aircraft** and documents about the history of aviation in Alaska, previously available only to visitors in the Anchorage museum; now online at *www.alaskaairmuseum.com*

- **Complete archives of Utah newspapers:** Available through Public Pioneer, Utah's Online Library (*pioneer.utah.gov/magsnews.html*). Complete online collections are available for *Emery County Progress Digital Collection 1900-1910*, *Wasatch Wave Digital Collection 1889-1922*, *Messenger Digital Collection 1893-1922*, and the *Grand Valley/Times Independent Digital Collection 1896-1932*

In the sciences, more progress exists, thanks to early efforts to provide electronic access to current journals. For example, PubMed offers free access to citations and abstracts from over 4000 journals (more than 12 million articles).[15] *http://www.ncbi.nlm.nih.gov/entrez/query/static/overview.html* and offers a subscription service that accesses full text articles. The National Science Digital Library, *www.nsdl.nsf.gov/indexl.html*, funded by the National Science Foundation, aims to be an "online network of learning environments and resources for science, technology, engineering, and mathematics (STEM) education at all levels." A range of materials is just beginning to become available, many chronicled by the American Association for the Advancement of Science *www.sciencemag.org/netwatch/*. Examples include:

- The Alexandria Project Maps *http://www.alexandria.ucsb.edu/* a comprehensive map collection managed by the University of California at Santa Barbara.

- A comprehensive collection of material on fungi run by the University of Tennessee at Knoxville *mycorrhiza.ag.utk.edu*

- A spectacular collection of images and other information on earth science, geology, oceanography, and other subjects collected by the American Geological Institute in Alexandria, Virginia *www.earthscienceworld.org/imagebank*

- The Long Term Ecological Research Network in Albuquerque, New Mexico maintains extensive documentation on ecological issues including a detailed National Invasive Species inventory at *intranet.lternet.edu/archives/documents/Newsletters/NetworkNews/spring03/spring03_pg09.html*

- Treebase at *www.treebase.bio.buffalo.edu/treebase/* maintained by the State University of New York at Buffalo has a comprehensive collection of information on trees.

Rich as they are, these collections are only a fraction of what should be made available. Digitization of the collection at the Longfellow-Evangeline State Historic Site, for example, would illuminate the early history of French-speaking settlers in Louisiana that inspired Longfellow to write his epic poem "Evangeline." The history of innovation could be explored through the Henry Ford Museum's collection. Labor history could be enlivened through the writings and speeches of Mother Jones, collected in the West Virginia State Archives Library. The impact of the civil rights movement could be powerfully told through the collection in Memphis, TN's National Civil Rights Museum.

Barriers to Digitization

Cost: The cost of converting material presents by far the greatest barrier to most groups around the country. A few collections are being made available through an assortment of grants from individuals, federal and state governments, and foundations. The process is very uneven; most important collections remain completely unavailable. Since most current funding is limited to a one-time grant and comes from a range of sources, there has been no formal or continuous process of evaluation for form or content. Few institutions have developed policies or budgets that will ensure the migration and refreshment of digital content.

The challenge of acquiring new material in digital form should be less difficult since much material is now "born digital." To give an idea of the cost dimensions, however, the Library of Congress alone is already spending $100 million specifically to preserve its new content through the National Digital Information Infrastructure and Preservation Program (NDIIPP). Much of the cost of digitizing material comes from the need to

pay skilled professionals to handle the original material and ensure that it is properly labeled and documented. The cost of scanners, computers, and other devices is also significant, particularly for smaller institutions.

Funds for digitization nationwide are wholly inadequate. Subscriptions to collections of journals, such as Elsevier's *Science Direct*, *www.elsevier.com*/ can be purchased at a single price—but the price exceeds the means of small school systems or individuals. ArtSTOR *www.artstor.org*/ is designed to make art collections available to participating universities and colleges for research purposes while protecting the intellectual property of the museums that hold the originals. Even the largest institutions often find themselves acquiring material faster than they can digitize it. And many collections are deteriorating before they can be captured: 20th century paper becomes brittle, early movies are stored on highly flammable material. Even modern media are not exempt. For example, CD/DVD media—the suggested storage medium for digitized music—have a limited physical life. According to a recent article, CD-R's (recordable CDs) have only a two-year shelf life.[16] *http://www.aktu.nl/pc-active/cdr.html*

Intellectual property concerns: The core advantage of digital collections—the ability to make and transmit copies virtually without cost—raises justified concerns for holders of intellectual property. Owners have blocked digital access to many valuable collections of texts, images, sound recordings, and other materials. Concern about ownership can also make it difficult to make many public collections available. Ownership of digital rights may not be clear. And a public museum with a box full of old photographs may be reluctant to put the material online because of uncertainty about the status of the original photographer's copyright. Solutions to these dilemmas can be developed but require urgent attention. Commercial approaches are being developed to allow digital access to "e-texts," music, video and other material while protecting the rights of copyright holders. But the field continues to change as new technical and legal procedures evolve. No dominant standard has emerged; without a central coordinating agency to work on these problems, the field is likely to remain unsettled.

Nobel laureate and former NIH Director Harold Varmus, co-founder of Intel Gordon Moore, and several other prominent scholars are leading an effort to make all scientific literature free on the Internet.[17] They argue that it is extremely wasteful to prevent medical research results from being disseminated as quickly and efficiently as possible—particularly when public funds supported the research. Academic publishing, however, is extremely conservative; scholars are justifiably concerned that they will not get academic credit unless they publish in standard print journals. Today, at least a third of the current academic journals are available online, though at high prices. The economics of publishing technical material presents additional challenges. Expensive library subscriptions and royalties pay for about 75 percent of the cost of academic publishing. New models must be found.

Common Standards: The art of digital capture is in fast-moving flux, which may be unavoidable in order to ensure continual progress in the technology. But the dizzying array of individual projects makes it difficult to develop consistent, reliable management of the growing digital collections. It's not enough to rely entirely on powerful search engines that struggle to make sense of countless formats and products of highly varying quality. Compatibility must be assured and standards must be set by an impartial public body such as DO IT. One major issue is the core set of information that should be attached to digital information—whether a text, a recording, an image, or some other form. Standard methods have been developed for book and article citations (the ISBN provides a unique identifier for books) and the music industry has a variety of standards. The problem becomes more challenging when the original material is an artifact, an excerpt from an animation, or some other format.

There is disagreement today about the minimum set of information that should be provided (author, location, etc.) and how it should be recorded. The Dublin Core Metadata Initiative has received approval as an international "resource discovery metadata standard on the Internet" (ISO 15836). It provides "a foundation block of modular, interoperable metadata for distributed resources."[18] *http://www.dlib.org/dlib/april03/weibel/04weibel.html* But much work remains before the standard is universally accepted and ambiguities about interpreting the standard are resolved. (Is "location" the location of the object today, or where it was discovered?)

Another issue deals with the technical standards used to store the material. Standards for representing digital text are complex although standards such as the Adobe.pdf are now used widely. But it is likely that tools will continue to change and improve. The situation is vastly more complex for images, 3D representations, and video. Tools for reading multiple formats continue to evolve but there is growing concern that digital archives may be difficult to translate as time passes. Documents and old photographs stuck in an attic will always be accessible. But without interoperable standards, the next generation's children going to their grandparents' attic are likely to find a strange pile of storage devices and obsolete formats.

How DO IT Will Advance Digitization

Improved funding available from DO IT would build on the successful models already underway, and it would dramatically increase the scale and pace of digitization while providing national coordination to harmonize the delivery of content. Carefully evaluated grants would encourage collaborative efforts among institutions with complementary or interconnected materials and facilitate the creation of rich digital environments. DO IT would evaluate the programs it funds, disseminate important content, and foster the adoption of best practices that are being developed.

DO IT would provide funding to advisory groups to develop criteria and help to establish urgently needed guidelines and interoperable standards. The Trust will encourage widespread adoption of these because it will be an important source of funding for digitization. It would establish task forces to tackle issues of intellectual property, metadata, and problems encountered in ensuring continuous migration of archival collections, to ensure compatibility and the longevity of these resources.

Part of the teacher's responsibility will be to show students how to access and use the awesome digitized resources that DO IT can help develop and make available. These resources can be distributed through public broadcasting stations, the Internet, and other electronic pathways. To people schooled in the 20th century it may seem unrealistic to talk of adolescents and even younger children enriching their education by tapping into these matchless resources—the Library of Congress, the Hubble Telescope, the Smithsonian Institution, NASA, the vast cultural, educational, and instructional programming services of public broadcasting—but that is precisely what they are beginning to be able to do.

Until now, our great cultural institutions have been somewhat tangential to the educational process: useful "add-ons" for those who can visit them in person, but not integral to classroom activity, and not, therefore, a normal part of curriculum. The digital revolution will change that for good. Early digitizers have begun to demonstrate what an important—and massive—resource this material will be when it is directly accessible and fully integrated into learning. One of DO IT's early priorities will be to assist institutions across the nation to digitize their collections so they, too, can become direct contributors to educational systems, not only within their own communities but also regionally, nationally, and internationally. Before very long, undigitized assets in museums and libraries will be, in educational terms, underutilized assets.

Managing and Delivering Digitized Resources

Digitization by itself, however, is not enough. Digitized images and accompanying contextual materials must be organized into systems, courses, sites, and programs that make them accessible and readily useable. At the same time, *learning management tools* are needed so that teachers, learners, and education professionals can take full advantage of all this new content for application to tasks such as performance analyses, timed interventions, parent/teacher communications, and more comprehensive student portfolios.

Digital video, satellite, and broadcast technologies: Though not as easily accessible as the online world, these distribution mechanisms may ultimately deliver some of the best educational solutions. Parts of the nation (the States of Iowa and Ohio, for example) are crisscrossed by miles of fiber optic cable, much of it "dark", or unused —and that is in addition to spare capacity in digital cable systems. Most urban and suburban communities also have ITFS systems (microwave), and many rural areas have access to satellites. All these are broadband connections.

One strength of these technologies is interactivity: real, face-to-face interactivity that schoolchildren and adults alike find compelling. There is also digital public television, which has 178 licensees serving almost 350 separate communities. Each of them has a license to digital spectrum and a special mission for education. Public television stations all over the country are beginning to experiment with new kinds of delivery—direct to servers in schools and prisons, through streaming portals, even (as in New Jersey) by creating a 'digital classroom.' Like the online community, they will need substantial R&D help to develop innovative software, content, and powerful learning systems. Only such R&D will enable the nation to capitalize on its substantial investment in local, regional, and national public station and network infrastructure.

The task is to bring together the best of the learning sciences and the best of the computer sciences to serve the nation's urgent educational needs.

Workforce Training

In 1690, philosopher John Locke suggested that "the commonwealth of learning" required "master-builders, whose mighty designs in advancing the sciences will leave lasting monuments to the admiration of posterity."[19]

Chief of Naval Research Jay M. Cohen puts it bluntly: "Today, as we face an uncertain world, the strength of our nation—intellectually, economically, and militarily—will only be as great as our commitment to learning and excellence in education."

Growing Demands

In the 21st century, education must be a lifelong experience. Virtually every job will be redefined by new products, new production methods, and new markets reshaped by technology. The skill levels required for entry to most occupations will rise, and skills must be repeatedly updated and certified. The changes are obvious for technical professionals who will need to master sophisticated information systems and automated equipment. But truck drivers must learn to operate GPS navigation systems and operate well in international "just in time" delivery networks. Clerical workers have all but disappeared. Routine clerical tasks have been automated and today's clerical employees find themselves designing and operating web services and talking directly to customers to answer questions and tailor products and services for individual needs.

Unfortunately, too many people are not prepared. In 2000, an American Management Association (AMA) survey of midsized and larger businesses found that 38 percent of job applicants taking employer-administered tests lacked the reading and math skills needed in the jobs for which they applied. That percentage had doubled in four years, compared to the 19 percent of job applicants not qualified in 1996. The AMA attributes this sharp rise not to rapidly declining basic literacy skills in the labor pool, but to rapidly rising requirements for reading and math skills.

New technologies, information and competition will make today's state-of-the-art products and processes obsolete tomorrow. In more competitive international markets and a world where new technologies and concepts spread at Internet speed, firms that cannot quickly move new products and services to market, or achieve productivity gains through new tools and methods, will simply not survive. Advances in information technology, biotechnology, materials technology, robotics, nano-devices, and other areas are accelerating the pace of change. The most important new technologies will undoubtedly be completely unexpected. By some estimates, jobs will be wholly restructured every seven years. Few working Americans will be able to remain competitive in their present jobs without continually learning new skills.

Staying Ahead

To stay ahead, employers are reorganizing their workplaces. They are streamlining production to allow teams of people to work together and take on greater responsibilities. In these more flexible workplaces, even lower-level employees perform work that used to be done by managers or specialists, including planning, budgeting, supervising, troubleshooting, and working directly with customers. Compared with more traditional workplaces, today's workplaces have fewer managers and flatter hierarchies. As a result, they demand employees with higher, more versatile skills.[20]

Firms will not be able to maintain competitive advantage unless they match investments in new technology with investments in the skills of their employees. But this places new demands on the nation's educational systems. Many nations have large pools of highly educated people willing to work at comparatively low wages. The infrastructure needed to deliver high quality education and training to employees at all levels has become critical to the ability of US firms to compete. In 1997, people with a college education earned two and a half times more than workers with only a high school education.

It was once possible to get a solid middle-class job with a high school degree and retire after 30 years of doing that job. No one can count on such a career today. Employees must be prepared to acquire new skills at regular intervals simply to stay with a single employer. And many will change jobs and careers multiple times—some by choice and some by necessity. Secretary of Labor Elaine Chao estimates that: "The average person will change jobs nine times by the time he or she is 32."[21] The National Alliance of Business estimates that 85 percent of all jobs in the US today require education beyond high school.[22] A recent Hudson Institute study found that 60 percent of future jobs will require training in skills that only 30 percent of today's workers possess.

Staying Ahead in Unconventional Workplaces

Rising skill levels are also essential for maintaining the superiority of the US armed services and for meeting growing needs for homeland security. The US military must keep pace with the rapid changes in technology that give US forces commanding superiority in intelligence, communication, precision weaponry, mobility, and many other areas.

The military must adapt rapidly to new threats and to new regions of combat. The Defense Science Board emphasizes that "War fighting success is as dependent upon the proficiency of people as it is upon the hardware with which they fight. We need training superiority as much as we need technical superiority."[23]

Training is imperative for homeland security. Fire, police, medical, and other personnel must prepare not only for natural disasters but a difficult set of terrorist and other threats. These challenges require an extraordinary repertory of expertise and place extraordinary new demands on teaching and learning.[24]

Lifelong learning, too, is essential. It helps Americans take advantage of the benefits of a technologically rich economy and to cope with adversity as well. High-school dropouts were three times as likely to be unemployed as college graduates in 2002. Poor education is also an accurate predictor of social pathology. Nearly half of all Americans, but only about 12 percent of state prison inmates, have some education beyond high school; prisoners are twice as likely not to have completed high school.[25]

Lifelong Learning

Americans understand the need for education. A Washington State University survey in 1996 found that more than half of all Americans between 18 and 49 think that additional education or training is "definitely important" for success in their work; an additional 25 percent think that additional training is "probably important." Significantly, more than half of employed older workers, including those over 65, also think that further education is important. As Americans live longer, healthier lives, they are starting new careers and pursuing new interests well past traditional retirement age.

Americans are not only talking about lifelong learning, they're acting on their convictions. In 1995, more than 80 percent indicated that they received job-related training during the past three years. The ability of Americans to receive the education they want is, however, linked to income. The more education a person has, the more likely that he or she will receive further education. More than 90 percent of employees with bachelor's degrees have participated in adult training in the last three years, and more than half participated in the previous year. Only 60 percent of employees without high-school degrees participated in a training program during the past three years. While few survey participants felt unqualified for further training, many face severe barriers to getting more training. Cost was the greatest obstacle cited by younger Americans, but lack of time was listed by about 60 percent of those aged 30 to 50. For a parent, especially a single parent, driving across town after work to sit in a classroom can be very difficult.

Corporations are beginning to experiment with ways to use new online technologies to enhance skills and improve on-the-job training. For example, Black & Decker,

McDonald's, and Home Depot are starting to install Internet connected job training facilities. A Black & Decker vice president told the *Washington Post*, "We estimate each hour of e-learning is replacing three to four hours in the classroom." Noting that e-learning is still in its infancy, one executive predicted that its social impact will be huge. With the prospect of giving "educational access to many people who were not able to access it before, the implications will be nothing short of overwhelming in our lifetime."[26] Corporate universities are playing a growing role. *The Chronicle of Higher Education* reports that the number of corporate universities in the United States has grown from 400 in 1988 to more than 2,000 currently.[27] All of these institutions recognize that new learning technologies are needed to meet expanding demand for a skilled work force.

Government agencies, in addition to the Department of Defense, are also beginning to take advantage of the new technologies' unprecedented skills training opportunities. The Agriculture Department has begun to offer an Internet course on commodity trading to dairy farmers, who prefer the online version to classroom lectures. The Justice Department, in a pilot effort, estimated that it saved $10.7 million by enabling managers to take electronic courses over two years, compared with the costs of classroom training.[28]

In-Home and Community Education

The workplace will not be the only engine of education: the home and the community will be just as important in the knowledge-based information society. Local and neighborhood demand will be high.

- There are growing requirements for health education, local government information, and senior citizen involvement;

- New (and interactive) community roles will be required of museums, libraries, public broadcasters, and other cultural organizations;

- More people than ever will need to upgrade their skills and academic qualifications from home, some by taking credit courses and online degrees, many more by participating in informal types of learning.;

- At the other end of the spectrum, educational technology can contribute to the safety and security of each community—by helping to train first responders, by developing emergency procedures, by making sure that all citizens, especially emergency personnel, can be informed quickly and accurately in the event of a major threat or natural disaster;

- And the more people are connected and involved, the more they will participate in civic democracy.

Jobs from Information Technology Itself

Information technology has created thousands of jobs in fields that did not exist a few years ago. The Partnership for 21st Century Skills, a public/private coalition of business and education groups formed in 2002, recommends five critical steps to improve the quality and competitiveness of the U.S. work force:[29]

- *Emphasize learning skills*, such as communication, thinking and problem-solving, and interpersonal and self-directional skills;
- *Integrate IT tools with learning skills*, using them to access, manage, evaluate, and create information;
- *Expand learning beyond the classroom walls*—businesses and community groups can assist schools to give students real-world experience;
- *Add new content areas to teaching*—global awareness, financial, economic and business literacy, civics literacy, health literacy, and
- *Develop assessment technologies* that offer immediate feedback to teachers and students.

Online learning, distance learning, and intelligent tutoring systems with built-in assessment will be among the most productive learning tools for the working and job seeking segment of the population. In 1950, 80 percent of jobs were classified as *unskilled*. Today, an estimated 85 percent of all jobs are classified as *skilled*, requiring education beyond high school.[30] Labor unions, too, recognize the need for continuous worker training and skills updating. The Communications Workers of America (CWA) represents 700,000 workers in high-tech industries. Determined to help its members upgrade their skills and their educational qualifications, CWA recently joined with major telecommunications companies and Pace University to establish the National Coalition for Telecommunications Education and Learning (NACTEL). *http://csis.pace.edu/nactel*

Elementary and Secondary Schools

America's elementary and secondary students are the best connected in the world. In the past ten years, federal, state, and local governments have invested over $40 billion to put computers in classrooms and connect them to the Internet.[31]

- The national average for computers in classrooms is one computer for every 3.8 students.[32]

- Ninety-four percent of public schools now have Internet access, more than three-quarters of them via high-speed lines rather than dial-up connections.[33]

- One of the fastest-growing budget items for educational technology is the relatively new wireless Internet technology known as WiFi. By positioning their laptops within a few hundred feet of access points, or "hot spots," students can get ultra-high-speed connections whenever they need them. An estimated $1 billion was spent on WiFi by K-12 schools in 2002-03. The figure is expected to double in 2003-04.[34]

Connectivity Is Not Enough

There is, however, a startling dichotomy between the *connectedness* of American students and their ability to use it in education. In its 2001-02 survey, Market Data Retrieval reported that only 11 percent of schools (out of more than 25,500 surveyed) claimed that even a majority of their teachers could integrate technology into curriculum.[35] And those teachers who do acquire computer skills find few opportunities to use them. Most available software does little more than transfer traditional classroom content to the screen—textbooks are reformatted as electronic texts on CD-ROMs; lectures and syllabi are simply transferred to the Web.

Most young people, regardless of background or circumstance, can quickly become skilled at operating digital devices, Web and multimedia tools—often more skilled than their teachers. Outside of school, they routinely use cell phones, chat rooms, instant messaging, electronic games—to communicate and have fun. Physical dexterity is not the only skill required to operate these devices; they require cognitive skills as well—the ability to reason, to analyze, to *think*. These skills are undoubtedly stimulated by the logical leaps and links that are the keys to moving freely within the digital world, and they are exactly the skills that can, and should be, used to great effect in every person's education. Instead, too many of our children quickly discover that, despite the presence of computers and broadband connections, formal education is conducted much as it was in their grandparents' time. There are many reasons for this—overstretched teachers, concentration on testing and assessment, cautious parents, inadequate budgets—but one reason is most critical: the research is lacking.

For example, a landmark series of studies demonstrated that one-on-one tutoring improved student achievement by two standard deviations over group instruction, the equivalent of raising the performance level of 50th percentile students to the 98th percentile, an astonishing jump. Imagine the impact on American society if we could replicate this success throughout education. If computers and advanced information technologies can implement even a portion of these tutoring strategies, as several learning systems have already demonstrated, significant learning gains could be made across the board.

The Teacher's Changing Role

New technologies can lead to dramatic changes in the role of the teacher. Since the time of Aristotle, and probably long before, the principal mode of teaching has been lecturing—passing knowledge by word of mouth, with or without textbooks and visual aids.

But now the teacher can become more of a *facilitator*: a guide to sources of information and knowledge, a catalyst for critical thinking and discussion, a stimulus, a thought-provoker, a moderator. The technology can provide more time and opportunity for the teacher to act as tutor to individual students and to immerse students in learning experiences.[36]

Teachers as Software Collaborators

Such ambitious goals may sound utopian to inner-city teachers who already have their hands full, and to school officials, even in affluent districts, who must cope with steep budget cuts. But teachers hold the key, and the researchers' work will succeed only if it is enthusiastically adopted by teachers. Today, comparatively primitive tools, such as video streaming and distance learning, help to meet the immediate needs of teachers, often because they have helped develop them.

It makes sense that, with DO IT's help, teachers should be deeply involved in the future development process. The National Center for Information Technology in Education (NCITE), founded in 2001, a partnership between Teachers College of the University of Nebraska–Lincoln, and Nebraska Educational Telecommunications, is one of several new institutions that can put new educational technologies to use when they are developed, to close the gap between learning sciences and computer sciences. The new information technology center at LSU is another such center for practical research. In these educational laboratories, teachers, learners, and scientists together can be intimately involved in developing new software and content.

New Legislation Makes the Task More Urgent

Federal education legislation popularly described as "No Child Left Behind" challenges everyone involved in K-12 education: teachers, administrators, students and parents.

Interactive information technology can help. Collectively, provisions of the 2002 Elementary and Secondary Education Act focus on the need for every child to achieve basic standards in core subjects.

- States are required to test every student in grades three thru eight annually in the basic skills of reading and math. This makes it urgent that research into using interactive information technology for immediate assessment data analysis (including techniques of embedded assessment and data mining) should receive high priority. In a 2002-03 pilot trial, Idaho became the first state to use computerized "smart tests" that adapt to each student and give rapid feedback.[37]

- The list of core subjects (those in which students must have more than just basic competence) now includes English, reading or language arts, mathematics, science, foreign languages, civics, government, economics, arts, history, and geography. Learning and computer scientists are already beginning to assist the teaching of math and science using intelligent tutoring systems and interactive simulations, but much more is needed. Digital technologies are contributing to other subjects as research extends the capability of educational technologies to give students access to resources beyond the classroom walls. Other digital technologies will also contribute; some offer different (sometimes better) forms of interactivity and access to enriching, three-dimensional content in libraries, museums, and remote laboratories. These contributing technologies include digital television, as well as satellite, cable, and microwave connections.

- No Child Left Behind also acknowledges the importance of IT literacy. Students are required to be proficient in information technology by eighth grade. Computer scientists need to develop methods of teaching IT that are accessible and penetrable by everyone.

- The law requires that districts use 25 percent of their 'edtech' block grants on professional development in technology—enabling teachers to make proper use of it, with special attention to integrating advanced technologies into classroom curricula. For this to occur, technology training must become a major part of the curriculum in teachers' colleges.

Learning Technology in Today's Classrooms

No school district in the nation is more celebrated for its transformation from failure to success than that of *Union City, New Jersey*. It offers an early demonstration of what dramatic progress can be made even in the early stages of using learning technologies in K-12 grades. In 14 years, this 11-school, largely Hispanic system has gone from the worst among N.J. city systems to the best. In one seven-year period, eighth grade test scores jumped from 33 to 83 percent in reading, 42 to 65 percent in writing, and 50 to 84 percent in math. The system's executive director, Fred Carrigg,

credits a combination of focused leadership, close involvement of teachers and parents, a concentration on literacy, a rigorous interdisciplinary approach, the use of individual instruction plans—and most important, **learning technology**. An article in the Spring, 2003 edition of *Edutopia*, the magazine of the George Lucas Educational Foundation, concluded that Union City teachers believe, "While a solid, research-based curriculum put Union City on the road to achievement, technology is what pushed it to great heights…."

School districts vary enormously in their use of classroom technology—from state of the art to zero usage (although a decreasing percentage of schools in the U.S. now qualify for the latter category). If there is a national mean at the end of the 2002-03 school year, it is probably a school that accepts computers as somewhat more than word processors and information storage facilities, and recognizes that Internet access can be a useful "add-on" to learning resources (but still an "add-on", not an integral part of the curriculum). A school at the national mean will, sadly, have little specialized learning software.

In 2000, the National Research Council brought together leaders in learning science to produce a comprehensive report entitled, *How People Learn*.[38] Produced by a two-year study, the report identified five needs for learning technology in K-12:

- Bring exciting curricula based on real-world problems into the classroom.
- Provide scaffolds and tools to enhance learning.
- Give students and teachers more opportunities for feedback, reflection, and revision.
- Build local and global communities that include teachers, administrators, students, parents, scientists, and other professionals.
- Expand opportunities for teacher learning.

With computer-based learning tools, grade school students conducting experiments can graph their data and interpret results immediately. One study found that 125 seventh and eighth graders who used this early software had an 81 percent gain in their ability to interpret and use graphs.[39] A study of 249 eighth graders revealed that these students gained significant ability to pinpoint inaccuracies in their graphs and data.[40]

These kinds of programs are not limited to quantitative skills. A multi-media designers' program was used by high risk, inner-city high school students to create electronic yearbooks and displays for local museums. The students were found to have gained computer skills, task management skills, creativity, and self-confidence.[41]

Some 30,000 schools across the nation now have access to relatively old-fashioned video streaming services, most of them from online portals. A 2002 independent evaluation of the most popular of these portals, *unitedstreaming.com*, found that students using it had achieved a 12.6% average increase in test scores.[42] Available evidence indicates that online streaming is no longer the most efficient way to deliver video to the classroom. Public broadcasters NJN, New Jersey; KERA-TV, Dallas; and KCPT-TV, Kansas City; are experimenting with using digital broadcast signals to send material directly (and much faster) to tuner-equipped servers in schools. Much development remains to be done.

Digital Tools Used Today

The Jasper Woodbury Solving Series developed at Vanderbilt University provides twelve interactive video environments that challenge students with real-world scenarios that enable them to understand and apply basic concepts in math.[43] A middle-school class in Tennessee watched a video from the Jasper Woodbury series showing how architects design safe play areas. The video posed a challenge for these children to design a playground themselves, using elements of geometry, arithmetic, and measurement skills. The class showed significant gains in their understanding of geometry, and also showed improvement in their ability to work together and present ideas. More than a year later, the students remembered the lessons and described them as fun. Tests showed improvement in math skills, complex problem solving skills, and a more positive attitude compared to students who did not use this learning-by-doing series.[44]

Technology tools can provide continuous measures of areas of competence and weakness that will help teachers work more effectively with individual learners. The more challenging the task, the more assessment and feedback are necessary. Computer-based assessment will allow the students to advance more rapidly. Several computer–assisted assessment systems have been deployed, and they have demonstrated the benefits of more frequent feedback and better assessment data. The SMART challenge series offers multiple resources for feedback and revision. With its instant assessment capabilities, the series improves students' performance. Such learning tools not only enable students to enhance their learning; they can also analyze each student's step-by-step reasoning and the process by which he or she reached the correct answer.

Another early program, DIAGNOSER, helps teachers improve student achievement in high school physics by assessing their preconceptions about physical phenomena—beliefs that may seem to fit their every day experiences but fail to reflect a physicist's view of the world. These misconceptions set up activities that help students reinterpret the phenomena correctly. Classes assessed by DIAGNOSER proved superior in their understanding of critical physics skills compared to other classes.[45]

Digitizing Professional Development for Teachers

Many veteran teachers are untrained in, or hesitant to use digital technology. While freshly minted teachers have had a greater exposure to technology, their IT skills are often limited to the basics such as typing and conducting web searches. A recent survey of 811 school districts found that more than a quarter of new teachers were rated "novices" when it came to using the Internet in their teaching.[46] Ironically, students in the classroom often have a better idea than teachers of what software will illustrate a particular concept.

With current technologies, few teachers can achieve the necessary ability to integrate technology into their teaching. The only way for teachers to take advantage of what is on offer is through professional development programs and frequent skills retraining. In the new classroom environment, teachers must develop a vision of how to blend new interactive digital tools and systems with their teaching in order to increase their students' efficiency in learning.

Exciting new interactive teaching systems currently in R&D, examined by the Learning Federation, promise to offer an array of easy-to-use tools that will increase teachers' capabilities. As more user-friendly learning technologies appear for specific curricula, teachers will be able to use them without becoming sophisticated technology experts. *PBS TeacherLine* is a web site *http://teacherline.pbs.org/teacherline/* where teachers can find useful toolkits such as *The Virtual Mathematics Academy*, self-paced professional development based on principles and standards established by the National Council of Teachers of Mathematics.

Such tools will offer personalized instruction that adjusts to the pace of the individual student; automated assessment to track each student's progress; rich simulations to provide more memorable learning experiences, and electronic access to outside experts. The same types of tools developed to help students learn can also support educators in their use of technology. Technological innovation and advances will never (and should never) replace teachers, but they will enable teachers to be more efficient, vastly improving learning outcomes.

Distance Learning

The size of the United States, the remoteness of so many Americans from the centers of learning, dictated that distance learning was an early feature of American education. Beginning as correspondence learning more than a century ago, distance learning came into vogue via educational radio and television, and eventually went online. Now, with electronic interactive capacity, learning from remote sources has the potential to enrich education in ways never dreamed of even a few years ago.

Molded by its location on the Great Plains, Nebraska has been a pioneer of distance learning. Nebraska Educational Telecommunications (NET) plays the central role and

has the infrastructure in place to reach into every corner of the state—a network of public radio and television stations, a 28-channel satellite system, a compressed video service, a cable network, and a fiber-optic two-way link connecting all the schools and colleges. One product of its Interactive Media Group is a project called *CLASS*—a complete online version of the accredited Nebraska high school diploma sequence, consisting of 54 courses used with 138 print-based courses available throughout the state, offered through the Independent Study High School of the University of Nebraska-Lincoln.

Learning, using distant resources, is a great gift to remote and rural areas. Urban and suburban schools and colleges are also using distance learning to tap into specialist teachers and resources not available in their own neighborhoods—a teacher of Japanese, or a major literary figure offering a master class on writing. Distance learning has become a familiar tool from pre-K right through college and on into lifelong learning. It is an especially valuable resource for those in remote and rural areas, for senior citizens, for workers seeking new workplace skills, and for the disabled. Students prevented from attending school due to illness need it; so do home learners and adults who want to return to school but cannot get to a classroom (or would be uncomfortable sitting in one). More surprisingly, perhaps, distance learning is today often a regular feature of education in many places where distance and geography present no great problems.

Model Programs: Where Distance Is No Barrier

The Frontier Learning Network is an innovative effort by Oregon's North Central Education Service District to integrate distance learning into its curricula, minimizing the divide between remote rural counties and urban centers. The public school system of Milwaukee has constructed an advanced broadband network for its schools; more than 4,000 classrooms have direct fiber connections to a wide area network. More than a third of the city's schools have facilities for two-way interactive video connections, used most often for project-based learning in which (for example) students talk to judges to learn how the judicial system works; get math and science lessons from Discovery World, a local community-based organization, and talk to Milwaukee college students about life after high school.

Sixth graders at West Toledo's Larchmont School studying ancient Egyptian culture made three virtual visits to the *Egyptomania* exhibit at the Cleveland Museum of Art, talking on camera each time to the museum's curators and experts. "We turn on the computer and camera and hook up the microphone," explained one student. "We control the camera with the computer and the remote control. We talk to people where we see them and they see us. We can talk to people and see them clear across the world."[47]

Virtual Schooling

Using elements of virtual learning is an increasingly common experience for high school students, but the total experience of virtual schooling is comparatively rare. Nevertheless, 16 states have either established virtual high schools, or are planning to do so in the next school year.[48] In June, 2003, Governor Jeb Bush signed legislation to enable Florida's Virtual School to be funded in much the same way as the state's regular school districts—but with this difference, that its funding will be based not on the number of students enrolled, but on the number who achieve passing marks in the 75 online courses offered by the school. Unlike many traditional schools, Virtual School credits require that the student pass a final examination at the end of the course. Without that qualification, not even flawless grades for the course work will earn credit.

The old steel town of Midland, Pa. is the headquarters of the Western Pennsylvania Cyber Charter School. Its elementary and secondary students from all corners of the state number nearly 2,000. They are taught online and have performed well in state achievement tests. At least one parent is required to be at home to supervise a child's work. The school's teachers are in constant touch with their pupils online and by phone, and regularly "meet" with them in virtual classrooms.[49]

Virtual schooling has obvious advantages for some students. Courses can be completed at the student's own pace and time, unbounded by semesters or academic years. To be effective, courses need to be rich in content and offer students the individual tutoring (mainly online, sometimes by telephone, occasionally in person) they are unlikely to get in traditional classrooms. No branch of schooling stands to gain more than virtual schooling from the research envisaged by DO IT.

Higher Education

While K-12 classrooms are basically equipped for the digital revolution, higher education classrooms, by and large, are not. A much higher proportion of college students own their own computers than is the case in K-12, but Market Data Retrieval's *2002 College Technology Review* found that 36 percent of higher education classrooms lacked Internet access (the comparable figure for public K-12 schools was six percent). Worse, *The 2001 Campus Computing Survey* reported that 25 percent of public universities and community colleges are cutting their academic computing budgets along with other academic subject budgets.[50] Other statistics note a considerable disparity between the IT infrastructure to be found in community colleges, which have a higher proportion of minority students, and public universities and other institutions of higher education.[51] And while K-12 school districts are bound by law to use 25 percent of their federal technology funds for training teachers in the use of technology, no such regulation or federal technology fund applies to higher education.

Understandably, perhaps, the nation has concentrated on the glaring needs of the K-12 system. Higher education, however, which prepares a very large proportion of the nation's workforce—notably the fastest-growing segment, the workforce that will depend most on IT skills—needs more attention. In its recent report, *Building A Nation of Learners* (2003), the Business–Higher Education Forum (BHEF) points to a dangerous and widening "skills gap" between traditional training and the requirements of 21st century business and industry.

Higher Education's Digital Deficit

The Business-Higher Education Forum report says that this country—the federal government, in particular—can no longer delay addressing this "skills deficit." It points to a Department of Education report predicting that unless immediate action is taken, by 2020 the United States will have a shortage of 12 million workers who have the college-level skills to keep the economy competitive.[52] The BHEF report concludes, "the need for a fundamental systemic change in learning and teaching remains crucial in order to achieve a nation of learners."[53]

These findings hold important implications for the future of higher education. Demand for it will intensify as more people seek college degrees in order to secure higher-paying jobs. Indeed, in the 1990s new college enrollments rose rapidly among individuals from groups that have, historically, been marginalized during K-12 education. Many are the first members of their family to attend college. The need for skills refreshment will also result in more individuals enrolled in classes and certification programs. Traditional sources of learning, such as universities, colleges, and community colleges, will continue to play critical roles in giving workers the knowledge and skills to succeed.

A variety of new institutions are also entering the market. For example, fewer than 25 percent of those taking college or university courses fit the traditional model of 18-to 22-year-olds living on campus and relying on parents to pay most of their college expenses. Many are older, and already in the workforce.[54] Colleges and universities are striving to meet these growing, highly diverse educational needs. More and more are using information technology to increase access to courses, faculty, learning materials, and equipment. They are also beginning to use learning technology to improve teaching and learning outcomes.

Reshaping Higher Education

For more than a century, students have had to fit their learning into an academic year that was devised for an agricultural economy. It was generally necessary for students to be physically located on campus, or nearby. For most students, neither the time nor the place for learning was negotiable. New information technologies help break down these barriers, just as they make it easier to change the ways people learn and are taught.

As in the K-12 world, there is an urgent need for authoritative research and experimentation in higher education. The Pew Learning and Technology Program is one of several that have undertaken research and helped to monitor the success or failure of innovative ideas and applications. One of its studies, by Carol Twigg, pointed to four ways in which learning can be improved: by making it more learner-centered, more individualized, more interactive, and more outcome-oriented.[55] New interactive learning technology can make this possible.

Models of What's Possible

- **Rio Salado Community College in Tempe, Arizona—the learner-centered approach:** Allows flexibility in when and where students learn. Rio Salado has 26 separate enrollment periods, with a new class starting every other week. It serves 34,000 credit students each year, most previously unserved or underserved adults who could never fit the traditional academic calendar. There is no campus; students take online courses with online tutoring. Rio Salado achieves test results on a par with students at other institutions. [*www.rio.maricopa.edu*]. *The University of Phoenix Online*, one of the first accredited universities to offer complete degree programs (bachelor's, master's and doctor's) via the Internet, is similarly geared to the needs of the non-traditional student. It has 40,000 men and women enrolled, all of them in full-time jobs and at least 23 years of age. *www.uoponline.com*

- **The individualized learning approach: transforming math teaching at Virginia Tech, the University of Alabama, and the University of Idaho-Moscow**. Together, these three have "quite literally revolutionized the way math is taught," reported *The Learning Marketplace. www.center.rpi.edu/Lforum/LM/Feb03.html*. Virginia Tech's Math Emporium, for instance, uses new technologies to individualize its course in linear algebra. Self-directed study enables each student to tailor a course to his or her needs, which would simply be impossible in the traditional lab-and-lecture mode. Virginia Tech offers its students a learning center with 500 workstations. Scores have risen by 17.4 percent and the failure rate has dropped by 39 percent, while cost-per-student has fallen from $91 to $21. *http://www.emporium.vt.edu*

- **Outcomes-oriented courses: University of California at Berkeley.** Reliable ways to assess students' progress, or lack of it, have been a special problem for large freshman courses; teachers lack the tools to monitor students and to step in if things go wrong. *Chemistry 1A*, with 2,100 students, is UC Berkeley's largest course—more than half the freshman class. More than 100 support staff were required. With new information technologies, that number has been slashed and students are better served. Lectures are enhanced with graphics and animation, live lectures appear online, and there's an online lab manual with interactive exercises

for future lab experiments, quizzes, and automatic grading. Best of all, perhaps, teachers (and students) get immediate feedback and assessment at every stage. *www.cchem.Berkeley.edu*

- **The University of Southern California's Institute for Creative Technologies (ICT):** A joint effort of the Army, the entertainment industry, and academe focused on better education and military training. USC efforts include a project to explore the role of storytelling for training teams of US Army soldiers for crisis management and leadership skills. Participants assume various roles in a US Army tactical operations center, working to address situations the team learns through a web-based interface. Situation presentations use media of high production value, including maps, video-based news broadcast feeds, audio-based radio communications from soldiers in the field, and text-based intelligence reports. Interactive storylines enable a high degree of interactivity in the virtual environments while preserving the narrative control necessary to achieve both learning and entertainment goals.

  The ICT games project is creating immersive, interactive, real time training simulations to help the Army teach decision-making and leadership skills. ICT games devote an unusually high percentage (about 60 percent) of processor resources to artificial intelligence compared to typical computer games.

- **The Vanderbilt-Northwestern-Texas-Harvard/MIT (VaNTH) Engineering Research Center in Bioengineering Educational Technologies:** Finding new ways to formulate and deliver learning materials in bioengineering (*www.vanth.org*). The Center focuses on projects in learning science and technology that can be applied in bioengineering education, including new computing methods for course delivery and assessment methods for judging the effectiveness of the materials. The Center is using baseline study data to understand the learning characteristics of bioengineering students and will use this to take into account the knowledge, skills preconceptions, and learning styles of the learners.

- **The Institute for Simulation and Training and the University of Central Florida:** Advancing modeling and simulation technology and increasing understanding of simulation's role in education. The institute works with the military services and the entertainment industry. Because the modeling and simulation shops at Disney and Universal Studios are located within half an hour of the Institute, collaboration and joint research are convenient. The university's immersion jukebox project will allow participants to engage in a full-body experience of African-American blues that integrates music, movement, film, visual art and interactive techniques to allow the participants to create music while triggering relevant visual information. *http://www.mcl.ucf.edu/projects.html*

An exhibit for the Orlando Science Center will allow visitors to explore "virtual" longleaf pine forest canopies. The exhibit will address specific education goals outlined in Florida's Sunshine State Standards and the American Association for the Advancement of Science (AAAS) Project 2061: *Science for all Americans*. The virtual forest exhibit is being designed with levels of experience appropriate for kindergarten through high school students.

- **The United States Army:** No single organization has done more to transform its learning facilities and methods than the all-volunteer US Army. It supplies higher education opportunities as an incentive for young people to opt for military service, and it also supplies those opportunities to its large workforce stationed around the world, often far from educational institutions and generally unable to sit in classrooms and accommodate academic schedule requirements. *eArmyU* is an online learning service, still in its early stages, that is learner-centered, individualized, interactive, and flexible. It currently provides 85 programs from 23 higher education institutions to 35,000 soldiers serving in 17 countries (*earmyu.com*).

University Digital Research

University sponsored and conducted research in many fields is critically important. Digitization and other entry requirements for research in the digital age are costly, but universities must pay the price—they cannot be left out.

The specialized tools they had hoped to have—among them, the Next Generation Internet program and Internet2—are proving elusive for most. Internet2, with research speeds that make possible a great variety of remarkable new applications, still connects only 202 of the more than 4,000 degree-granting institutions in the country.[56] But those roadblocks are being overcome. For example, the *TeraGrid*, a super-fast network developed by IBM, will connect powerful, high-performance computers at four research centers, creating a giant virtual computer, accessible from any point on the Grid, and capable of 13 trillion+ calculations per second.

Important applications are beginning to become apparent. At the University of Pennsylvania, the National Distributed Mammography Archive is bringing advanced methods of breast cancer diagnosis and screening to patients across the nation. The Grid connects teaching hospitals at Penn, the Universities of Chicago and North Carolina, and in Toronto. Eventually, it will be able to serve thousands of hospitals and give physicians the analytical tools to diagnose individuals and identify cancer 'clusters' in the population.

Higher education institutions are already spending, on average, five percent of their total budgets on IT.[57] That is a substantial amount, but only half as much as the minimum universities need to spend in order to keep up with, let alone surpass, the current pace-setters in Europe and Asia. Other nations are moving forward at a brisk

pace. Walter Hu, the Beijing-based chief information officer of Cernet, the Chinese public-private company that provides Internet services to more than 1,000 universities in China, predicts that, within five years, five to ten million Chinese college students will use educational software for learning, and that number will possibly reach 20 million within ten years. Similarly, in Singapore, the National Technical University has begun to exploit the Internet, using educational software that will allow professors to post course material, conduct discussions, and administer tests online. Now, all 22,000 students and most professors at the university use it.[58]

Non-Traditional and Lifelong Learning

In addition to the renewed learning process that will go on in the workplace, many people want to augment knowledge (and sometimes their educational qualifications) in ways that are not necessarily related to work. In this new knowledge-based environment, every potential lifelong learner should have a wide range of formats to select from—online courses with access to interactive elements; television courses (more often supplied via video-on-demand nowadays); distance learning (more immediate but time-sensitive); CD-ROM and DVD software; even old-fashioned face-to-face classroom learning. Or, more likely, a combination of different formats. The role of information technology in lifelong learning is, quite simply, to make it possible. Technology also has the potential to accomplish what all effective education requires: to make the experience exciting and absorbing. What most lifelong learners need from the new technologies can differ in many respects from what the classroom requires. Forms of interactivity are more important—Q&As, feedback, the ability to question an intelligent tutor, an avatar or "virtual mentor," even the need to hear an actual human voice occasionally. Most people, at some stage, will want their learning experiences to be collaborative and to have a human connection.

Older Population, Newer Modes of Learning

Perhaps the most compelling argument for making lifetime learning a high priority is the unmistakable trend in our own demographics. By 2025, twenty percent of all Americans will be age 65 or older. Between 70 and 100 million baby boomers—educated, talented and productive—will have been retired for a significant period. Many need to remain active and productive, whether in full time or part time employment or other activities. Our economy, our health care system, and our democracy need older Americans to remain active and productive.

Norway has already decided how to deal with the problem, which it views as an extraordinary opportunity. It has established The Competence Network, which embraces a far-reaching restructuring of both education and labor reform. Its farsighted goal is to give all Norwegians access to lifelong learning so they can develop new skills and acquire additional knowledge, and educational qualifications. One objective

is to keep older people in the workforce longer to strengthen the Norwegian economy and place less burden on the nation's health and welfare services. By forging a large-scale collaboration between the Norwegian Confederation of Business, the Industry Federation of Trades Unions, and the government, Norway has created the "Competence Network" (NKN) to bring online learning opportunities to all Norwegians. NKN is a portal that links the entire population to education and training opportunities, virtually from youth through senior years.[59]

DO IT will look at the major resources for lifelong learning, our cultural institutions such as libraries and museums, and help them move into the digital age. The Trust also will concern itself with assisting humanities and social sciences, other major resources for lifelong learning, to move strongly into the advanced information technologies.

Libraries, Museums, and Cultural Institutions

Few nations have better preserved their history and memory than ours, and few have used their cultural institutions more constructively (and endowed them more generously from private sources) to tell the multi-faceted story of our nation, our planet, and its inhabitants.

All these institutions have education at the front and center of their missions. But the greatest portion of their role has been inside their walls. The digital revolution sets them free and enables them to have access inside the classroom, in the curriculum, and inside the home. A virtual presence amplifies and extends their real presence. The excitement and enthusiasm currently felt in libraries, museums, historical associations, zoos, botanical gardens, and cultural institutions of all kinds are generated by the growing awareness of what the new digital technologies will enable them to do.

School systems are beginning to exploit their new direct connections with local and remote cultural institutions. Charter schools are being located in museums, and public libraries are being located in schools. In Detroit, the new Fine, Performing and Communications Arts High School will house both a sophisticated digital production facility for the local public broadcaster that serves the entire Detroit community, and two separate performance spaces for the Detroit Symphony Orchestra.

Libraries: There are 16,000 public libraries in this country, 3,400 academic libraries, and 2,600 special libraries (military, government, medical, etc.). More than 97 percent have Internet access.[60] Public libraries, in particular, are much more than repositories of information: they are forums for cultural and democratic exchange, centers of literacy and learning within their communities, and, more recently, a public place where *anyone* can go to explore the Internet.

As early as 1994, with funding from the U.S. Congress and the private sector, the Library of Congress was able to establish the National Digital Library. One of its first

priorities was to take advantage of the new availability of the Internet to reposition a four-year-old CD-ROM project called *American Memory* as a web-based project. In many ways, *American Memory*—with its demonstrable reach into classrooms all over America, its comprehensive *Learning Page* web site, and its *American Memory Fellows Institute*, which trains teachers in the use of primary sources in the classroom—is a benchmark project for all other libraries. That is exactly what it was intended to be, but public libraries in communities throughout the nation have neither the means nor the expertise to emulate the Library of Congress.

- **Digitization** of library collections (or, at any rate, of significant parts of them) is the essential prerequisite, but there is no coordinated national program to digitize materials deemed to be of national aesthetic, linguistic, cultural, or historical value—as there is in the United Kingdom, Canada and France, for instance.[61] There are isolated examples of activity—Colorado is one of them. The Institute of Museum and Library Services (IMLS) gives National Leadership Grants for Preservation or Digitization. But there is a growing fear that the teaching of American history in the digital era will be dispossessed of its local content by the failure to have local collections digitized. Congress is spending $100 million on the National Digital Information Infrastructure and Preservation Program (NDIIPP), which charges the Library of Congress to develop the key capabilities of a digital preservation network. So the federal government is paying for the essential preliminary work at the federal level. But for the rest of the nation, and especially for local communities, digitization remains a problem of enormous dimension.

- **Training librarians** to make use of the new technologies is an equally fundamental need. Aside from places of formal education, public libraries are the only community institutions that exist to empower individuals in a networked economy. Libraries of the Future has programs such as *Equal Access Libraries* (professional development for librarians) and *Education Access* (librarians and school teachers working together). And there is the 50-state library infrastructure development project funded by the Bill and Melinda Gates Foundation, which includes resources to train librarians in the use of computers, but the United States still has nothing analogous to The People's Network in Britain, a program developed by Resource: The Council for Libraries, Archives and Museums, that provides up-to-date skills training for all of that nation's librarians.

- **Innovation and experimentation** are urgently needed. A basic lack of R&D impedes the development of new learning tools, systems, software, and content based on digital technologies. That such initiatives would yield results is attested to by the success of *Youth Access*, for example, locally-tailored after-school programs using learning technologies that are available in libraries in Detroit, San Francisco, and Arizona. Among its participants are recent immigrants who seek work-related skills for future employment.

For a large and needy segment of the population, public libraries are the gateway to two essential services of the digital age—e-learning and e-government. They provide electronic inquiry services, virtual reference shelves, and rich sources of community information. They help people acquire essential skills, qualifications, and training. They guide people through the complexities of local, state, and federal departments. *Curriculum Online* is a British initiative, launched by the government in January, 2003, to enable learners to have broadband access to libraries, museums and galleries, archives, theater companies and orchestras. The goal is to support and enrich the national curriculum with materials from these sources that can be used by teachers in the classroom and learners at home.[62]

Museums

No institutions have more in their collections to enrich American education and learning than the nation's museums. Collectively, they represent a vivid and encyclopedic knowledge resource that may be available on class field trips, but is still inaccessible to the classroom. That can change.

Like libraries, museums require a huge and costly program of digitization. Only 32 percent of museums that responded to the Institute of Museum and Library Studies's technology survey in 2002, reported any activity in digitization and most of them still have a long way to go to develop even the most basic online skills. The statistics are not good: Only 62 percent of the nation's museums even have web sites, and less than four percent use more specialized technologies like 'extranets' or 'virtual reality tours'; 13 percent have no online technologies at all.

Nevertheless, as in the world of libraries, a few leading institutions have invested to begin the process of digitization and to experiment with new means of public connectivity and access. While these experiments most often focus on online technologies, there are other broadband carriers—fiber optic cable, satellite, microwave and all forms of wireless, and digital broadcast signals—that may sometimes prove more receptive to the peculiar problem of recreating the "virtual presence" of an artifact outside its museum environment.

What is needed (and what DO IT will offer) is the opportunity for museum professionals to work with scientists and teachers on experiments that make use of digital technologies, and even advanced computing and nanotechnology—not to supplant the museum experience but to "image" it, to present it in a different medium, with as much fidelity as possible.

That this can be done successfully is proved by an example such as *www.AMICO.org*, the Art Museum Imaging Consortium, launched by the Association of Art Museum Directors in 1996. Basically, it is no more than a gallery, but what a gallery! It contains digital images of 100,000 great works of art from more than thirty art museums

in North America. Besides paintings, drawings and prints, it includes sculptures, photographs, mixed media, architecture, costumes, jewelry, decorative arts, textiles, tapestries, even American samplers and quilts. Each object is accompanied by its own documentation, and many carry scholarly background notes. The database can be accessed by schools, colleges, and other institutions of learning for a subscription that works out to about 40 cents per student per year.

Very few museum tools are as comprehensive as AMICO—and even fewer as ambitious and exciting as a digital age conception at the Rose Planetarium at the American Museum of Natural History in New York, developed as part of the museum's partnership with NASA. Nevertheless a number of large and a few medium size American museums are beginning to develop gallery interactives, online exhibits, digital kiosks, downloadable teachers' guides, and other tools. Several are also exploring how to link up with local classrooms in genuinely interactive connections (most often fiber optic or wireless) that enable students and museum experts to examine and discuss artifacts and exhibits, together. Streaming engines are also beginning to be used. The City University of New York Graduate Center New Media Lab has a web site— *www.streamingculture.org*— whose goal is to "make interactive streaming media manageable and affordable for distinguished arts organizations."[63]

To encourage museums to focus on the creative use of technology, DO IT will consider funding *IT regional resource centers* dedicated to meeting the fundamental new media and telecommunication needs of local cultural institutions. These resource centers may provide education and training, regional workshops, software and web site development, aggregated telecommunications access and management, negotiated purchasing discounts and other services and benefits.[64] Importantly, they would also help poorer museums afford digital technology innovations that would otherwise be out of reach.

Model Projects at Museums

A sampling of the IMLS list of National Leadership Grants suggests the projects currently being funded. They may not be particularly sophisticated, even by today's digital standards, but they supply striking evidence of the museum community's growing appetite for innovation and accessibility.

- **The Indianapolis Museum of Art and Indiana University-Purdue University Indianapolis** (IUPUI) have joined forces to create a database of art treasures from around the world for classrooms in central Indiana. The project proves that the study of art enhances a variety of different subjects, including geography, math, and science. *http://www.imls.gov/closer/archive/hlt_c0700.htm*

- **The Museum of the Rockies and Montana State University at Bozeman** are partners in a project to create a searchable database of 1,500 images of Native American history from five Montana collections. They feature the Cheyenne,

the Gros Ventres and twelve other Plains Indians cultures. *http://www.imls.gov/closer/archive/ hlt_c0500.htm*

- **Florida's ecology** is the subject of a new web site that has been made possible by an IMLS National Leadership Grant to museums and libraries that have important collections for the study of the natural world. A single database is being established that will be searchable by anyone interested in Florida's ecological and environmental problems. *http://imls.gov/closer/archive/hlt_c0600.html*

- **The Bronx Zoo and the Wildlife Conservation Society** are developing multimedia components to the zoo's Tiger Mountain exhibit of Siberian Tigers. Interactive touch-screen terminals will enable visitors to summon up a behind-the-scenes look at the care of a modern zoo animal or an overview of the endangered state of tigers in the world. *www.wcs.org/home/zoos/bronxzoo/*

- **Connecticut History Online** is a collaboration of the Connecticut Historical Society, the Thomas J. Dodd Research Center at the University of Connecticut, and Mystic Seaport. It is developing a comprehensive, web-based virtual collection of some 14,000 graphic images that document Connecticut's social, educational, political, civic and cultural life between 1800 and 1950. The database is for use by teachers and students in grades 7-12. *www.cthistoryonline.org/*

Assisting the Humanities and Social Sciences

The great range of academic disciplines encompassed by the humanities and social sciences includes the majority of the 'core subjects' identified in the No Child Left Behind legislation as compulsory for all K-12 students. These humanities subjects, such as history, literature, and language, thrive on dialogue, performance, and erudition, knowledge of the past, and the ability to relate it to the present and future. They need significant investments given their crucial importance to the quality of our society, the character of our educational system, and their integral role in American culture.

One such DO IT investment might be in a *National Digital Library for the Humanities and Social Sciences*—not a single depository, but a system of well-organized digital resources accessible through a number of portals. It could be organized and funded on much the same basis that the National Science Digital Library has been supported by NSF. There are dispersed digital libraries and archives on specialized subjects within the humanities (the *Perseus Project* depicting ancient Greece and Rome is one of the earliest and best known), but no architecture that connects them or refers them to each other exists.

Another favored proposal for future development is the *Humanities Indicators Project* —a powerful database, which is much in demand in education, publishing, and humanities research. Like the library project, it parallels one already in operation—*Science and Engineering Indicators*, a core activity of NSF. Similarly, *texts* are of particular

importance in the humanities: their digitization is eagerly sought. "Scholarship and teaching in the humanities are largely (but not entirely) about texts: historical texts, literary works, scholarly writing. Digital technology can make texts more widely accessible; more easily queried…and, eventually, will change the nature of how we write."[65]

In the meantime, the humanities have a vigorous if small complement of digitally based research and teaching tools that demonstrate what an extraordinary potential exists. Examples include:

- **The Valley of the Shadow Project** at University of Virginia's Institute for Advanced Technology in the Humanities (IATH), follows two communities, one Northern and one Southern, through the experience of the American Civil War. The project is a hypermedia archive of thousands of sources. Students can explore every dimension of the conflict and write their own histories, reconstructing life stories of the period.

- **The Committee for Pre-College Instruction in Philosophy, of the American Philosophical Association**, is working to identify and encourage projects that use digital technology to inspire rigorous philosophical inquiry among secondary school students. Two early starters are *The Cave*, a multimedia presentation of Plato's Allegory of the Cave in Book VII of *The Republic*, which will be available to high school teachers on the committee's web site. The other is a special series of the philosophy talk show, *No Dogs or Philosophers Allowed*, featuring high school students in public conversations, available through the Association's web site.

Homeland Security and Community Safety

In its 2001 report, the United States Commission on National Security in the 21st Century concluded that "despite the end of the Cold War threat, America faces distinctly new dangers, particularly to the homeland and to our scientific and educational base"[66] DO IT's capacity to fund public applications of new information technologies will play a significant role in confronting both these dangers.

The Commission emphasized how to achieve coordinated, effective responses to emergencies *at the local, or community, level*: "The first priority should be to build up and augment state and local response capabilities. Adequate equipment must be available to first responders in local communities. Procedures and guidelines need to be defined and disseminated and then practiced through simulations and exercises. Interoperable, robust, and redundant communications capabilities are a must in recovering from any disaster."[67]

Using New Technologies to Heighten Security

Clearly, the research, development, and exploitation of effective information technologies to fulfill this need must rank among our most vital priorities. Civilian and military medical personnel throughout the country need to be trained quickly to respond to emergency events. Unfortunately, many feel unprepared and current programs to provide this training are not adequate to the task.

New information and interactive training technologies must be exploited. DO IT will undoubtedly place this challenge at the top of its agenda. Many communities are already seeking ways to respond to this requirement. But the efforts are only at the earliest stages and are missing the advantages of interactive, advanced information technologies such as virtual reality, simulations, and electronic tutors geared to the level and sophistication of each trainee.

For example, New Jersey's public broadcast network, NJN, is mandated by the legislature to serve as the state's emergency broadcast system. It is establishing a digital communications system that can transmit emergency data, graphs, evacuation maps, video and audio at very high speeds to desktop computers to support the N.J. State Office of Emergency Management (OEM) and homeland security efforts. Efforts are also underway between NJN and the N.J. Department of Health and Senior Services to develop an emergency communications network connecting hospitals across the state.

Community Building

In his "Second Treatise of Civil Government" (1690), John Locke defined "the bonds of civil society," as "agreeing with other men to join and unite into a community." Information technologies create a whole new category of instruments to forge strong community bonds.

That process of bonding civil society, so fundamental to the American democratic system, will be enhanced at the community level by DO IT's support of the technologies that can promote such bonding at a level and a pace that are new. In addition to the cultural institutions discussed earlier, now emergency services—hospitals, public health services, civic and social services, local governments and others will be able to capitalize on the benefits of DO IT's content, software, and virtual presentation initiatives.

The Broadband Community

The key is connectivity. The broadband universe is growing—in April, 2003 it was estimated that 30 million American adults (or 16 percent of the adult population) had broadband connections at home[68] and that is in addition to the rapidly expanding universe of workplaces, schools, libraries, etc. There are more forms of broadband than the online variety—fiber optic cable, wireless, satellite, and digital broadcasting

are all important. The most go-ahead communities are developing broadband services using ingenious combinations of these modes.

An impressive, perhaps surprising example is the small agricultural town of **Glasgow, Kentucky**, with 14,000 inhabitants and its own Broadband Information Highway Project, the brainchild of Glasgow's municipally owned public power utility, Electric Plant Board (EPB). In 1989, EPB began to offer cable services to Glasgow residents over its brand new hybrid fiber coax network. In 1995, it added 120 miles of broadband facilities and offered the town high-speed Internet access. It costs residents $24 a month (as opposed to a national average of $45.31). The school system takes full advantage and is able to transmit video from any classroom to any television set in town. Glasgow today has the lowest unemployment rate in Kentucky and one of the highest business growth rates.[69]

Many community services that will benefit from local broadband systems such as Glasgow's are not themselves part of the education system. They include government and social services such as welfare-to-work, the prison system, employment agencies and the whole apparatus of civic democracy. These services share a common need to acquire interactive tools. For that, they will rely on developments in digital content, and DO IT should be the most likely source of such assistance.

Public Health and Education

One-third of all the 'hits' on web sites in this country are on health sites, but the quality of their information can be highly questionable and even dangerous. One of DO IT's priorities will be to develop systems and software that will enable community medical providers—local hospitals, public health officials, medical practitioners—to offer reliable and essential health information.

One nascent example is **The Stanford Behavioral Medicine Media Laboratory**, which is developing Internet-based multimedia programs for health education in middle and high schools. It aims to start model programs based on games and simulations to improve young people's dietary practices and increase exercise in order to overcome the obesity epidemic among adolescent boys and girls.

Other pioneer applications of digital technology in health will serve as models for DO IT sponsorship. **The Medical College of Georgia** (MCG), for example, is developing a telemedicine program in partnership with the Fort Gordon/Eisenhower Army Medical Center and the Georgia Institute of Technology (GIT). An early project is a telemedicine program in home care for those suffering chronic disease. Called the *Electronic HouseCall System*, it was piloted in Augusta, Georgia. The system uses dedicated bi-directional cable lines, with the patient having a touch screen to send and get information. Patient and doctor can video conference with each other, and the patient can send basic information—pulse, blood pressure, temperature, heart function,

glucose levels, etc.—without having to contact medical staff. Once connected, the doctor is able to use a stethoscope as part of a virtual examination of the patient.[70]

Another model of community service is the use of advanced information technology to educate children of migrant laborers—to track their educational progress and requirements from place to place, and to make sure they get a proper education without interfering with their parents' livelihood. Online technologies are beginning to provide some answers. In Oregon, four percent of the state's public school students are children of migrant workers. Many stay in the state year-round but are constantly on the move to meet seasonal labor demand in a local economy largely based on agriculture and forestry. **Integrating Technology Into Migrant Education (InTime), a program of the Oregon Department of Education**, had a five-year federal grant to develop and demonstrate new uses of technology to strengthen the academic achievements of migrant children and help track them through the system. Children were not the only beneficiaries; workshops were run for parents to help them understand the system and lead them to software, and television and online programming in English and Spanish. *www.intime.k12.or.us*

Community Partnerships

Community broadband alliances depend on local groups to work together, raise funds together, and pool their resources. This is the sort of effective and efficient community effort that DO IT should encourage. One farsighted model: **LaGrange, Georgia**, sixty miles southwest of Atlanta, a town of 27,000 people at the center of Troup County, which made the local basic decision to become competitive and prosperous in the 'information economy' more than a decade ago. LaGrange city leaders arranged for its citizens to be connected "each to all" through a unique public-private partnership with the local cable company. Today, LaGrange offers its residents free broadband Internet service via the local cable system. Customers get a wireless keyboard, a set-top box, five e-mail addresses and a parental control feature. "Mini-Intranets" have sprouted—92 of them, at last count—arranged in categories such as Arts, Medical, Churches, Service Organizations, etc. The city also provides an organization, *Technology NOW*, to promote technology and PC training for all residents. *www.lagrange-ga.org.*

To create this type of community broadband alliance, a 'hub' or catalyst is required. It could be a utility (as in LaGrange), an educational institution, a local media group, a public broadcaster, or some combination of them. *Public television stations*, which reach into virtually every home in the nation, and are generally the only locally owned and locally controlled outlets left in American television, are tailor-made for that role. Connecticut Public Television, a statewide network, has been mapping, and now interconnecting the state's cultural, health, civic, and community assets. WHYY-TV in Philadelphia has declared its facility "civic space" and proposes to initiate an instructional media portal for Philadelphia and the surrounding counties. In California,

eight public television stations have joined forces to create *California Connected*, a powerful new presence in primetime and on the web.

Northeast Ohio is a particularly good example of a community that is pioneering the use of information technology to transform itself economically, culturally, and educationally. It is a model that DO IT can effectively encourage and spread. The seventeen-county region has a diverse rural and urban population. Once the heart of the rust belt, the region has embarked on a strategy that involves government, non-profits, museums, schools, universities, healthcare, business, industry and the media working in partnership. Two organizations operate as its 'hubs' or catalysts, both of them specially created to meet this challenge:

OneCleveland, a nonprofit umbrella organization seeks to create a broadband community in Northeast Ohio. It offers high-speed Internet and data services through a wired and wireless network "to increase access to education, cultural activities, research, healthcare, and government services while systematically addressing the digital divide." Charter members are Case Western Reserve University, the City of Cleveland, Cleveland Municipal School District, Cleveland State University, Cuyahoga Community College, Greater Cleveland Regional Transit Authority, and the NASA Glen Research Institute.

Ideastream, created in 2000 as a public service multiple media organization for Northeast Ohio, was the result of a merger between the region's leading public radio and television stations. It is, in many ways, a new concept, designed for the digital age. Besides serving as a major supplier of educational services, including video streaming for schools and interactive distance learning for other educational institutions, *ideastream* has digital broadcast and ITFS (microwave) frequencies and is designing ways to use them for community collaboration. In partnership with Playhouse Square, *ideastream* plans to build a new Community Public Service Media Center in the heart of downtown Cleveland, where it will be both an educational center and a technology hub for the Northeast Ohio region. It, too, requires research and development support for advanced interactive content.

Barriers to Change

Lack of funding is the most obvious barrier to research and development of new content and software to exploit the extraordinary potential of emerging information technologies. In the late 1990s, ways were found to equip schools with computers, access, and connectivity. Now they must be given the means—the content and software—to make proper use of these valuable assets. Without them, this country's 21st century workforce will lack the education, training, and job skills to keep this country either competitive or secure.

Copyright is a rising problem in promoting the use of advanced information technologies. How to achieve a proper balance between rights owners and users of materials created with the help of public funding is a hard issue to settle on fair and reasonable terms that serve the public interest and are fair to developers and rights owners. It should be one of DO IT's early priorities.

Equally difficult issues must be confronted, and soon, regarding the use of **interoperable and compatible technical standards**, regardless of their source. If Americans are to benefit to the full extent from the nation's investment in educational technology and digital content, then interoperable and open standards need to be found on terms that will benefit both the private and public sectors.

Attitudes and misconceptions are a barrier. In the words of Allen Glen, professor and former dean of education at the University of Washington, "the biggest obstacle to school change is our memories."[71] The fact is we are still dealing with something of a generational divide.

Often, opposition to educational change, especially when it involves the introduction of modern information and learning technology, is expressed in such comments as, "Yes, but we don't know it will work, do we?" or "Education is a people-intensive, not a technology business. Aren't we just trying to replace people with machines?" In answer to the first question, that is precisely why the commitment to an extensive program of R&D is so important. In the words of Secretary of Education Rod Paige, "These new capabilities [of information technology] have done more than simply make organizations more efficient—they have forced leaders to rethink markets and reengineer business structures and processes that led to dramatic improvements in quality.

"Schools have lagged in this information revolution. Indeed, education is the only business still debating the usefulness of technology. Schools remain unchanged for the most part despite numerous reforms and investments in computers and networks. The way we organize schools and provide instruction is essentially the same as it was when our Founding Fathers went to school. Put another way, we still educate our students based on an agricultural timetable, in an industrial setting, while telling students they live in a digital age."

"The problem is not that we have expected too much from technology in education—it is that we have settled for too little. Many schools have simply applied technology on top of traditional teaching practices rather than reinventing themselves around the possibilities technology allows."[72]

As to the second question, skepticism that technology applied in education will turn a "people-intensive" business into a production line—no one in either K-12 or higher education thinks it will take fewer teachers to staff schools in the 21st century. On the contrary, the Hart-Rudman Commission on National Security estimated a need for 240,000 new and qualified K-12 teachers in science and math alone by 2010, out of a total requirement for 2.2 million new teachers.[73] The challenge is to enable them to teach effectively and efficiently. Technology, rightly used, supports teachers; it will never supplant them.

Conclusion: What DO IT Will Accomplish

Taking a systematic, tightly managed approach, DO IT will fill critical gaps in existing research, development, and the delivery of technology-based learning products and services. It will do for education in its broadest sense, and training, what NIH does for health and NSF does for science.

It will finance advanced concepts in using technology to transform the process of learning and training, providing aids to instruction that are tailored to each individual learner and teacher. It will support the development of tools that provide powerful learning experiences for any person, in any subject, in any location.

DO IT will help traditional and non-traditional trainers and adult learners to use these tools. It will serve teachers, enabling them to make the classroom hour a more exciting, pleasurable experience while freeing time to concentrate on individual students. It will help new immigrants gain language and other skills needed to enter the workforce, and help first responders and other emergency workers cope with emerging diseases, potential terrorist threats, and other natural and man-made disasters.

In a competitive economy, DO IT will help individuals master the great variety of changing skills needed for success in every industry, profession, or service. It will open lifelong learning opportunities and help elderly people manage their health care and their lives. And with its resources for digitization, the Digital Investment Opportunity Trust will enable our society's great public service institutions to move faster toward making available their rich treasures for the digital age.

End Notes

[1] *Visions 2020, "Transforming Education and Training Through Advanced Technologies,"* September 2002, U.S. Department of Commerce Technology Administration, Office of Public Affairs, Washington, DC

[2] *Building a Nation of Learners* (Business-Higher Education Forum, 2003), p. 1

[3] Center for Workforce Preparation, U.S. Chamber of Commerce

[4] Defense Science Board, *Training Superiority and Training Surprise, 2001, www.dtic.mil/ndia/2001testing/chatham.pdf*

[5] Advisory Panel to Assess Domestic Response Capabilities for Terrorism Involving Weapons of Mass Destruction (Gilmore Commission), *Third Report*, September 2001, *www.rand.org/nsrd/terrpanel/terror3-screen.pdf*

[6] Rutgers Professor H. Bruce Franklin, *Under Attack for 150 Years*, The Clarion, City University of New York, p. 10, Summer 2003. Adapted from his book, *Vietnam and Other American Fantasies*

[7] *The Video-Game Wars Explode Online*, Business Week, December 10, 2002

[8] Phillip J. Bond, Under Secretary of Commerce for Technology: memorandum to NSTC, June 2003

[9] Kathy Seal, *Transforming Teaching & Learning Through Technology*, Carnegie Reporter, Spring 2003, p. 30

[10] Digital Library Federation, *A New Approach to Finding Research Material on the Web*

[11] National Humanities Alliance, *White Paper on the Digital Promise Project*, p. 1

[12] ARL Collections & Access Issues Task Force, *Collections & Access for the 21st-Century Scholar: Changing Roles of Research Libraries*, ARL Bimonthly Report *225* (December 2002)

[13] Arnold Lutzker, et al., *Brief Amici Curiae of the American Association of Law Libraries, et al., in Eric Eldred, et al., v. John Ashcroft*, May 2002, pp. 19-20

[14] Samuel G. Armistead, *Oral Literature of the Hispanic World*, Faculty Research Lecture, 1998

[15]Figure is for Medline which is part of Pubmed

[16]Jeroen Horlings, *CD-R's binnen twee jaar onleesbaar* PC activ August 19, 2003

[17]Amy Harmon, New Premise in Science: *Get the Word Out Quickly*, Online, New York Times, December 17, 2002

[18]Makx Dekkers, Stuart Weibel, *State of the Dublin Core Metadata Initiative*, April 2003, D-Lib Magazine, April 2003

[19]John Locke, *An Essay Concerning Human Understanding*, 1690

[20]US Chamber of Commerce, *A Chamber Guide to Improving Workplace Literacy*

[21]Quoted in *Learning for the 21st Century: Are Your Schools on the Right Track?*: Report by the Partnership for 21st Century Skills, May 16, 2003, p. 21

[22]*www.nab.com/data4.htm*

[23]Defense Science Board, *Training Superiority and Training Surprise, 2001*, *www.dtic.mil/ndia/2001testing/chatham.pdf*

[24]Advisory Panel to Assess Domestic Response Capabilities for Terrorism Involving Weapons of Mass Destruction (Gilmore Commission), *Third Report*, September 2001, *www.rand.org/nsrd/terrpanel/terror3-screen.pdf*

[25]Bureau of Justice Statistics, 2003, *Survey on Inmates in Local Jails*, 1996 and 1989

[26]*Corporations Embrace Online Learning*, Washington Post, April 24, 2003, p. E O1

[27]Craig, Elbert, *Corporate universities springing up across the U.S.* ePeak News. 1, vol 109, September 4, 2001

[28]Washington Post, *op. cit.*

[29]*Learning for the 21st Century: Are Your Schools on the Right Track?* Partnership for 21st Century Skills: draft report, May 2003

[30]National Alliance of Business: *http://www.nab.com/data4.htm*

[31]*The Sustainability Challenge: Taking Edtech to the Next Level:* Benton Foundation and the Education Development Center's Center for Children and Technology, March 2003

[32]Market Data Retrieval, quoted by Kathy Seal, *Transforming Teaching & Learning Through Technology*, Carnegie Reporter, Spring 2003, p. 26, which compares to 12 students per computer as recently as 1998 (*The Sustainability Challenge, op. cit.)*

[33]Kathy Seal, *op. cit.*

[34]Yukari Iwatani, *Schools Look To Wireless To Boost Learning* (iWon—Computers & Technology), April 22, 2003

[35]Kathy Seal, *op. cit.* p. 27

[36]Vint Cerf and Caleb Schutz, Teaching in 2025: *Education and Technology Transformed* (*Visions 2020*, Departments of Education and Commerce, 2002)

[37]*The Sustainability Challenge*, Benton Foundation and the Center for Children & Technology, 2003, p. 8

[38]National Research Council Report, *How People Learn: Brain, Mind, Experience, and School.* National Academic Press, Washington DC, 2000

[39]Mokros, J.R. and Tinker,R.F. (1987). *The impact of microcomputer-based labs on children's ability to interpret graphs*. Journal of Research in Science Teaching (1987) 24:369-383

[40]Nachmias, R., and Linn, M.C. *Evaluations of science laboratory data: The role of computer-presented information*. Journal of Research in Science Teaching *op. cit.* 24:491-506

[41]Roschelle, J., Pea, R., Hoadley,C., Gordin, D., Means, B. (2001). *Changing How and What Children Learn in School with Computer-Based Technologies*. The Future of Children, 10 (2). Los Altos, CA, Packard Foundation. pp. 76-101

[42]Boster, Meyer, Roberto and Inge, *A Report on the Effect of the Unitedstreaming Application on Educational Performance* (August 2002)

[43]Cognition and Technology Group at Vanderbilt. *The Jasper Project: Lessons in Curriculum, Instruction, Assessment, and Professional Development*

[44]Pellegrino, J.W., Hickey, A., Heath, K. Dewey, N.J., and the Cognition and Technology Group at Vanderbilt. *Assessing the Outcome of an Innovative Instructional Program: The 1990-1991 Implementation of the Adventures of Jasper Woodbury*. Technology Report No. 91-1. Nashville, TN

[45]Hunt, E. and Mistrell, J. *A cognitive approach to the teaching of physics.* Classroom Lessons: Integrating Cognitive Theory and Classroom Practice. pp. 51-74. K. McGilley, ed., Cambridge, MA: MIT Press (1994)

[46]*Are We There Yet?* (National School Boards Foundation, 2002)

[47]Ohio Educational Telecommunications Network Commission, 2001

[48]Technology Counts 2003, *Education Week* (May 9, 2003)

[49]Sara Rimer, *High School Is Virtual*, New York Times, June 14, 2003

[50]Kenneth C. Green, The 2001 *Campus Computing Survey, http://www.campuscomputing.net.*

[51]*Ibid*.

[52]Anthony Carnavale and Donna Desrochers, *The Missing Middle: Aligning Education and the Knowledge Economy* (Educational Testing Service, 2002)

[53]*Building A Nation of Learners* (Business-Higher Education Forum, 2003), p. 15

[54]*The Condition of Education 2002*, National Center for Educational Statistics

[55]Carol Twigg, *Improving Learning and Reducing Costs: Redesigning Large Enrollment Courses*, the Pew Learning and Technology Program, Center for Academic Transformation, Troy, N.Y. Rensselaer Polytechnic Institute, 1999. These categories of improvement are also the principal ones cited by BHEF in its report.

[56]Irving Wladawsky-Berger, V/P Technology & Strategy, IBM, *IT and Education: Toward A National Education Infrastructure*: Speech at Department of Commerce (September 2002)

[57]*Cost of Supporting Technology Services* project, 2001: *http://www.costsproject.org*

[58]B*lackboard Expands Reach in Deal to Set Up Chinese Colleges with Its Software*, The New York Times, September 1, 2003, p. C 3

[59]*Lifelong Learning in Norway: An Experiment in Progress*, International Longevity Center Issue Brief, December 2001

[60]Diantha Dow Schull, *The Digital Opportunity Investment Trust Act: Remarks for a Report to Congress* (June 25, 2003)

[61]Diana Dow Schull, *op. cit.*

[62]*Opportunities and Barriers to the Use of Broadband in Education*, Broadband Stakeholders Group (2003), pp. 21-22

[63]IMLS, *Status of Technology and Digitization in the Nation's Museums and Libraries*, 2002 Report

[63]*Opportunities and Barriers to the Use of Broadband in Education*, Broadband Stakeholders Group (2003), pp. 21-22

[64]AAM, *White Paper on Digital Promise*, 7/30/03

[65]National Humanities Alliance *White Paper on the Digital Promise Project*—draft, p. 7

[66]*Road Map for National Security: Imperative for Change*, Phase III Report of U.S. Commission in National Security/21st Century, February 2001, p. iv

[67]*Ibid.*, p. 14

[68]John B. Horrigan, *The Broadband Difference*, April 28, 2003 *www.neca.org/source/neca_224.asp*

[69]*A Broadband World*: Benton Foundation/Alliance for Public Technology (2003)

[70]*Ibid.*

[71]Quoted in *Technology to Transform Our Schools: A Digital Promise White Paper* by Milton Chen, George Lucas Educational Foundation (June 2003)

[72]*Vision 2020, op. cit.*

[73]*Roadmap for National Security: Imperative for Change.* (Phase III Report): The U.S. Commission on National Security in the 21st Century, February 2001

1717 K St. NW Suite 209
Washington, DC 20036
T (202) 454-4683
F (202) 675-1010

www.digitalpromise.org
digitalpromise@fas.org

Design/Edit: Reingold, Inc.

4. Research & Development Roadmap

Creating The Digital Opportunity Investment Trust

A Proposal to Transform Learning and Training for the 21st Century

A Report to The Congress of The United States

As authorized in P. L. 108-7

Respectfully submitted:

The Digital Promise Project

Lawrence K. Grossman

Newton N. Minow

Co-Chairmen

Anne G. Murphy

Project Director

Federation of American Scientists

H. Kay Howell

Learning Federation Project Director

October 2003

www.thelearningfederation.org

DIGITALPROMISE *www.digitalpromise.org*

The Learning Science and Technology R&D Roadmap Executive Summary incorporates a series of technology research roadmaps, or plans, developed over a three year period by the Federation of American Scientists and the Learning Federation, a partnership among industry, academia, and private foundations to stimulate research and development in learning science and technology. The full series of research roadmaps is available at *www.thelearningfederation.org*.

We gratefully acknowledge the funding support of the 2003 Congressional appropriation to the Federation of American Scientists for the Digital Opportunity Investment Trust (DO IT). A major part of that funding supported the Learning Federation's Learning Sciences and Technology Research and Development Roadmap, which appears in the DO IT Report to Congress. We also gratefully acknowledge the additional funding support of the organizations that sponsored this work and helped make possible the Roadmap:

Microsoft Research
Hewlett Packard
Carnegie Corporation of New York
National Science Foundation
Department of Defense, DDR&E
Hewlett Foundation

Research & Development Roadmap

Learning Federation Steering Committee

Executive Leadership

Randy Hinrichs, Group Research Manager, Learning Science and Technology, Microsoft Research

Henry Kelly, President, Federation of American Scientists

Andries van Dam, Vice President for Research, Brown University

Steering Committee Members

Ruzena Bajcsy, Director, Center for Information Technology, Research in the Interest of Society, University of California, Berkeley

John D. Bransford, College of Education, University of Washington

Gene Broderson, Director of Education, Corporation of Public Broadcasting

Edward Lazowska, Bill & Melinda Gates Chair in Computer Science, University of Washington

Elliot Masie, President, MASIE Center

Richard Newton, Dean of the College of Engineering and Roy W. Carlson, Professor of Engineering, University of California, Berkeley

Donald Norman, Co-founder, Nielsen Norman Group, Professor Emeritus, Cognitive Science and Psychology, University of California, San Diego

Raj Reddy, Herbert A. Simon University Professor of Computer Science and Robotics, Carnegie Mellon University

Shankar Sastry, Chair of Electrical Engineering and Computer Sciences, University of California, Berkeley

William Spencer, Chairman Emeritus, International SEMATECH Board

Janos Sztipanovits, E. Bronson Ingram Distinguished Professor of Engineering, Vanderbilt University

Ann Wittbrodt, Research and Development Manager, Education Services, Hewlett-Packard Company

Project Management

Kay Howell, Director, Information Technologies, Learning Federation Project Director, Federation of American Scientists

Kendra Bodnar, Director, Learning Technologies Project, Federation of American Scientists

Thomas Kalil, Assistant to the Chancellor for Science and Technology, University of California, Berkeley

Introduction

The Learning Federation Learning Science and Technology R&D Roadmap

Catalyzing a revolution in how we teach and learn

With this technology Roadmap for innovation in learning science and technology, the Learning Federation charts a course toward creating revolutionary new learning environments and launching the action plan to make those real. The plan focuses entirely on identifying research that can lead directly to better learning outcomes and greater access to quality education and training for anyone with a desire to learn. It outlines a vision of what our nation could achieve with adequate investment, accompanied by a research plan that can realize that vision—a plan with clear targets, clear research objectives, clear priorities, and a management plan to ensure continuous evaluation and feedback. Put in operation, this plan will enable us radically to improve approaches to teaching and learning through information technology. Our goal is to catalyze a partnership joining companies, universities, the educational community, government agencies and private foundations to execute this plan. Information technology, used both in classrooms with well-educated and motivated instructors, and at home and in the workplace by individuals, can greatly increase the productivity and accessibility of education and training.

About the Learning Federation

The Learning Federation was formed in 2001 as a partnership among industry, academia, and private foundations to stimulate research and development in learning science and technology. The Learning Federation has focused on developing this Roadmap, with the goal of producing a well-designed research plan that identifies research priorities, an R&D chronology and metrics of success and a management plan for forming research teams and disseminating R&D results.

The Learning Federation is led by a Steering Committee of national leaders in learning science and information technology to provide advice and guidance, review and endorse the plan, and act as advocates on its behalf. In addition, more than 70 leading researchers, from industry, academia, and government donated time and labor to help us develop this Roadmap through their participation in focused workshops, interviews, and preparation of technical plans.

Rationale

Emerging technologies make it practical now to approach learning in ways that theorists have advocated for many years. Unfortunately, the practices recommended by educational psychologists and cognitive scientists are not pervasive in America's classrooms and training centers. Individualized instruction, subject-matter experts, and rich curricular activities are often simply too expensive. Expense and related challenges often cause both formal education and corporate training to rely on strategies that ignore the findings of learning research.

In a landmark series of studies, Bloom and colleagues demonstrated that one-on-one tutoring improved student achievement by two standard deviations over group instruction (Bloom, 1984).[1] While no one was surprised to learn that one-on-one tutoring improved learning, the degree of improvement was surprising—the equivalent of improving the performance of 50th percentile students to that of 98th percentile! Imagine what an impact this could make on American society if we could replicate this across the educational enterprise. Researchers have sought to understand why such dramatic differences exist. Among the possible explanations are: individualization (that instruction can be tailored to the learner's particular needs), and instructional intensity (the number of interactions between teacher and student during a tutorial). If computers and advanced information technologies can implement even a portion of the ideal tutoring strategies, substantial learning gains should follow. Indeed, several learning systems have already demonstrated impressive learning gains.

For the first time in history, technology exists that can make vastly improved learning systems routinely available. But we can achieve this goal only by undertaking a long-term, large-scale effort to develop, test, and disseminate tools for building advanced

learning systems. The positive prospects have been marred by false promises and gross underestimates of the task's complexity. There's no question that improving learning systems is one of the most difficult, and most important, research challenges facing the nation today.

Given an aggressive and successful program of research, computer simulations could let learners tinker with chemical reactions in living cells, practice operating and repairing expensive equipment, or practice marketing techniques. Simulations could make it easier to grasp complex concepts and transfer this understanding quickly to practical problems. New communication tools could enable learners to collaborate on complex projects and ask for help from teachers and experts from around the world. Learning systems could adapt to differences in student interests, backgrounds, learning styles, and aptitudes. They could provide continuous measures of competence, integral to the learning process. Such measures could help teachers work more effectively with individuals and leave a record of competence that is compelling to students and to employers. And new tools could allow continuous evaluation and improvement of the learning systems themselves.

Some of these objectives require difficult but straightforward extensions of known technologies or adapting to learning goals the design concepts that have succeeded in business or research. Others will require fundamental advances. A successful research strategy must begin with the clearest possible vision of what is being attempted, and a strategy for managing research that invites and tests a wide range of approaches. The strategy must also be rooted in experience. New learning systems must be tested in practical ways, working with real students and teachers. The successes and failures of these tests will provide essential guidance for future research.

Sophisticated computer software is essential for implementing most of the new objectives—software ranging from simulations of biological processes to systems designed to answer questions using automated systems, with live instructors and experts. Without high-quality software tools, practical tests of advanced instructional concepts are impossible. With poor or amateurish software tools, it is difficult or impossible to determine whether the concept or the implementation has failed the student.

Developing these software tools and systems will be like other software development efforts: difficult, labor-intensive, and expensive. Building these specialized tools is far beyond the capacity of most instructional designers. Tools to decrease the level of effort are desperately needed. A key goal of the applied research explored in the Learning Federation involves creating a useable range of interoperable, well-performing, extensible software tools that can lower the cost of entry for educational materials and systems.

The scale and scope of the research effort proposed in the research Roadmap are unprecedented in education. It will require a new partnership combining the talents and resources of government, industry, and private foundations. Current investments in learning science and technology are fragmented and often discontinuous, both within and across public and private sectors. There are many players in the learning technologies space, no dominant companies or standards, and the application markets are extremely diverse and disjointed. The total national investment in education and training is approaching one trillion dollars, yet the nation is probably investing only about $50 million in basic research or $200 million in applied research—most of this in the Department of Defense.

While more funding is essential, a special research management approach is equally important in order to build the needed research teams and focus the research. The research program should be built around a clearly articulated set of goals that are constantly debated and updated. The work must be divided into manageable programs built around clear, tightly integrated objectives. A disciplined process must be put in place to develop and continuously revise these objectives. And there must be a process for establishing clear research priorities—and the flexibility to tailor research investments to meet many different needs.

The Learning Federation was formed to focus this diverse community by fostering communications and a common purpose among the players while influencing research by identifying where intellectual effort is most likely to bear fruit. It is meant to motivate a new investment, and provide a first draft of a management plan to guide investments when new programs begin. Following the model of other successful research ventures, we will adopt a regular system of reviewing goals and priorities.

The Research Roadmap

This research plan was built using methods pioneered by the SEMATECH Corporation, which for more than a decade has built and revised a research plan for semiconductor manufacturing. Using advice from panels of experts from companies, universities, government research facilities, and others with unique expertise, a series of five component roadmaps was developed, each addressing critical learning science and technology R&D areas. Expert input was solicited during a series of specialized workshops, consultative meetings, and interviews. We designed the roadmapping process to encourage discussion and debate throughout the relevant communities, including the nation's leading researchers in the learning sciences, software designers, private sector and educational personnel.

The roadmaps provide an assessment of the R&D needs, identify key research questions and technical requirements, and detail the chronology of the R&D activities over the next five to ten years. Each roadmap also articulates long-term goals and shorter-term benchmarks. Collectively, by articulating a vision of next-generation learning systems, these roadmaps provide a comprehensive strategic view of the field which can guide researchers, industry, and funding agencies as they enable continued innovation in educational technology.

The R&D roadmaps are constructed to support both basic research and highly applied efforts to build tools, design software, and develop courses using the products of this research. The research plan is crafted to ensure that supported research will generate a continuous flow of carefully evaluated instructional components, instructional strategies, and tools adaptable to multiple contexts, including university and corporate learning. The tools developed will enable increases in scale that will make these capabilities readily affordable to all. In turn, affordability will permit routine use of new tools in schools, colleges, workplaces, and homes. The research plan embodies the following key characteristics:

- **Focus on pre-competitive R&D.** The product of the research will not be a specific, marketable course or product but rather pre-competitive concepts, technologies, and tools—exemplified in prototype models. Prototypes will be built

with an eye to quick translation into practical courses or new immersive, interactive learning environments and interactive tools. While the Roadmap is designed to achieve ambitious long-term goals, it will also be crafted to ensure that supported research will continuously yield results that can be converted into practical products.

- **Focus on real but "stretch" applications.** The new tools envisioned here, stimulated by this Roadmap, will make it possible to measure a richer range of a person's ability —and to do so in a way that is clear to the learner, employer, instructor, and teacher.

- **Initial focus on post-secondary** (two-year and four-year colleges and universities and industry training functions) and lifelong science, math, engineering and technology education, directly addressing workforce development needs. Our focus here will include teaching specific job-related skills as well as the underlying principles necessary for learning new skills quickly. Corporate America's needs are growing rapidly and solutions are likely to be adopted quickly in these areas of learning. **The insights gained will, however, be useful in all learning—for children, adolescents, and adults.**

Research Roadmap Components

A series of five component roadmaps define the overall research plan. Each of the five addresses a critical learning science and technology R&D focus area. The five major research topics, summarized in the table below, were identified at a National Science Foundation-sponsored workshop held in November 2000.

Component Roadmap	Research Priorities
Instructional Design for New Technology-Enabled Approaches to Learning Understanding how people learn, how experts organize information, and the skills of effective learners	• An integrative framework to enable generalization and integration of research results. • Tools for determining and assessing learner characteristics. • Methods and tools for practice environments. • Understanding how features of games can be used to improve learning.

Building Simulations and Exploration Environments for Technology-Enabled Learning Systems How to build complex virtual environments that reflect current understanding of physics, chemistry, biology, mathematics, and other disciplines that permit exploration-based pedagogy	• Interoperability within and across disciplines (geometry, ontology, message passing, etc.). • Certification & management techniques for validating & updating simulations. • Model scalability for use at many levels of resolution and complexity. • Techniques to navigate simulations and visualizations at different levels of detail; feature-based navigation; and scene management. • Adapting simulation and exploration environments to learning environments.
Question Generation and Answering Systems for Technology-Enabled Learning Systems How to take advantage of the benefits offered by emerging technologies to facilitate inquiry and get questions answered	• Tools to stimulate learner questions and generate questions that stimulate learning. • Interfaces that make it easier for students to ask questions and to provide guidance on what sorts of questions can be (or should be) asked. • Tools for comprehending and answering learner questions. • Tools for interpreting learner answers. • Tools to advance the discussion with the student and to summon teachers and other experts as needed.
Learner Modeling and Assessment for Technology-Enabled Learning Systems What to measure, when to measure and how to use the information	• Models of content expertise, competency and pedagogy. • Automated modular assessment design, development, delivery and analysis. • Multi-dimensional learner models and measurement methods.

Integration Tools for Building and Maintaining Advanced Learning Systems Strategies for using learning system tools to build learning systems	• Course building tools for designing scenarios, creating assignments, designing response to information gathered from student observer tools, and programming avatar behaviors. • Shareable Content Objects that can hide the underlying technology and use terms and visualizations familiar to instructional designers. • Tools and services to assist developers in the application of metadata. • Tools to establish an open process for worldwide collaboration on building and maintaining learning environments.

The following sections offer a general overview of each component roadmap and summarize the research priorities and milestones. The complete roadmaps are available at *www.thelearningfederation.org*.

Instructional Design for New Technology-Enabled Approaches to Learning

Cognitive science has long recognized that learning environments that provide learners opportunities to apply their knowledge to solve practical problems and invite exploration and play can lead to faster learning, greater retention, and greater motivation. Indeed, apprenticeship experiences and play imitating expert behavior are the most ancient forms of instruction.

Unfortunately, these learning strategies are rarely used today because they are difficult to implement in standard classroom environments. But, expected improvements in technology may significantly reduce the cost and complexity of implementing learning-by-doing environments. The combined forces of high-powered computing, unparalleled bandwidth, and advances in software architecture are poised to make realistic gaming and simulations more feasible and economical. How should these new tools be used, with whom, and for what?

Research Challenges in Instructional Design

This roadmap identifies research priorities for designing and evaluating simulations and gaming in instructional environments We need to understand the most effective learning strategy for each subject and each learner and use this information to design the learning experience. We need to understand which variables influence learning: motivation, prior experience, interest. We need to understand how best to use discovery-based learning, games, and other exploration-based learning, as well as the most appropriate roles for teachers, coaches, experts, and other supporters of learning.

A framework to enable generalization and integration of research results

Today, an instructional designer can use numerous taxonomies and techniques, many of which are labor intensive. We need to develop and validate techniques for cognitive tasks involving higher-order skills and develop methods for analyzing collective or team tasks. This will enable us to establish a common framework in which researchers can conceptualize their studies and understand how individual studies (i.e., the specific variables and context being tested) fit into the larger picture. Then, research results can be better integrated across factors to identify gaps in understanding.

Tools for determining and assessing learner characteristics

Each learner brings a unique set of knowledge, skills, preferences, and experiences to a task. We need tools that will enable learning systems to specifically account for those unique characteristics in designing and delivering instruction. Individual learners show variables such as: prior knowledge, prior skill, prior experience, misconceptions, and interests. In addition, a number of other personal attributes have been shown to affect learning: motivation, personal agency/self-efficacy, goal orientation, goal commitment, emotional state, self-regulation, misconceptions, interest, and spatial ability.

Developing practice environments

Current knowledge of how to create effective simulation-based practice environments is not specific enough to provide robust guidelines for designers. The issue extends beyond the design of simulations, to the question of how to structure such environments so that they strongly support learning. For example, researchers now use modeling techniques to insert realistic human actors into simulations. This can heighten the authenticity of the learning experience by allowing trainees to practice higher-order skills with realistic actors. These computer-generated actors can provide a low-cost

alternative to more traditional role-playing strategies by reducing the need for human actors. They can also allow team members to practice effectively, even without live teammates. We need automated tools to streamline the development of simulation-based practice environments, which now are largely manual and typically very costly.

Determining how features of games can be used to improve learning

Empirical research is required to better understand what features of games can be used to improve learning outcomes, and to develop guidelines based on that research. Which characteristics of games can be applied to improving learning? The answer to this question seems to be that games increase motivation, but it is not entirely clear why. For example, games typically include competition (either against a human opponent or a computer-generated one); they are often story-based, with strong characters, and such games typically "keep score". The research challenge is to determine which, if any, of these features is essential to learning.

Research Challenges in Instructional Design

Research Priorities	R&D Outcomes
Integrative Framework to Facilitate Generalization and Integration of Research Results	• Automated tools for classifying and identifying task demands, knowledge types and establishing instructional objectives. • Automated tools for cognitive task analysis that link task demands to knowledge types and learning objectives. • Automated team task analysis capabilities that link task demands with knowledge types and learning objectives. • Documentation on the nature of challenges that are typical in games and why they work.
Tools for Determining and Assessing Learner Characteristics	• Prioritized list of learner characteristics to study and tools to measure and assess. • Open standards software that can be embedded in third party simulations that diagnose and remediate across general, spatial, technological parameters.

	• Automated processes for adjusting the learning environment in accordance with the learner's initial knowledge and experience. • Empirical results of the relationship between goal orientation and aspects of technology-enabled learning systems across multiple subject domains/ skill classes. • Embedded, open source tools to adjust curriculum/ instruction based on goal orientation and content.
Methods and Tools for Practice Environments	• Empirically-validated strategies for developing scenarios and cases that are linked to task types and learner characteristics; these strategies will reduce time to develop effective scenarios and cases by 50%. • Automated tools for assessing fidelity and authenticity based on learning goals and learner characteristics, including a library of techniques for enhancing the authenticity and fidelity of practice environments. • Validated modeling strategies for creating simulated teammates and adversaries that produce achievement equivalent to human actors. • Automated coaching strategies that dynamically adjust according to learner achievement and demonstrate time/cost savings and learning ability. • Tools to guide design of computer-assisted collaboration in learning.
Identify Features of Games that Can Be Used to Improve Learning	• Document features of challenges crucial for motivation and learning; develop guidelines for implementing challenges across task/domain types and learner characteristics. • Guidelines for developing compelling stories for learning; and mechanisms to assess the appropriateness of a story for learning.

	• Techniques for assessing immersion and engagement; guidelines for increasing immersion and engagement in learning games. • Guidelines for developing games that optimize mastery orientation in games; demonstrate optimization that reflects a 50% increase in mastery orientation. • Techniques to increase motivation in games across tasks and learners and demonstrate 50% learning increases.

Question Generation and Answering Systems

Cognitive science research has demonstrated that learning improves when students ask questions. Yet, it is well documented that most learning environments do not stimulate many learner questions. According to one research study, a typical student asks .17 questions per hour in a conventional classroom and 27 questions per hour in one-on-one human tutoring. In addition to rarely asking questions, many learners do not know how to ask good questions. Students rarely observe good collaborative dialogue because many classroom environments are set up for teacher monologues more than dialogues.

Making dialogues and questions a routine part of learning systems requires tools for managing and responding to learner queries that integrate question generation and answering capabilities. We need computer tools that can: 1) answer students' questions whenever they ask them; 2) formulate answers in a fashion that uses the specific pedagogical theory deemed most appropriate for the learner and subject; 3) deliver quick, correct, relevant, and informative answers; and 4) connect learners to teachers, coaches, and experts, as well as to computer-generated answers. As a longer-term goal, the learning system should have even more sophisticated facilities that diagnose student problems and provide help before the question is asked. We need computer facilities that can:

- Incorporate detailed learner profiling that keeps track of general capabilities and aptitudes of the learner and details about the history of learning episodes.

- Stimulate learner questions through learning situations such as challenges, contradictions, and obstacles to important goals.

- Teach learners how to ask good questions, by direct instructions on questioning or by a person or computer that models questioning skills.

Research Challenges in Question Generation and Answering Systems

The Question Generation and Answering Systems roadmap describes five key research priorities for increasing the frequency and quality of questions, as well as methods for delivering answers to learner questions.

Tools to stimulate learner questions and generate questions that stimulate learning

We need more systematic research on the characteristics of learning environments that trigger particular categories of questions. The relationship between features of different learning environments and the landscape of questions needs to be documented in order to better understand what characteristics of those environments stimulate genuine, information-seeking questions, rather than questions merely to attract attention, monitor conversation flow, or serve social functions.

Interfaces that make it easy for students to ask questions and to provide guidance on what sorts of questions can be (or should be) asked

Cognitive psychologists have identified conditions in which it is appropriate to present information in single or multiple modalities (text, pictures, sound), to present information contiguously in time and space, and to avoid split attention effects. We need to investigate alternative multimedia designs related to computers asking and answering questions. For example, when is it best to deliver information in printed text versus speech, in language versus highlighted pictures, in static illustrations versus animated simulations, or to summon a human instructor or expert?

Tools for comprehending and answering learner questions

A significant research program is underway in question answering technology, although most is not focused on use for education. The AQUAINT (Advanced Question and Answering for Intelligence) Program managed by the Advanced Research & Development Activity (*http://www.ic-arda.org/InfoExploit/aquaint/*) has developed an ambitious research roadmap in the area and is actively pursuing the

broad range of research challenges identified. The work includes developing technologies and methods for understanding and interpreting complex questions, mining enormous databases to create relevant answers to those questions, and formulating and presenting the answers in terms that are clear to the questioner. The project is pursuing difficult technical issues such as managing dialogues where the questions, and the answers, may include pictures, graphs, videos and other media.

Learning research will benefit enormously by closer collaboration with such projects but additional research is needed to apply them to learning environments. Learning systems must pay careful attention to the context of the question and try to develop responses that reflect the recommended pedagogy (it may, for example, be best to answer some questions with other questions). And the impact of the question comprehension and answering facilities on learning gains must be closely evaluated.

Tools for interpreting learner answers

Learners find it easiest to express themselves when they can combine speech, gesture, and facial expressions. Information from all of these input modes must be interpreted, deeply comprehended, and evaluated pedagogically.

Tools to advance the discussion and to summon teachers and experts as needed

The question-answering system needs to respond to what the student says and also advance the conversation to meet pedagogical goals. The system should be able to recognize when it has reached its limit, and summon teachers or other experts, as needed. These individuals should be able to understand the context of the question, and know relevant details about the student so that their responses can be thoughtful, prompt, and relevant.

Research Challenges in Question Generation & Answering Systems

Research Priorities	R&D Outcomes
Tools to Stimulate Learner Questions and Questions that Stimulate Learning	• Decision aids for identifying the critical components of learning environments that stimulate question asking. • Published models that predict how varying features in a learning environment change quantity and types of questions. • Complete repositories of sample questions for additional new classes of learning environments.
Tools to Simplify Question Asking	• Intuitive interfaces that allow the learner to correct the system's understanding of the question. • Spoken language questions in open domains. • Utilities for annotating images for student use in deictic reference. • Automated markup of large text collections in support of question answering. • Models of student knowledge to coach learners on questions that should be asked.
Tools for Comprehending and Answering Learner Questions	• Natural understanding modules that perform within 10% of human interpretation of answers. • Complex answers compiled, merged, and generated from multiple sources, with confidence level. • Dynamically constructed answer justification sensitive to the user and session context. • Learning environments selected and tailored automatically to maximize landscape of important questions. • Electronic information within 2 seconds for all question categories; teacher, coach, or relevant expert response within seconds.

Tools for Interpreting Learner Answers	• Software utilities and authoring tools for marking up documents in learning repository and natural language processing components. • Tools for tagging and segmenting content to enable automatic matching of content to pedagogical taxonomies and educational objectives that perform as well as humans. • Tools to support integration of pens, eye-trackers, gesture analysis, etc. and to interpret/evaluate visual and action modalities. • Natural language understanding modules that perform within 10% of human interpretation of answers.
Tools to Advance the Discussion and to Summon Teachers and Experts as Needed	• Systems capable of asking the learner major questions or presenting problems that will require major attention and conversation. • Systems capable of responding to student assertions by giving feedback in a variety of forms: verbal feedback without intonation, verbal feedback with intonation, facial expressions, a visual symbol on the interface, etc. • Systems that summon teachers or experts, as needed. • Systems with audio and video speech recognition and speech synthesis implemented, plus evaluation experiments to assess effectiveness. • Systems that direct the learner to simulation and visual media when needed, interrupt when needed, etc.

Learner Modeling and Assessment for Technology-Enabled Learning Systems

Assessment is critical for managing effective education and training. Assessments that provide a rich measure of an individual's or group's knowledge and expertise provide

information for teachers, help learners recognize their own level of mastery, and create a rich record than can help future teachers and employers. Continuous assessment provides insights that are key for guiding the direction of instruction and providing optimal feedback, guidance, and learning resources tailored to the specific, immediate needs of individual learners. Ideally, every educational decision-maker, from teacher to human resource director, would have access to real-time valid data just in time to make a decision about an individual, group, or program. Better yet, the system that collects and analyzes the data would itself be smart enough to make the decision, and the system would over time improve its ability to make the best decisions.

Research Challenges in Learner Modeling and Assessment

This roadmap identifies five R&D priorities that will allow us to turn the research and software, heretofore confined to research labs and proof of concepts, into scalable, extensible, integrated Internet-based learning systems. The R&D will significantly increase the validity, efficiency, utility, effectiveness, and widespread use of learner modeling and technology-enabled assessment.

Establish models of content expertise, competency, and pedagogy

We need to map and integrate existing content, competency, and pedagogical models into an agreed-upon framework that can standardize and automate task analysis, assessment design, and use. As a first step, we need to specify the skills, knowledge and abilities to be measured. This requires breaking down the content/job/performance domain into its fundamental knowledge and skill components. The more fine-grained the breakout of skill components, the better we can test particular sub-skills, and the more specific the diagnosis of knowledge gaps. This will lead to greater validity and effectiveness of the assessment and learning.

Automated modular assessment design, development, delivery, and analysis

A modular design for assessment “objects” is needed to simplify development, delivery and analysis. The learning object strategy separates the content of instruction from its presentation/delivery and specifies one or more standard stand-alone units of instruction (the learning objects) and their modular content elements. Assessment “objects” need to be reusable, accessible via search mechanisms, and capable of dynamic assembly like “learning objects” in many current learning systems. Tools are needed to manage

the assessment elements and to assemble the "objects." The task of developing an object-based strategy for assessment will be more complicated than for learning content. An assessment object-based strategy must specify the reusable components of multiple assessment task types and multiple response types. In addition, it must also include reusable mechanisms for scoring and combining evidence from multiple sources to generate probabilistic inferences about mastery of particular objectives or competencies.

Multidimensional learner models and measurement methods

In online learning systems, the information in the learner model is usually at a very gross level, representing whatever the system recognizes as "assignable units" or learning objects. We need to add other layers of granularity and dimensionality to the competency data in learner models in online learning systems to more precisely diagnose knowledge gaps and to adapt the instruction continuously.

Reporting and use of assessment and learner modeling data

Feedback and guidance are essential components of a learning environment. They point out performance errors, correct them, and allow the learner to proceed to mastery. There are many dimensions of feedback and guidance that can be varied: timing, content, amount, specificity, medium, and control. Once we have established rules for feedback decisions, we need software that allows an author to specify rules for triggering particular types of feedback. Authoring software is needed to facilitate entry of feedback segments that can be intelligently, dynamically pieced together, or presented in a variety of media, for example, text, or spoken by a character.

Web services infrastructure for integration of software applications and services

We need to develop a larger infrastructure to integrate various authoring tools, analysis and reporting services, and decision aids. This would enable a scenario, for example, in which an author would create tasks in one application that could be delivered as part of an online assessment or learning experience. In both cases, the response data would be sent to another service for analysis; the resulting diagnosis could be sent to a reporting service or back to the learning environment to trigger feedback or the next piece of content to be presented. Work in this area will involve close collaboration with standards groups.

Research Challenges in Learning Modeling and Assessment

Research Priorities	R&D Outcomes
Establish Models of Content Expertise, Competency, and Pedagogy	• Map content/competency models and agree on a shared core model and terms. • Map pedagogical models and agree on a meta model and terms. • Task analysis methodology and software that reflect the core content model and enables automated generation of tasks to elicit and measure those skills.
Tools for Automated Modular Assessment Design, Development, Delivery, and Analysis	• A general assessment object architecture with standard item/task templates for measuring particular types of knowledge and skills, with rules for generating the content of the variable slots in the templates and rules for scoring alternative types of responses. • Authoring tools to automate creation, storage, and assembly of components. • Tools and mechanisms for scoring and aggregating data from multiple sources. • Integration with learning environments and data tracking/reporting systems.
Multidimensional Learner Models and Measurement Methods	• Validated multidimensional learner models and their components and guidelines for when to use more and less elaborate learner models. • Tools to support insertion of monitoring capabilities into multiple learning systems. • Tools to specify analysis and actions based on particular levels of mastery and motivation. • Decision-aids for choosing different types of measurements and level of detail based on context, budget and purpose.

Tools for Reporting and Use of Assessment and Learner Modeling Data	• Decision-aids/rules for personalizing feedback, and guidance and personalization of content. • Authoring tools for specifying rules and triggering feedback customized to individual needs. • Authoring tools that enable dynamic assembly of feedback segments and support a variety of feedback media, including text and spoken language. • Real-time generation of reports from multiple databases. • Data structures and application program interfaces (APIs) for transfer of data.
Web Services Infrastructure for Integration of Software Applications and Services	• Specification of the architecture, with APIs to connect component software applications, for example, authoring tools or reporting services, that reflect generally accepted standards. • Prototypes to validate integration of component services (authoring, scoring, analysis, maintenance of learner models; reporting) ready for integration. • Validate integration of component services. • APIs for integration with other e-business services.

Building Simulations and Exploration Environments for Technology-Enabled Learning Systems

Research has demonstrated that simulation environments are powerful learning tools that encourage exploration by allowing learners to manipulate parameters and visualize results. In academic settings, simulations can enhance lectures, supplement labs, and engage students. In the workplace, simulations are a cost-effective way to train personnel. Synthetic or virtual environments can support games, exploration, assignments with clear goals, or challenges. If they're well designed, such environments will motivate

learners to meet the goal, sustaining their eagerness to build the needed skills. The question is how to use simulations and synthetic environments to improve learning outcomes, while making them easier to build and incorporate into learning environments.

Research Challenges in Building Simulations and Exploration Environments

This roadmap identifies four key research topics that collectively should enable simulations and synthetic environments to improve learning outcomes. Building complex virtual environments that permit exploration-based pedagogy requires an unprecedented investment for building an effective community from the numerous groups of people that must contribute to developing these tools.

Interoperability

Interoperability is the ability of various simulation systems to work with each other in a coherent fashion. Effective combination and reuse of software objects require precise agreement on the coordinate systems and methods for representing complex geometric objects, the system of units employed, and the exact terminology used to describe objects (or ontology). Simulations show motion and interaction and thus require a precise taxonomy of verbs—that is, rates of change and flows of charge, chemicals, and bulk materials. They must also show changes in shape and even basic topology of objects.

Reuse, updating, and maintenance of simulations

A lightweight management structure can establish and enforce a set of simple rules, oversee final decisions about which objects offered meet the required standards, and maintain an index of components built to the agreed rules. Open source communities provide one such model for building a community of developers capable of providing the advanced simulation tools needed for science and engineering education.

Navigation of exploration environments

In order to develop orientation skills and situational awareness in a synthetic environment, users need a high level of fidelity to be able to navigate through the virtual space as if it were real. This fidelity requirement poses a number of hardware and software challenges, most of which are far from being solved—including realistic avatars, viewing, sound, movement, touch, and sensory integration.

Adapting simulation and exploration environments to learning environments

Simulations and virtual environments have to be smoothly integrated into education and training so that they enable, rather than encumber, learning. Future research should explore the nature and degree of support tools necessary for using simulations well in learning environments. In developing thinking skills such as scientific inquiry, simulations and exploration environments may need to be combined with other learner-support mechanisms, such as hints on how to design an experiment.

Research Challenges in Simulations and Exploration Environments

Research Priorities	R&D Outcomes
Interoperability for Integration into Learning Environments	• Common network software architecture with standard protocols that govern the exchange of information about the state of each of the participants in the simulation. • Common underlying architecture for maintaining information about the state of the environment related to a particular simulator. • Adoption of unified ontology by communities of simulation developers. • Development of a STEP-like 3D modeling environment that can be used for modeling dynamic interactions and organic shapes.
Reuse, Updating, and Maintenance of Components	• Established procedures for peer review and validation of results against experiments. • Easy, valid methods for tracking of the provenience of data and methods and identification of authors. • Procedures for bug reports and reliable version control. • Standards for the "metadata" used to identify the data and software. • Methods and tools to ensure that appropriate credit is given to authors.

Navigation of Exploration Environments	• Immersive 3-D networked simulations with no perceivable latency for multiple users of moderately complex visual simulations on simple clients. • Techniques to navigate simulations and visualizations at different levels of detail. • Feature-based navigation and scene management. • Simulations of a full range of instruments that are interoperable with synthetic environments. • Noninvasive and accurate tracking that sense and react to the user and the user's environment. • Avatars that allow merging of motion capture and diagnostic imaging modalities to completely describe human movement. • Complex force feedback (haptics) displays that run on the desktop.
Adapting Simulations and Exploration Environments into Learning Environments	• Model scalability for use at many levels of resolution and complexity. • Virtual game worlds composed of customizable synthetic environments. • Multi-player, multi-educational resources available anywhere, anytime through any internet-connectable interface. • Predictive computer-based modeling and simulation that can substitute for many aspects of physical testing and experimentation.

Integration Tools for Building and Maintaining Advanced Learning Systems

As we have built specifications and standards to support web-based system-directed learning systems, the means for creating interoperable and robust instructional content have emerged. But current specifications have defined a technically complex infrastructure that is unfriendly to instructional designers. This roadmap identifies the development and integration tools to bridge the gap between the complexity of web-based learning systems and the instructional design community.

Research Challenges in Integration Tools

The roadmap identifies three research priorities: tool architecture, shareable content objects, and metadata. A major challenge is the development of a stable delivery platform that can scale broadly and be incrementally built upon.

Tools that are intuitive, non-technical to the user, and robust will require research, experimentation, and time to develop. If the underlying infrastructure continues to change very rapidly, tools evolution will continue to be modest. Stabilization of underlying infrastructure standards will be key to developing next-generation learning tools, even though (some argue) locking into technical standards too early may stifle innovation. While standards can be confining, few could argue the success of the Internet and the World Wide Web which exist precisely because of open standards. Broad public access to learning content requires an infrastructure that interoperates. We need a common infrastructure in order to produce deliverable advanced capabilities.

Another challenge is striking the balance between ease of use and robustness. It may continue true that the most effective learning environments are the most difficult and expensive to develop, and therefore of limited use. It may also turn out that search-based “just in time” instructional material that is very simple to construct, store, find, and deliver becomes the mainstay of distributed learning.

The research identified in this roadmap will address both possibilities. The roadmap requires that we examine existing and emerging interchange protocols, formats and services that relate to the entire process of content development through to deployment.

Interfaces to other services such as authentication, learner profiles, and assessment, need to be identified and rationalized. We need experiments that demonstrate the interoperation of different levels of development.

Course building tools

Little work has been done from the perspective of instructional design, to understand the flow and interchange requirements. As a result, today courses of instruction must be essentially hand-crafted and then packaged and exported to larger delivery systems.

The cycle of build-test-modify-repeat is cumbersome, complex, costly and off-putting to developers. It stifles innovation in content that might otherwise occur. Tools are required at a variety of abstraction levels yet must seamlessly exchange information, structure, logic, content, and rules during the development process. A defined environment is needed that allows content to be developed and tested with few intermediate steps.

Shareable content objects to simplify use

Content development is the deliberate process of creating and organizing a variety of digital assets such as text, graphics, pictures, illustrations, etc., into a form that can be electronically delivered to a learner. Content objects vary in size and complexity, but often address a single idea, subject, or learning objective. Over the years, content-writing tools have been created by software engineers who are familiar with the underlying interactive media capabilities of computers. Understandably, many of these engineers know little about instructional design strategies, terminology, or models. As a result, their tools tend be complex and "techie." If tools can be made that are simple and easy to use by non-technical authors, more people who understand learning and instruction can contribute to a growing body of sharable content objects. Development costs will reduce, and quality will increase as communities of practice develop.

Tools and services to assist developers in the application of metadata

Standards for learning object metadata now exist, but few tools or practices have been developed. Current metadata standards do not address how and when metadata should be applied or used. Most tools are cumbersome and time-consuming, and few search engines use learning object metadata effectively. Tools and services are required to assist developers in applying metadata at all levels of content development. These

tools need to be customized to meet the needs of various communities of practice. A special area of required research would develop tools and/or agents that can perform intelligent searches of metadata during authoring, and eventually in real time, for "on the fly" content aggregation.

Tools for collaborative building and maintenance of learning environments

Technology based learning design communities have recently embraced the idea that instructional content can and should be developed as potentially reusable and interoperable objects. These objects then need to be organized into contextually relevant groups for delivery to the learner. Tools that can import content objects and provide scaffolding for related activities such as assessment, instruction, or problem solving have been developed only recently, and are still in a relatively primitive state in part because the underlying technology standards for content objects are fairly new, and because the process of creating instruction through the aggregation of content objects is somewhat new to instructional designers. A new class of tools is needed that can ease the search and importing of content objects, determine delivery ordering and scaffolding, and permit the application of sequencing rules that are part of a particular instructional strategy.

Research Challenges in Integration Tools

Research Priorities	R&D Outcomes
Course Building Tools	• Extensible model for how tools and services might interconnect and self-discover. • Enabling Formats and Standards.
Shareable Content Objects to Simplify Use	• Content creation tools designed for instructional designers that hide technical implementation. • Tools that seamlessly integrate varied content types for non-technical authors. • Seamless search and access to digital assets. • Tools that support merging content formats including: static, interactive, stream-based, and active; and examine the authoring, integration and deployment issues. • Integration tools for combining disparate media types.

Tools and Services to Assist in Application of Metadata	• Implementation guidelines for developers in different domains. • Tools to map semi-automatically across domains and determine impact on content developers. • Tools to automate the application of metadata to all levels of content, perhaps through intelligent analysis by agents. • Methods to connect current and emerging intelligent search and retrieval services that use learning metadata with increasingly complex services and information.
Tools for Collaborative Building and Maintenance of Learning Environments	• Documented requirements of tools that support various pedagogical and theoretical approaches; tool examples that support the models. • Rules-based sequencing approaches capabilities for non-technical designers. • Strategies for creating "mini context" templates for reusable compound learning objects that can support many different communities of practice (e.g., Higher Ed, Training, Performance Support, etc.). • Search strategies to enable "real time" assembly of content based on learner profiles, mastery, subject, etc.

Creating an Effective Management Structure to Implement the R&D Roadmap

The R&D Roadmap identifies critical, long-term technical issues that need to be addressed if we are to realize the potential for technology to transform the way we learn. This potential cannot be fully exploited without significant, sustained basic and applied research in learning science and technology.

Current R&D funding levels are grossly inadequate. R&D efforts are fragmented and often discontinuous. There is no established community of researchers, industrial

participants, educators, and educational institutions from which to mobilize teams that span technology and learning to develop, evaluate, and distribute tools. Large-scale, sustained efforts are required. We must involve multiple disciplines in both academia and industry including education, psychology, cognitive science, communication, human-computer interaction, software engineering and design, information science, computational linguistics, statistics, social scientists, and subject-matter experts.

This management plan describes the critical characteristics of a management structure that can execute the technical research plan this Roadmap proposes. The scale and scope of the research identified in this Roadmap is unprecedented in education. It will require a new partnership melding the talents and resources of government, industry, and private foundations.

This new partnership will not replace current learning science and technology R&D programs. Indeed, existing programs have contributed significantly to producing the research results that provide solid evidence that progress is possible. But a new R&D program is essential to enable large-scale, focused, sustained efforts that are not supported by existing programs. A new research management approach is essential to build the needed research teams, focus the research, and guide research by identifying where intellectual effort is most likely to bear fruit. This management approach should complement the current learning science and technology R&D programs to ensure that more applied research and larger-scale demonstration projects are supported. These efforts are critical to create a range of interoperable, well-performing and extensible software tools that can lower the cost of entry for educational materials and systems. This will enable economies of scale and scope and make possible wide-spread, routine use of advanced learning systems.

Management Structure Requirements

It is essential that the research be well managed. An effective management structure can: ensure critical research challenges are addressed; maintain proper balance across research priorities; form research teams; ensure proper linkage of program components; track progress towards goals; and ensure dissemination of results. An effective management structure should:

- Support a broad portfolio of research ranging from basic research to demonstrated tools and systems.
- Provide mechanisms for combining government and corporate research funds.
- Produce continuous feedback from institutions attempting to use the developed tools in practical environments.
- Help create interdisciplinary R&D teams.
- Facilitate close collaboration among business, academic, and government research, development, and demonstration teams.
- Fund and manage projects that involve significant numbers of people working together for multiple years.
- Assess progress, and when necessary eliminate failing projects and approaches.
- Permit contractual flexibility allowing fast response, and timely use of talent wherever it is found (e.g. university, corporate, and non-governmental organizations).
- Support international collaboration where appropriate.
- Disseminate research that private firms can convert into practical products.
- Attract and foster creative research managers respected by the research community.
- Know, and take advantage of, the results of other information technology R&D efforts and ensure LS&T requirements are articulated to the broader IT community.

Current Management Models

Federal R&D funding is allocated using many mechanisms under diverse authorities. Each approach stems from specific agency needs and the historical era when programs began. Research funding mechanisms include:

- Direct federal management of research (e.g. the NASA manned space program or the National Institute of Standards and Technology).

- Government Owned and Government Operated (GOGOs) and Government Owned and Corporate Operated (GOCOs) laboratories such as the Department of Energy's national Laboratories, Federally Funded Research and Development Centers (FFRDCs) such as MITRE and the Institute for Defense Analysis, and other laboratories. Altogether there are more than 700 such facilities employing more than 100,000 scientists.[2] The organizations typically conduct most of their work in their own facilities, but can also manage external contracts with university or corporate research organizations, or arrange for Cooperative R&D Agreements (CRADA) in which government and private research organizations agree to collaborate without direct transfer of funds.

- Competitively funded, investigator-initiated, peer-reviewed grants to universities, businesses, and consortia funded through organizations such as NSF, and much of NIH. These programs can also fund multi-year, multi-participant research partnerships such as the Semiconductor Research Corporation, the NSF Research Centers, and the planned NSF Science of Learning Centers.[3]

- DARPA's traditional approach of giving an ambitious research challenge and significant resources to a single program manager with great flexibility about how to manage the research. (In recent years DARPA has focused much more heavily on delivering practical products that can yield measurable military significance within 3 years.)

- Directed set-asides for small businesses through the Small Business Innovation Research (SBIR) program.

Research Management Needs

The research management needs identified in the Learning Federation research plan are in many ways analogous to the modern requirements of military research and development. The Department of Defense (DoD) has recognized that its research is often most effective when it's directed in ways that help private firms develop innovative new products that will ultimately be purchased by the DoD. A generation ago, this

process proceeded under the premise that DoD would (a) be the first customer and (b) be able to purchase enough of the product to justify the private firm's production. In the past decade, this assumption can no longer be made since state-of-the-art products from DoD research often find their way into commercial products. Examples include the development of new materials and computer chips used in video games before they are used for defense purposes. Large as they are, DoD markets for new technologies are simply not big enough to justify initial production and marketing investments. As a result, DoD research has shifted dramatically to support rapid technical advances in areas where rapid commercial innovation will yield products directly relevant to DoD needs.

The research management strategy for executing the Roadmap should draw on the best features of DoD, particularly DARPA, and NSF R&D programs, and should incorporate the following features:

- R&D managed in accordance with a clearly defined roadmap that identifies goals and priorities for achieving them and that is regularly updated after consulting with experts in business, universities, and government.

- A strong team of program managers with a very small staff, each assigned a major component of the roadmap.

- Flexibility in research management (e.g. "other transactions authority") allowing fast response to new opportunities and an ability to draw on expertise wherever it may be found.

- Flexibility to establish new research centers, including corporate and university partnerships, that can focus efforts on a task for at least three to five years.

- The ability to establish a captive research center (analogous to work conducted on the NIH campus) if, and only if, the oversight board is convinced that such a capability is needed.

It will not be easy to devise a system capable of meeting these goals in ways that meet the needs of business and government investors alike. But it is necessary, given the

enormous public skepticism about the utility of more investment in learning research. In the federal government, the creative, high-risk management style of the DARPA probably most closely resembles the style of operation needed to successfully manage the research identified in the Roadmap.

Models for Public Support

First, can these programs be managed best as an extension of an existing agency or should a new organization be formed? As in the case of federal research management, there are many models for public support to choose among. None of the major agencies appears well suited to the task of managing the work described earlier. Research organizations such as NSF are not organized for such operational missions, although NSF does have a small program that funds IMAX movies, science museum projects, and other nontraditional educational materials, and NSF has supported on a limited basis development of instructional technology. The Department of Education started several software development programs during the 1990s, but almost all have been eliminated and replaced with block grants to states.

If a new organization is contemplated, there are many options to consider. The federal government has approximately 100 “independent agencies” including the Corporation for Public Broadcasting, the National Foundation on the Arts and the Humanities, the Smithsonian Institution, and the National Commission on Libraries and Information Science.

The proposed **Digital Opportunity Investment Trust (DO IT)** offers by far the most promising, thoughtful model for managing the research identified in the Roadmap. The management structure should provide ultimate accountability to the Congress, but also ensure that the management enjoys the stability and independence from political interference needed to ensure the highest-quality product. The NSF provides a widely acceptable model for meeting this goal. Its Director is appointed to a six-year term and reports to a strong, independent board. This model was also used in the newly authorized Office of Innovation and Improvement in the US Department of Education. DO IT’s proposed structure and governance reflect these criteria.

Recommended Funding

Current funding comes from several different agencies and is often fragmented and discontinuous. Most of the current research in post-secondary education and training is funded on such a small scale that real innovations cannot be developed or tested. Market realities have forced firms producing learning products to concentrate on near-term product development. They have been unable to undertake the basic research and development necessary to explore bold new approaches.

A number of recent studies have examined the opportunities presented by new learning technologies and concluded that additional funding is needed, and that a new way to manage the efforts are needed to capture the opportunity. These include:

- President's Committee of Advisors on Science and Technology (PCAST), *Report to the President on Educational Technology* (1997).
- The Web-based Commission, *The Power of the Internet for Learning* (2001).
- Dept. of Education, *eLearning: Putting a World-Class Education at the Fingertips of All Children* (2000).
- President's Information Technology Advisory Committee, *Using Information Technology to Transform the Way We Learn* (2001).
- CEO Forum, *Key Building Blocks for Student Achievement in the 21st Century (2003).*

The President's Committee of Advisors on Science and Technology (PCAST) argued for more federally funded research and recommended that "after a brief transitional period involving substantial yearly increases, a steady-state allocation of no less than 0.5 percent of our nation's aggregate K-12 educational spending (or approximately $1.5 billion per year at present expenditure levels) be made." The PCAST noted "In 1995 the U.S. spent about $70 billion on prescription and nonprescription medications, and invested about 23% of this amount on drug development and testing. By way of contrast, our nation spent about $300 billion on public K-12 education in 1995, but

invested less than 0.1% of that amount to determine what educational techniques actually work, and to find ways to improve them."[4]

The President's Information Technology Advisory Panel (PITAC), in its February 2001 report to President Bush, re-iterated the PCAST's recommendation and called for partnerships with industry and private foundations to co-fund an aggressive information technology R&D initiative. The PITAC urged for a "meaningful investment increase, capable of generating the quantum leap forward that is needed, and our realistic assessment of the Nation's ability to appropriately identify, qualify, staff, and manage the research projects." The PITAC recommended that federal investments ramp up rapidly to $400 million per year with an expectation of equal funding from other sources, for a total of $800 million. The Committee recommended partnerships to manage effectively and efficiently as much as $200 million per year including matching funds.[5]

We recommend an R&D funding level within DO IT of $225 million. This amount represents funding for new or expanded activities that reflect the urgency, breadth, collaboration, and scale of needed research. The amount available for research would be less than the $1.5 billion recommended by PCAST and less than the $800 million recommended by PITAC. But it would take a major step forward in the research investment urgently needed to apply learning science and technology effectively to education, training, and lifelong learning for the 21st century.

A variety of modes of research should be supported: single investigator, multi-investigator grants, as well as small and large centers. Large-scale, sustained efforts, that may last five or more years are required. Research efforts should involve multiple disciplines and draw on expertise from academia, industry, and government laboratories. Efforts that cost several million dollars per year should not be unusual. Projects should focus on non-incremental, high-risk, high-potential projects spanning theory, experiment, and application. The research should not undertake generic information technology R&D such as Internet security or higher-resolution displays, but should leverage and inform these investments.

Conventional, peer-reviewed university research in learning should clearly continue, but a new approach is urgently needed to capture the opportunity. Given the demonstrated

difficulty of funding a diffuse research program in learning, the new management approach should err in the direction of a focus on building workable tools—a process that can lead to a highly practical (and often very basic) research agenda.

Evaluating Progress

The ultimate goal of the R&D described here is improved learning outcomes. Objective goals include faster learning speed and greater retention, without unacceptable increases in costs, and lowering the standard deviation of outcomes. Each component roadmap defines a chronology of R&D, with milestones for years Three, Five, and Ten, and recommended measures for evaluating progress. On a broader scale, proposed metrics include:

- Recognized learning improvements.
    - Increase learning speed by 30 – 50%
    - Heighten transferability of training to practical experience by 30%-50%
    - Improve retention of knowledge and skills
    - Raise performance equivalent to an improvement of 1-1.5 letter grades

- Retention of diverse populations at all levels of education and training and in all disciplines.

- High level of technology-enabled tools in use among teachers and specialists.

- Greater ease for teachers and specialists in building new instructional systems in a variety of subjects that support the full range of students.

- Certification and accreditation of the learning systems to science, technology, engineering, mathematics, humanities, and other learning needs (basic mathematics and sciences as well as other disciplines; training for specific competencies in certification skills).

- Cost-effectiveness.

Conclusion

Throughout a person's life, corporate and personal success depends as never before on the quality of education that's available. The basic skills the modern workplace requires have risen dramatically for workers of all ages. To excel, employees must be able to think and read critically, express themselves clearly and persuasively, and solve complex problems. Explosive growth in information and knowledge makes it impossible for education and training programs to fully explore even a single topic. To assimilate this explosion of information, all our citizens need new intellectual tools and learning strategies to think productively about science and technology, mathematics, history, social phenomena, and the arts. Providing these intellectual tools and learning strategies will require re-thinking how we teach and learn. We must make learning more productive and more engaging, and we need strategies to vastly increase access to high quality education and training to ensure that all citizens can participate. The only affordable way to accomplish this is to exploit emerging technologies to implement the recommendations of cognitive scientists to guide and enhance learning. The Roadmap in this report suggests a practical way to accomplish this transformation of learning.

We have a great deal of work to do, but the opportunity to make making learning more productive and more engaging for all people is simply too important for us to ignore. In a world economy that demands and rewards the best-educated citizenry, the United States needs to keep pace. It is difficult to imagine any innovation since the land-grant college legislation of the l9th century that could more positively affect our nation's long-term prosperity. We urge the Congress to seize this practical opportunity, offered by the establishment of the Digital Opportunity Investment Trust, to ensure that the benefits of a technologically sophisticated society are broadly shared.

End Notes

[1] Benjamin S. Bloom, "The 2 Sigma Problem: The Search For Methods of Group Instruction as Effective as One-to-One Tutoring," *Educational Researcher* vol 13: no. 6, June-July 1984

[2] C. Dan Brand, Chair, Federal Laboratory Consortium (FLC), "Leveraging our Federal Research and Development (R&D) Investment Through Technology Transfer," *Testimony before Committee on Commerce, Science and Transportation, Subcommittee on Science, Technology and Space*, U.S. Senate, April 15, 1999

[3] For a recent review of research partnerships see Charles W. Wessner, Editor, *Government-Industry Partnerships for the Development of New Technology*, National Research Council, 2003

[4] *Report to the President on the Use of Technology to Strengthen K-12 Education in the United States*, President's Committee of Advisors, on Science and Technology, Panel on Educational Technology, March 1997

[5] President's Information Technology Advisory Committee, "Using Information Technology to Transform the Way We Learn," *Report to President G.W. Bush*, February 2001

Acknowledgments

The Learning Federation appreciates the advice and assistance of the many experts who briefed us, participated in our workshops, and reviewed drafts of this report. A complete list of attendees at the Learning Federation workshops appears in the detailed component roadmaps. We thank the workshop chairs for their excellent work in organizing highly effective, informative meetings:

Question Generation and Answering Systems Workshop Co-Chairs:
Lisa Ferro, MITRE
Warren Greiff, MITRE
Art Graesser, University of Memphis
Max Louwerse, University of Memphis

Learner Modeling and Assessment Workshop Co-Chairs:
Eva Baker, UCLA
Randy Bennett, Educational Testing Service
Ralph Chatham, DARPA
Randy Hinrichs, Microsoft

Instructional Design Workshop Co-Chairs:
John Bransford, Vanderbilt University
Peg Maddox, CISCO

Next Generation Approaches for the Geometrical Modeling and Dynamic Simulation of Biological Systems Workshop Co-Chairs:
Gerry Higgins, SimQuest, LLC
Andries van Dam, Brown University

The following persons made major contributions in writing the component roadmaps: Jan Cannon-Bowers, Instructional Design; Brenda Sugrue: Learner Modeling and Assessment; Phil Dodds: Integration Tools; and Izzat Jarudi for researching and developing early drafts of the Simulation and Exploration Environments roadmap.

We would also like to thank the staff of the Federation of American Scientists for providing administrative leadership and for drafting this report, which could not have been completed without their diligent efforts. We thank Marianne Bakia, who departed FAS just before completion of the roadmap, for her significant contributions.

1717 K St. NW Suite 209
Washington, DC 20036
T (202) 454-4683
F (202) 675-1010

www.digitalpromise.org
digitalpromise@fas.org

Design/Edit: Reingold, Inc.