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An Information Commons for E-learning

DESIGNING A DIGITAL OPPORTUNITY INVESTMENT TRUST

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In recent years, computer and Internet use in the United States has grown dramatically. Over half of all U.S. households have access to the Internet, up from 18.6 percent in 1997.[1] Moreover, our ability to store, process, and transmit information has continued to increase at a phenomenal rate. Since IBM's introduction of the first computer hard drive in 1957, for example, storage density has improved by a factor of 8.5 million.[2] In the last 30 years, the number of transistors on an Intel microprocessor has increased from 2,300 to 220 million.[3] Even amidst the burst of the "dot com" bubble, many believe that new information technologies are having a dramatic impact on the way we live, work, learn, and communicate with each other.

One of the applications of information technology that has attracted the most attention is "e-learning." Some argue that technology has the potential to transform education and lifelong learning. In the future, learners of all ages will be able to tap in to vast digital libraries and online museums, use powerful simulations and games to "learn by doing," and collaborate on projects with peers who are located half way around the world. Adults will be able to acquire new skills at a time, place, and pace that is convenient for them as they struggle to balance the competing demands of work and family.

In pursuit of this vision, the U.S. has made a significant investment in expanding access to the Internet at schools, libraries, and community technology centers. The "e-rate" program, for example, provides $2.25 billion per year to help schools and libraries get connected to the Internet. Thanks to this program and private, voluntary efforts such as NetDay, the percentage of K-12 classrooms connected to the Internet has increased from 3 percent in 1994 to 77 percent in 2000.[4] This investment in hardware and network connectivity is necessary but not sufficient. We will not realize the potential benefits of widespread access to information technology without also creating cutting-edge content and applications that have the potential to significantly enhance education, training, and lifelong learning. As discussed below, federal government spending on educational research and development (R&D) is less than 0.1 percent of total expenditures on K-12 education. Federal investment in R&D and testbeds for digital libraries is also small and limited to a few programs at the National Science Foundation, the Library of Congress, and agencies such as the Institute for Museum and Library Services.

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Many applications of technology for education and lifelong learning involve repurposing existing "analog" content, such as putting textbooks and lectures on the Web. This may have some limited utility, but the real payoff will come when we understand how technologies can reshape the way teachers teach and students learn.

A useful analogy is the way in which companies have embraced the Web and other information technologies. At first, companies used the Web to post corporate brochures and marketing information. After a great deal of experimentation, leading companies began to use information technology (IT) to transform their businesses and boost productivity. Companies that have become "e-businesses" are giving customers the ability to order goods that are tailored to their needs, slashing the time required to bring new products to market, providing 24x7 customer service, eliminating costly paper transactions, reducing inventories by providing real-time information to suppliers, and increasing the sharing of "best practices" within the firm using corporate intranets. Similar experimentation is needed to promote innovation and excellence in the use of technology for education, lifelong learning, and other civic purposes.

In the last several years, there has been growing support for the notion of an "information commons" accessible to all. For example, a group of academics led by Stanford professor Lawrence Lessig has created a new nonprofit organization called the Creative Commons. This organization will develop a set of free software tools and licenses that will make it easier for artists and authors to make some or all of their rights available to the public for free. Lessig and others believe that this initiative is important because a rich public domain allows us to "stand on the shoulders of giants by revisiting, reusing, and transforming the ideas of our works and our predecessors."[5]

Similarly, David Bollier has argued that the "tragedy of the commons," which suggests that a common resource will always be neglected and over-exploited, is not always the appropriate metaphor for understanding our current circumstances. In fact, "the more that information is shared (and then modified, corrected, and used as a platform for still further knowledge-creation), the more that knowledge grows and improves."[6]

This paper explores some of the proposals that have been made to create such a commons, such as the Grossman-Minow proposal for a Digital Opportunity Investment Trust (DOIT) and the Public Telecommunications Service (PTS), and identifies a few of the institutional and policy issues that I think are important, including the opportunity to pay for these new public investments through the earmarking of auction revenues paid by commercial licensees of the public airwaves. There are many possible visions of what an information commons might entail. In this paper, I focus on the potential of a commons to improve and enhance education and lifelong learning for all Americans.

I do not want to suggest that technology is a cure-all for every challenge we face in K-12 education, higher education, and workforce development. It is instructive to read the predictions of previous technological enthusiasts. In 1922, Thomas Edison said: "I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbook." In 1932, Benjamin Darrow said that radio would "bring the world to the classroom, to make universally available the services of the finest teachers, the inspiration of the greatest leaders." It is also sobering to learn that today, even at schools that are in the heart of Silicon Valley, "less than 5 percent of teachers [have] integrated computer technology into their regular curricular and instructional routines."[7]

If hype is not the answer, neither is inaction. Today, according to Nobel Prize Laureate Gary Becker, "human capital is estimated to be three to four times the value of stocks, bonds, housing, and other assets."[8] Even a small increase in the productivity of learning would yield huge returns. Given the importance of an educated citizenry to our economy and our polity, making the most of these new "Information Age" tools is the most sensible course of action.

Proposals for an Information Commons

Digital Promise

In April 2001, Lawrence K. Grossman, former president of NBC News and PBS, and Newton N. Minow, former chairman of the Federal Communications Commission, issued a report entitled *A Digital Gift to the Nation*.[9] This report calls for the creation of a Digital Opportunity Investment Trust, which would support innovative uses of digital technologies to enhance education, lifelong learning, and our civic and cultural organizations. The trust fund would be capitalized by dedicating $18 billion in revenue from upcoming auctions of temporary licenses to use the electromagnetic spectrum, also known as the public airwaves. Currently, the proceeds of spectrum auctions go to general federal revenues and are not earmarked for any specific purpose.

As Grossman and Minow note in their report, the United States has a long and successful track record of using public assets to finance investments in education and lifelong learning. In 1787, the Northwest Ordinance set aside public land to support the creation of public schools in every new state. In 1862, during the middle of the Civil War, President Lincoln signed the Land-Grant College Act. This legislation, sponsored by Senator Justin Morrill, helped create 105 land grant colleges and universities, including the Massachusetts Institute of Technology (M.I.T.), the University of California, Ohio State, and Cornell. Together, these colleges and universities award 500,000 degrees each year, 30 percent of all bachelor's and master's degrees, 60 percent of all doctoral degrees, and 70 percent of the nation's engineering degrees.[10]

Under the Grossman-Minow proposal, the government would earmark revenue from another public resource (other than public land)—the electromagnetic spectrum to capitalize a trust to finance investments in our common future. The Digital Opportunity Investment Trust would be modeled after organizations such as the National Science Foundation (NSF), the National Institutes of Health (NIH), and the Defense Advanced Research Projects Agency (DARPA), which have long supported innovation in science, health, and defense, respectively. DOIT would be given the mission to "[support] innovative and experimental ideas to enhance learning; broaden knowledge; encourage an informed citizenry and self-government; make available to all Americans the best of the nation's arts, humanities, and culture; and teach the skills and disciplines needed in this information-based economy."

Grants would be competitively awarded, with eligibility open to both individuals and local, regional, and national institutions devoted to "public purposes." The Trust would seek to encourage partnerships and alliances between businesses and organizations such as schools, libraries, museums, public broadcasters, community and civic organizations, and research institutes. To catalyze additional investment, matching funds from other public and private institutions would be encouraged, but not required.

A number of organizations and individuals have endorsed the proposal, including the American Association of Universities, CEOs from leading high-tech companies, the American Library Association, the Communication Workers of America, and the American Association of Museums. Senators Dodd and Jeffords have introduced legislation (S. 2603) that would create a Digital Opportunity Investment Trust. Representative Markey has introduced "The Wireless Technology Investment and Digital Dividends Act of 2002" (H.R. 4641). Both Republican and Democratic members of Congress requested that the National Science Board examine the Grossman-Minow proposal. The National Science Board called the Digital Promise proposal "a bold vision intended to increase the value of information technologies, the digital spectrum, and advanced Internet."

President's Information Technology Advisory Committee (PITAC)

The President's Information Technology Advisory Committee (PITAC) was created to advise the President, federal agencies, and Congress on issues related to the funding of information technology research and development. PITAC was composed of nationally recognized experts in IT research from the information technology industry, academia, and national labs. PITAC has been unusually effective and influential as a federal advisory committee. The committee's call in 1998 to increase federal funding for long-term IT research led to significant increases in President Clinton's FY2000 and FY2001 budget in this area.

In February 2001, the PITAC submitted two reports to President George W. Bush, entitled *Digital Libraries: Universal Access to Human Knowledge* and *Using Information Technology to Transform the Way We Learn.*[11] PITAC's *Digital Libraries* report calls for "anytime, anywhere access to the best of human thought and culture, so that no classroom or individual is isolated from knowledge resources." The report makes four principal recommendations: increased support for digital library research, the establishment of several large-scale digital library testbeds, funding to make all public federal material consistently available on the Internet, and federal leadership on intellectual property issues. PITAC found that more research was needed on topics such as:

- Metadata systems for describing and organizing digital collections (the Dewey Decimal System is a metadata system for conventional libraries);

- Automated management of very large digital collections that may exceed a petabyte in size, which is fifty times the size of the Library of Congress;
- Interoperability, which is the ability to find and retrieve information across multiple collections maintained by different organizations;
- Long-term storage and preservation to prevent digital information from being lost to future generations;
- Management of intellectual property rights; and
- Usability of digital collections by diverse populations (e.g. different languages, different skill levels).

Similarly, in their report on transforming learning, PITAC found that "education and learning R&D are dramatically underfunded." For example, of the $300 billion expended on K-12 education, it is estimated that less than 0.1 percent is devoted to R&D, as compared to the 23 percent R&D-to-sales ratio in the pharmaceutical industry. [12] PITAC calls for significantly expanded research on education and learning R&D, including topics such as:

- Identifying the most effective uses of information technology to enhance learning;
- Supporting learning by students with cognitive and physical disabilities;
- Creating tools that reduce the time and cost to develop content, which currently requires 100-200 hours to develop for every hour of instructional material;
- Developing educational technologies such as simulation and visualization that make difficult concepts accessible to more students;
- "Embedding" assessment in learning environments and that can be used to continuously guide instruction; and
- Constructing collaboration tools that can create "communities of learners," and the sharing of expertise among and between peers, tutors, and experts.

PITAC is the latest in a series of committees and organizations to call for increased funding for learning science and technology. This goal was also embraced by the Department of Education's most recent National Educational Technology Plan, which called for "research to improve the state-of-the-art in educational hardware and software, digital content, networked applications, and other technology-enabled applications of pedagogy and assessment."[13]

Public Telecommunications Services

In a proposal supported by a grant from the Ford Foundation, researchers from the University of Maryland (Peter Levine and Robert Wachbriot) have explored the potential of the Internet and electronic media to foster "civic renewal." In recent years, there has been growing concern about the health and vitality of our democracy and civil society, given "severe declines in voter turnout, trust in government, trust in other people, readership in daily newspapers, interest in public issues, and participation in voluntary associations."[14]

Levine and Wachbriot believe that electronic media may create new opportunities for citizens to engage in community and public types of problem solving. They would like to see an "information commons" that is accessible to all, that enables people to be producers as well as consumers of information, and that fosters discussions about public issues that bring together people with different views and perspectives.

They cite, as an example, a "Community Information Corps" that has been working to create an "Information Commons" for the west side of St. Paul, Minnesota. During the summer of 2001, for example, six teenagers interviewed 98 people and collected information from 30 organizations to create a map of 119 "learning opportunities," such as parenting skills, adult literacy, public health, homework help, and computer skills. The information will eventually be accessible using a geospatial information system and a clickable digital map of the neighborhood. Other Community Information Corps projects include: stories authored by aspiring journalists; Public Service Announcements produced by local youth; and a website produced by high-school students on "West Side" life.[15]

Levine and Wachbriot call for a Public Telecommunications Service that would:

- Link local "Information Commons" activities into regional and national networks;

- Assist communities, organizations, and citizens that want to provide content of civic value with money, equipment, and training; and

- Work with organizations such as a nationwide Community Information Corps to provide training to local organizations. The Community Information Corps might be a section of the AmeriCorps that recruits technically sophisticated young people who can help build the information capacities of local communities.

Foreign Government Efforts

A number of foreign governments have launched major initiatives to expand access to online educational and cultural resources.[16] One example is the United Kingdom's New Opportunities Fund, which generates its income from a lottery. The fund is investing £50 million (more than $75 million) to support various digitization projects around three broad themes: cultural enrichment, retraining, and citizenship.[17] Examples of projects include:

- Support for exploration of the ethical issues surrounding the biotech revolution, such as stem cells, cloning, xenotransplantation, and genetically-modified foods;

- Websites that feature local community participation opportunities for senior citizens, including learning, fitness, and volunteering;

- Online training for young entrepreneurs interested in starting their own business;

- Three-dimensional virtual reality models of famous archaeological excavations;

- Digitization of historic manuscripts, photographs, oral histories, paintings, etc.; and

- Online advice on the rights and responsibilities of citizens in ten different languages.

Policy and Design Issues for an Information Commons

Before creating an entity like the Digital Opportunity Investment Trust (DOIT), policymakers would need to make some basic decisions on its mission, structure, and mode of operation as well as grapple with several important policy issues. Below are a number of potentially important design and policy issues:

1. How broadly should the mandate of a new entity be defined?

The Digital Promise proposal emphasizes the need for investments in education and training, but also discusses the importance of bringing our civic and cultural organizations into the 21st century. The proposal for a Public Telecommunications Service stresses the importance of using the Internet and other forms of electronic media to foster civic renewal and participation in our public life. One could also imagine using the revenue from spectrum auctions and fees to support the development of IT applications that are not specifically related to education and lifelong learning, but have a clear public interest dimension. An example might include IT applications that improve the effectiveness of non-profit organizations, or online information and services that empower low-income communities that are underserved by commercial providers.

2. What kinds of activities should the entity support?

This obviously depends on the mission and mandate of the organization. For example, if its mandate were to promote education and lifelong learning, it might support:

- Research and development that is designed to advance the state-of-the-art of learning technologies, content creation, and digital libraries.

- Educational software, next-generation learning environments, digital content, large-scale digital libraries, and tools for content creation that incorporate and use advanced technologies.

- Standards-setting activities and the development of reference implementations in technical areas that support reusability, interoperability, and information discovery.

- Evaluation including, where appropriate, third party evaluation with an experimental design. Many experts believe that the "gold standard" for evaluation is "randomized field trials" in which individuals or organizations are randomly assigned to one of two or more interventions. This allows researchers to make statistically valid comparisons between the relative effectiveness of the interventions. Currently, only a tiny fraction of educational research uses randomized field trials.[18]

- Outreach and dissemination. Educational content will only be used if teachers and students are aware of it.

3. Are the activities envisioned under these proposals an appropriate role for government?

A number of concerns have been or might be raised about these proposals. Some argue that there is no need for them. Adam Thierer and Wayne Crews of the Cato Institute argue that "a better idea is to simply return those billions of dollars to taxpayers so that they might choose their own programming and decide for themselves what educational or cultural initiatives to fund."[19] Similarly, in testimony before the Democracy Online Task Force, *Wired* reporter Declan McCullagh argued:

> "How do we create a public space online? I think the answer is that we don't need to create one. We already have one, and an unexpectedly wonderful one at that. Think of the Internet as an unlimited expanse of public park, where soapboxes are free to anyone who wants one…It is true that obscure sites may not get the same number of visitors as more mainstream ones. But that's true offline as well as online: More people read Tom Clancy than Hemingway."[20]

It is certainly the case that it is free (or very inexpensive) to set up an e-mail list, create a webpage, start your own "blog" (weblog), or post to a Usenet news group. The fact that the Internet allows individuals to be producers as well as consumers of information is arguably its most important attribute and one worth cherishing and fighting to maintain. However, as discussed below, realizing the full potential of technology to improve education and lifelong learning will require sustained support for larger-scale projects, not all of which can be created exclusively by individuals and the "gift economy" of the Internet.

Some in industry have watched government activities in electronic commerce with trepidation, and have argued that the government should more rigorously adhere to policies such as the Office of Management and Budget (OMB) Circular A-76, which states that "the Government should not compete with its citizens."[21] Industry is particularly unhappy with the Internal Revenue Service, which has contemplated offering online tax preparation services, and the U.S. Postal Service, which is developing consumer financial services such as electronic bill payment. The analogous concern is that a project supported by Digital Promise might compete with a private e-learning company.

Although the Digital Promise proposal should clearly avoid duplicating private sector efforts, fears that it will crowd out private sector initiatives are misplaced. Indeed, it is likely to be a catalyst for additional private sector activity, in the same way that DARPA and NSF support for the ARPANET and the NSFNET led to today's thriving commercial Internet. By improving state-of-the-art learning technologies and by demonstrating their potential to significantly improve learning outcomes, the Digital Promise proposal will significantly expand the market for commercial e-learning companies.

Finally, some are worried that the public dollars will undoubtedly come with strings attached, particularly if the organization has a broad mandate to experiment with the civic uses of the Internet. I think this is a legitimate concern and is a strong argument for giving the organization a high level of political independence.

4. Is there a market failure?

Economists of all ideological persuasions and many policymakers are likely to ask whether these proposals address a specific market failure. That's because markets are an efficient means for allocating scarce resources, and governments are generally not.

I believe that there are several plausible "market failures" that a Digital Opportunity Investment Trust could help address. First, an explicit goal of the Digital Promise is to increase support for R&D for learning technologies. It is generally acknowledged that private sector firms will underinvest in R&D because scientific knowledge is non-excludable and non-rival. A good is "non-excludable" if it is difficult to prevent people from enjoying the benefits of it, even if they did not purchase it. A good is non-rival if an unlimited number of people can consume it. As Thomas Jefferson so eloquently put it, "He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me." Economists that measure the "rate of return" of R&D have concluded that the social rate of return is significantly higher than the private rate of return.[22] Even with the ability to secure patents for inventions, firms still can't capture all of the benefits that flow from investing in R&D.

In a recent paper, J. Bradford Delong and A. Michael Froomkin point out that digital goods in general lack rivalry and excludability, and that this has significant implications for 21st century economic policy. "As we look at developments along the leading technological edge of the economy, we can see that considerations that used to be second-order 'externalities' that served as corrections growing in strength to possibly become first-order phenomena. And we can see the *invisible hand* of the competitive marketplace beginning to work less and less well in an increasing number of areas."[23]

Furthermore, some of the projects that might be supported by the DOIT may lack immediate commercial potential, but may have high social rates of return. Consider, for example, the market for adult literacy software. There are tens of millions of Americans that are reading at the 5^{th} grade level or below. An adult without a high school diploma earns 42 percent less than an adult with a high school diploma. Forty-one to 44 percent of adults that scored at the lowest level of literacy (under the National Adult Literacy Survey) lived in poverty, as compared to only 4 percent to 6 percent of adults that scored at the highest level.[24] The social return for effective, engaging software for adult literacy would clearly be high. Yet the amount of money that is available for commercial developers to create software to address this market is a tiny fraction of the budget for the latest PlayStation2 or Xbox game. There is a compelling case to support research, development and evaluation on software that would allow adults with low incomes and low levels of education to upgrade their skills, such as adult literacy, adult basic education, GED equivalence, English as a Second Language, family literacy, and skills training for entry-level jobs.

The potential presence of a market failure is not sufficient to justify government intervention. One must also weight the risks of "government failure" against the potential social benefits of supporting the kinds of investments called for by the Digital Promise and other proposals. One could also respond to the market failures described above and try to develop technologies (e.g. digital rights management, digital watermarks, superdistribution) or policies (stronger protection of intellectual property laws) that create greater degrees of rivalry and excludability.

Policymakers must also design the most appropriate form of government intervention—ideally one that harnesses market forces to the maximum extent possible. For example, environmental policymakers have created markets for "the right to pollute" as opposed to using traditional command and control regulations. One open question is whether the goal of improving learning through creative use of advanced technologies can best be supported by (a) increasing investment in R&D; (b) increasing the purchasing power of potential users, such as school districts; or (c) some combination of the above. The answer to this question turns on how satisfied one is with the current "state-of-the-practice" of commercial educational software and content providers.

5. Where should the entity be located?

Policymakers could elect to create a Digital Opportunity Investment Trust or PTS in an existing agency (such as the National Science Foundation), create a new federal agency, or create a quasi-governmental entity.

In my view, if the Administration and Congress decided to give this task to an existing agency, the NSF would be the most appropriate candidate. It has some experience with funding educational technology research and content. It has several high-profile digital library initiatives, including one that has been done in partnership with cultural agencies such as the National Endowment for the Humanities, the Smithsonian, and the Institute for Museum and Library Services. NSF is relatively well run and is the only government agency to receive OMB's top rating for financial management.

There are some potential risks to giving this responsibility to the NSF, however. First, the NSF lacks expertise in many of the areas that might be funded under proposals such as the Digital Promise or the PTS. Although it has very strong ties with university researchers, it has weaker relationships with museums, libraries, civic organizations, public broadcasting, and the K-12 community. Second, support for this initiative might "crowd out" increases in other areas of research. The NSF is the only agency that has the responsibility for supporting all disciplines of science and engineering, and significant increases in the NSF budget are needed to correct the growing imbalance between biomedical research, and the physical sciences and engineering. Third, NSF has had a tendency to support many researchers with small grants, as opposed to backing a few teams with the resources that are needed to truly make a difference. Finally, although the NSF has funded many excellent educational software and technology-based curriculum projects at the K-12 and university level, many have disappeared without a trace after the initial funding has run out, or have failed to have an impact beyond the institution within which they were developed.

Creating an independent, quasi-governmental entity does have some potential advantages. The entity might have a great ability to raise matching funds from foundations and other nongovernmental sources, and might also be more flexible than a federal agency. A new entity would also have a great opportunity to recruit the people that are and establish a culture that is appropriate to its mission. Policymakers, however, may be reluctant to entrust a fledgling organization with the level of resources and responsibility that is contemplated under the Digital Promise and similar proposals.

6. How should the money be allocated?

Grants should be allocated on a competitive basis, with guidance from panels of outside experts. However, program managers should be given the discretion to fund risky or innovative proposals that may not make it through a traditional peer review process, and to select projects that make sense as a "portfolio" of activities and are likely to add up to more than the sum of the parts.

Making good decisions and attracting great proposals will require hiring first-rate program managers. If policymakers decided to make the organization a federal agency, it should aggressively use Intergovernmental Personnel Act (IPA) authority, used frequently by agencies such as DARPA and the NSF. The IPA allows government agencies to hire people from universities and certain non-profits for up to four years. By using this authority, the organization can help ensure that its program managers are the peers of the best people in the field.

Grants also need to be large enough and of sufficient duration to make a difference. Developing cutting-edge educational software, for example, may require a team of cognitive scientists, computer scientists, subject-matter experts, specialists in user-centered design and human-computer interaction, and programmers in addition to active collaboration with one or more school districts to provide early feedback. These kinds of multidisciplinary teams can easily cost several million dollars per year or more to support. Large-scale digitization efforts such as the American Memory project discussed below can cost tens of millions of dollars.

Some experts believe that the federal government has not supported grants with the necessary scale and scope. For example, some argue that traditional educational technology research projects conducted in a lab or a single classroom do not shed any light on what it will take to move these innovations into everyday use in a large number of classrooms.[25] Others believe that supporting projects that provide an infrastructure for a wide range of educational uses of technology will be critical. In the K-12 context, that might include technology use in many subject matter areas, data-driven analysis of student performance, teacher-parent communication, multimedia student portfolios, and online professional development for teachers. No single application will convince schools and other educational institutions to aggressively adopt new technologies, just as no one single application of computers (e.g. e-mail, word processors, Internet search, spreadsheets) will be sufficient to drive adoption.[26]

7. *What should the intellectual property (IP) policy of the entity be? How will this affect the sustainability and scalability of projects?*

This is an enormously complicated topic, given that the IP policy is likely to balance several competing objectives. Current federal statutes such as the Bayh-Dole Act allow universities to patent and license inventions made with support from federal funding, but they are not required to do so. An analogous approach for content and software (which usually involves copyright, as opposed to patent policy) would be to allow the grantees to make their own decisions on copyrighting and licensing material that is produced.

As opposed to leaving IP policy in the hands of grantees, the government could encourage grantees to put their works in the public domain, or alternatively, experiment with various "open source" or "open content" approaches. This might have several advantages. First, it could maximize public access to the content and software funded by the organization. Second, the content and software could attract a community of people willing to improve upon it, which has happened with successful open source software projects, such as Linux, Sendmail, Perl, and Apache. Third, it could reduce the risk that a company feels that one of its competitors has been given an unfair competitive advantage by being granted exclusive rights to government-funded IP.

However, making software and other forms of content "free" to the public does raise important issues about sustainability and scalability. Many of these projects will require added investment to make them available over time, and to make them available in a form that is truly useful to more people. These costs might include storage, high-speed Internet access, marketing, customer support, porting the product to multiple platforms, translating the content to new formats, making enhancements, etc. If the content is free, companies may not be willing to make these investments and non-profit entities may be denied the revenue stream that is needed to break even.

For example, two of the most successful large-scale digitization projects in the United States, JSTOR and AMICO, are both interested in becoming self-sustaining.[27] JSTOR, a non-profit organization originally funded by the Mellon Foundation, acquires rights from publishers to complete sets of scholarly journals in the social sciences and humanities, digitizes the content, and makes this electronic archive available on the Web through institutional site licenses. AMICO, the Art Museum Image Consortium, has still images and detailed background information on 78,000 works of art, including paintings, sculptures, drawings, prints, photographs, and manuscripts. AMICO is licensed to universities, libraries, schools, and museums. If these projects made their content available to the public for free, it is difficult to see how they would become self-sustaining.

There are a number of companies that are exploring the commercial viability of different open source business models. Some companies are concentrating on making money by providing service and support. Others are making proprietary enhancements to open source software, which is permitted by some open source licenses (e.g. BSD) but not by others (e.g. the GNU General Public Licenses). Making software supported with public dollars available to the public under a BSD-style license would allow companies to profit from their incremental investment in improving the product, while still maintaining unrestricted access to the original version.

Given that the goal of the initiatives that are under discussion is to create an "information commons," any IP policy should clearly favor public domain and/or open source approaches. However, given the uncertainty about how these approaches will impact the sustainability and scalability of the projects over the long-term, some experimentation with other IP policies and business models should be permitted.

There should also be support for a centralized archival function, such as the Internet Archive, which currently maintains a 100-terabyte collection of 10 billion web pages going back to 1996.[28] If, after the initial funding runs out, the grantee is unable to host and maintain the content, the Internet Archive (or similar organization) could provide some level of continued access to the public.

Possible Projects to Improve Education and Lifelong Learning

It is impossible to determine, in advance, the kind of ingenuity and creativity that support for an "information commons" might unleash. Below are a few examples that demonstrate the variety of ways in which technology might improve education and lifelong learning. Although many of the examples focus on K-12, the intent of the Digital Promise is to support innovation in higher education, life-long learning and workforce development as well.

Virtual Worlds

During the last several years, interest in so-called "massively multiplayer online games" or "virtual worlds" has exploded. One of the most popular of these virtual worlds is a "swords and sorcery" game called EverQuest, with an estimated 400,000 active subscribers as of summer 2001. EverQuest is based on role-playing games such as Dungeons & Dragons, in which players design characters by choosing a race, occupation and gender as well as physical and mental attributes. Each of these characters will have different strengths and weaknesses. An ogre, for example, is strong and hard to kill in battle, but stupid. An elven wizard has the ability to cast magical spells, but will not last long in hand-to-hand combat.

When logged on to the game, players move through a 3-dimensional world, either by themselves or with other groups of players. If they succeed in killing the computer-generated characters that they encounter, they gain treasure, items with magical powers, new skills, and an ability to emerge victorious from battles with more dangerous creatures.

Many players find themselves spending a large amount of time in these virtual worlds. One recent study concluded that the average EverQuest player was spending 4.7 hours a day in Norrath (the name of the EverQuest virtual world), and that more than 30 percent of the adults surveyed spent more time in Norrath than they did at work.[29] Players give a number of reasons for enjoying the game, including the ability to explore a fantasy world, interact socially with other players, pretend to be someone else, and achieve goals, such as completing a quest or becoming more powerful.[30] Some players are even willing to pay "real" money for the "virtual" currency and treasure of these worlds.

One obvious question is whether virtual worlds could be used to teach children and adults anything more than how to kill monsters and take their treasure. One such effort is the NSF-funded MUVEES project (Multi-User Virtual Environment Experiential Simulator), which is being developed by researchers from Harvard, George Mason, and the Smithsonian Institution. The goal of MUVEES is to simulate a town from the 1880's called River City. Middle-school students are given the task of exploring this 3-D virtual town to find out why its citizens are plagued by various illnesses. They communicate with each other via instant messaging, and also get clues from computer-generated "avatars" that represent the citizens of the town. The simulation is designed to help students learn experimental design. Students have to identify a problem through observation and inference, and then formulate and test a hypothesis. Another key goal of the researchers is to dramatically improve the educational outcomes of the bottom third of the students who are "disengaged from schooling and typically are difficult to motivate even by good teachers using inquiry-based pedagogy. We are studying whether MUVEs with deep content and challenging activities that resemble the entertainment and communication media these students use outside of school can reengage them in learning."[31]

Another interesting experiment would be to determine whether virtual world technology could be used to give at-risk youth the skills that they need to start and run their own business. Many programs have been developed to provide young people with basic entrepreneurial skills, such as opportunity recognition, sales and marketing, reading an income statement, and raising capital. Unfortunately, access to programs such as entrepreneur "summer camps" for students is limited. As the EverQuest example illustrates, it is relatively straightforward to increase the number of people that can participate in a virtual world by adding servers. Local chambers of commerce could encourage young people to participate in these virtual worlds by sponsoring tournaments, and business executives and MBA students could serve as online mentors.

To date, most game developers have been reluctant to explore alternatives to the "hack and slash" genre.[32] In part, that is because these virtual worlds involve significant development costs. EverQuest took three years to develop and saw its development team grow to 30 people. Sony Online Entertainment now has 50 developers who are adding content to the game. Even with these large development costs, only a small percentage of games ever become significantly profitable. There is a real risk that adding a significant amount of educational content to a game could make it less engaging and compelling.

To me, the success of virtual worlds and video games in general raises the following questions:

- How and to what extent can educational content and pedagogy be added to virtual worlds and other game genres without undermining "game play"?

- Would game companies make their game engines and software development kits available to researchers or developers seeking to explore the educational potential of games?

- What is the commercial market for educational games, and is government seed funding necessary to get commercial companies and university researchers to explore the educational potential of games?

Visualization, Modeling and Simulation

Many experts believe that software for visualization, modeling and simulation can be a powerful tool for enabling students to more intuitively understand difficult concepts, and to apply what they have learned in real-world contexts. For example, software developed at UC Berkeley called ThinkerTools simulates objects on the screen that move according to the laws of physics. The program can adjust gravity and friction, and add arrows representing force, acceleration and velocity, so that students can actually "see" Newton's Second Law of Motion (F=ma). Middle school students that used the software were able to outperform high school physics students in their ability to apply these concepts to real-world problems.[33]

There are a number of different approaches to using simulation for learning. Roger Schank and his colleagues have been developing educational simulations for schools, universities, and companies that allow students to learn by doing, learn from failure, and learn from stories. Schank's approach is to create "goal-based scenarios" which are closely related to roles or jobs that the student hopes to be able to perform in the future:

- In *Immunology Consultant*, students must successfully diagnose a patient that has a disease with an immunological cause. Students must interview the patient, request lab tests, and consult a large database of video clips from experts.

- In *Mastering Project Management*, new hires at Deloitte and Touche acquire some of the soft skills associated with the management of large projects by interacting with a fictional client. They learn how to deal with delays, client confusion about the scope of a project, and conflicts between multiple stakeholders. The course was designed to highlight the most common and expensive mistakes that inexperienced managers make.

- Simulations developed to train customer service representatives has allowed GE Capital Services to cut training time by 50 percent. After training using the software, new hires outperform experienced employees.[34]

Student-Authored Content

People who are skeptical of the educational value of computers and the Internet should look at the quality of the educational content that students have created. One organization that has helped stimulate a broad range of educational websites produced by students is ThinkQuest, started by Advanced Network & Services in 1995.[35] Since then, tens of thousands of students and teachers from over 100 different countries have participated, developing interactive websites on topics as diverse as starting a small business, Chinese regional cuisine, genetics, the human circulatory system, Van Gogh, rhetoric, and Mahatma Gandhi. In collaboration with a number of partners, ThinkQuest is now supporting programs in many different regions and countries, and those that are targeted to specific audiences. One is called "Imagining the Future," which encourages students and educators to explore how students will learn when they have access to high-speed networks, large-scale public digital resources, and advanced platforms for creating educational products.

One research direction that shows promise for increasing the sophistication and educational value of student-authored work is an approach called "programming by demonstration" (PBD). The goal of PBD is to make it possible for novices to program computers. Currently, even among novices that take a computer course, less than one percent continue to program once the class ends. For most people, learning to think like a computer does not come easily. Advocates of novice programming compare the status quo to "having a car that you can't drive. Instead, you must have a chauffeur to drive you around. Even worse, the chauffeur takes his orders from a company, not from you."[36]

A prominent example of a PBD technology is Stagecast Creator, a software tool that enables children to create and share their own interactive stories, games and simulations. A commercial spin-off from the Apple Advanced Technology Group, Stagecast Creator allows most children to create running visual simulations within 15 minutes. For example, imagine that a student wants to create a train simulation in which an engine moves to the right if there is a straight piece of track to its right. Using Stagecast Creator, this can be accomplished simply by dragging and dropping the engine, without any recourse to a traditional programming language.

The authors of the program report that one class using the program asked to extend the school year so that they could continue to work on their simulations, and that a third of the class continued to come to school during the next six weeks of vacation.[37] Using Stagecast Creator, simulations have been created that allow students to learn about probability, the diffusion of molecules through membranes, and the sudden appearance of recessive mutations in fossil records.

Intelligent Tutoring Systems

Research has shown that the difference between those taught in classroom groups of 30 and those taught by an individual instructor could be as high as two standard deviations. In other words, the average student taught by a one-on-one tutor performs better than 98 percent of the students in a standard classroom. Obviously, providing every student or adult learner with a one-on-one tutor is not an economically feasible solution. Researchers, however, have been working to develop software that has some of the benefits of an individual instructor, known as "intelligent tutoring systems" (ITS). These systems have one or more of the following capabilities:

- Continuously assesses the current strengths and weaknesses of the student's understanding of the subject material;
- Generates appropriate instructional material that is tailored to the progress of the individual student;
- Contains a computer model of what an "expert" knows in a particular subject area;
- Employs a variety of pedagogical approaches, including explanations, guided discovery learning, coaching and critiquing; and
- Monitors, evaluates, and improves its own teaching performance over time as a function of experience.[38]

Although researchers have not developed an ITS that is as effective as a one-on-one tutor, they have made significant progress. Scientists at Carnegie Mellon University, for example, have collaborated with an award-winning math teacher to create a "cognitive tutor" for Algebra I.[39] Students who have used the tutor have performed 15 to 25 percent better on standardized tests, and 50 to 100 percent better on assessments of complex mathematical problem solving. High school students that used the Cognitive Tutor Algebra were more than twice as likely to enroll in Algebra II after a year of geometry than the students in a traditional Algebra I course.

The software has a number of advanced capabilities. Teachers can create their own math problems that are more personally or culturally relevant to students. When a student is having problems, the Algebra Tutor provides hints and feedback that maximize learning opportunities for the student, as opposed to immediately providing the right answer. The software is also designed to help students make connections between multiple ways of representing and solving problems, using tables, graphs, equations, and text. This software has been commercialized by Carnegie Learning Systems. Although the company is still struggling to succeed commercially, their Cognitive Tutors in Algebra I, Geometry, and Algebra II are now being used in 35 of the nation's 100 largest school districts.

Another interesting example of an intelligent tutor is the Reading Tutor, created by Jack Mostow's Project LISTEN.[40] The goal of the project is to "listen to children read aloud and help them" using speech technology and expertise from a number of other fields, including intelligent tutoring, cognitive science, and human-computer interaction. Students wear headsets with microphones and read aloud stories as the computer displays sentences on the screen. The reading tutor intervenes when the reader makes mistakes, gets stuck, or asks for help. For example, if the computer hears the student mispronounce a word, it may offer a clue, such as pronouncing a rhyming word with a similar spelling. One evaluation of the Reading Tutor in an inner-city elementary school found that third-graders who started almost three grades below their grade level were able to make an average of two grade levels of progress in less than eight months.

The team developing Project LISTEN has also been exploring the potential of intelligent tutors to be used to experiment with different instructional interventions. "Each time the specified situation arises, the computer chooses randomly among its alternative actions. The computer records the machine-observable consequences of this choice on the ensuing dialogue. Subsequent analysis assesses the outcome of its chosen action."[41]

The social benefits of increasing the number of students who can read well by the 4th grade would be enormous, as outlined in Congressional testimony by NICHD's (National Institute of Child Health and Human Development) Reid Lyons:

- By middle school, children who read well read at least ten million words during the school year, while children with reading difficulties read less than 100,000 words during the same period.

- According to the National Center for Education Statistics, 38 percent of fourth graders can't read and understand a paragraph that one would find in a simple children's book—a rate that is as high as 70 percent in some low-income urban school districts.

- Over 75 percent of the children who eventually drop out of school report difficulties in reading. Only 2 percent of students who receive compensatory education in reading ever receive a 4-year college degree. At least half of adolescents and young adults with criminal records have reading difficulties. And in some states, the size of prisons a decade in the future can be predicted by fourth grade failure rates.[42]

Improving Learning Outcomes for Students with Disabilities

According to recent government statistics, more than five million students ages 6 to 17 received special education services during the 1997-98 school year.[43] Advocates of technology for students with physical and learning disabilities believe that information technology can help "level the playing field."

One example of a product that is helping students with learning disabilities is FastForWord Language. Scientific Learning, the company that developed FastForWord, claims that students who train with this product make language gains of 1 to 2 years in just 4 to 8 weeks. The product is based on recent advances in our understanding of dyslexia and other language learning disabilities. In spoken English, the brain automatically blends 44 component sounds (phonemes) into words at a rate of 8 to 10 phonemes per second. People with dyslexia have difficulty translating this process to print. They have difficulty breaking spoken words into their component words (phonological awareness) and matching these letter sounds to the letters that represent them (phonetics). Using a technology known as functional magnetic resonance imaging (fMRI), researchers can watch different parts of the brain "light up" in real time as they perform certain intellectual tasks. When asked to perform tests that measure their basic abilities in phonological awareness, dyslexic readers show less activity in the brain region that links print skills to the brain's language areas.[44]

Researchers at Rutgers and University of California, San Francisco, developed video games designed to improve the reading skills of children with language-impairments such as dyslexia. In one of the programs, a clown utters two closely related sounds that have been stretched out to 400 milliseconds. (Most children can recognize phonemes lasting only 40 milliseconds.) Once the children can distinguish between these sounds, they can move on to more rapid and realistic phonemes, and eventually to words, sentences, and stories.[45] Several university researchers founded Scientific Learning in 1996. As of December 2001, more than 100,000 students had used the product.

Another leading example that helps students with physical disabilities is M.I.T.'s Physics Interactive Video Tutor (PIVoT).[46] Students have 24-hour access to video clips of their professor demonstrating and explaining difficult concepts, answering frequently asked questions, and going through problem solutions step by step. PIVoT also provides 35 lectures, an online textbook, and physics simulations. By partnering with the National Center for Accessible Media (NCAM), M.I.T. has been able to make this course more accessible for students who are blind, visually impaired, deaf and hard of hearing. Multimedia clips are captioned for students who are deaf or hard of hearing, and also have audio descriptions for students who are blind or visually impaired. The graphics and image maps contain text tags that make it easier for a student using a screen reader or a talking Web browser to navigate the website. NCAM is also leading an effort to develop standards for online learning resources accessible to people with disabilities.

Access to Our Shared Cultural Heritage

An important educational application of information technology is to put access to our shared cultural heritage at the fingertips of every American. Perhaps the best known effort is the Library of Congress's American Memory project, which has already digitized more than seven million digital items from over 100 historical collections, including photographs, prints, drawings, manuscripts, rare books, maps, sound recordings, and moving pictures. Some of the collections that are available on the Internet include: documents from the Constitutional Convention, Mathew Brady photographs from the Civil War, a multimedia exhibition of all Presidential inaugurations, the notebooks of Walt Whitman, and slave narratives from the Federal Writers' Project.[47]

The Library of Congress has also created a "Learning Page" to make these digital resources more useful to educators. For example, "pathfinders" organized around events, people, places, time and topics have been created so that educators and students can find for what they are looking. The Library also supported American Memory Fellows, which includes 250 teachers and librarians who participated in summer institutes and developed dozens of lesson plans that take advantage of these primary materials.

There are many regional efforts that are seeking to do what the Library of Congress is doing at a national level. In Colorado, for example, libraries, museums, archives, and historical societies are all working together to support a Colorado Digitization Project. Participants have digitized an incredible wealth of information on Colorado's history, culture, government, and industry including virtual field trips to ghost towns, background on the 1913-14 Colorado Coal Strike, and 50,000 photographs documenting the history of the American West.[48]

In recent years, technologies for digital preservation, such as laser scanning, have improved sufficiently to provide rich, three-dimensional access to cultural and historical landmarks. Archeologists and conservationists are concerned that many of the wonders of the world will be lost to tourism, neglect, looting, pollution, and armed conflict. Digital tools can be used to "virtually reconstruct" sites that no longer exist or have been subject to significant damage. Virtual heritage projects have been used to reconstruct or capture Olympia in the year 200 B.C., Stonehenge, Incan ruins, or the terra-cotta warriors of the Chinese emperor Qin Shihuangdi. Some initiatives are exploring the use of video game technology, such as the Virtual Reality Notre Dame (VRND) project. Users are able to take a 3D walk-through of the cathedral, while a multilingual virtual tour guide is available to tell you where you are, what you are looking at, and the history of that particular part of the cathedral.[49]

Integrating E-Science and E-Learning

New information technologies are having a dramatic impact on the way research is being conducted in a variety of disciplines. Scientists in some disciplines are creating "collaboratories" (laboratories without walls) composed of high-speed networks, supercomputers, huge databases, remote instruments, and software tools for simulation, collaboration, information visualization, and data mining. Experts believe that this will accelerate the pace of scientific discovery and allow teams of researchers to tackle problems of greater complexity.[50]

An example of a discipline that is clearly in the process of being transformed by e-science is astronomy. Astronomers and computer scientists are now creating a National Virtual Observatory—a federation of online databases that will have information on billions of celestial objects. The data sets will cover the entire sky in different wavebands (e.g. radio, infra-red, optical, X-ray.) The developers of the NVO believe that "in a few years it will be easier to "dial-up" a part of the sky than wait many months to access a telescope…It will democratize astronomical research: the same data and tools will be available to researchers, irrespective of geographic location or institutional affiliation."[51]

Fortunately, the NVO team is also thinking about its education applications. They are working to develop an "Encyclopedia Galactica," a user-friendly interface to the NVO for both novice and advanced users. Researchers will create online, inquiry-based curricula and educational games that allow students to explore the solar system. NVO data will be available at museums, science centers, and planetariums. As researchers from other disciplines begin to create their own e-science projects, support for educational component for these initiatives is also needed.

Supporting the Social Dimension of Learning

Pavel Curtis, a pioneer in online communities, once observed that "other people" are the "killer app" of the Internet. Researchers in the field of Computer-Supported Collaborative Learning (CSCL) believe that learning is a social process, and that the Internet allows students to learn from their peers, teachers, experts, and members of the general population.

Researchers such as Amy Bruckman and her group, for example, have been working to develop and experiment with software that supports the social dimension of learning. MOOSE Crossing is a text-based virtual world that allows young children to learn creative writing and object-oriented programming from one another. Bruckman argues that these kinds of online communities can provide a ready source of role models. "If, for example, girls are inclined to worry that programming might not be a cool thing for a girl to do, they are surrounded by girls and women engaging in this activity successfully and enjoying it."[52]

Another project developed by one of Bruckman's students (the Palaver Tree Online) created a structured way for middle-school students to learn about history from elders in their community who experienced it. Students were able to learn about World War II by interviewing veterans and the civil rights movements by talking with older African-Americans.

Researchers at the Ontario Institute for Studies in Education have created Knowledge Forum, a software tool that allows students and their teachers to create text notes and graphics, read, build on, and link to each others' notes, and participate in small group debates and discussions. Studies have shown that students that use the software can make more rapid progress in language, reading, and vocabulary skills compared to peers in a control group, and are better able to explain complex scientific concepts.[53]

Broadband content and applications

Currently, most K-12 schools are connected at T1 speeds (1.5 megabits/second) or less, and most households are connected at dial-up speeds (28-56 kilobits/second). However, a growing number of universities, community colleges, and K-12 school districts are connected to Internet2, a research network that can transmit data at speeds of up to 2.4 gigabits/second, or more than 40,000 times faster than a dial-up modem.

One initiative that the Digital Promise could support is experimentation with broadband applications of the Internet. In addition to the educational benefits, this could also stimulate the demand for broadband to homes and businesses. Many high-tech leaders are concerned by the slow pace of broadband adoption in the United States, and have called on President Bush to adopt a national goal of making 100 megabits/second broadband available to 100 million households by 2010. They have also called for the government to do more to stimulate demand for broadband by promoting applications that require it, such as e-learning.

The Internet2 K-20 initiative provides us with a glimpse of what is possible. At least 24 state-level K-12 and K-20 education networks are participating, connecting schools, community colleges, libraries, museums and hospitals to Internet2's high-speed national backbone. A growing number of content-related projects are participating in this initiative[54]:

- UC Berkeley's "Conversations with History" allows students to download video interviews from prominent statesmen, economists, political analysts, scientists, historians, writers, and artists from around the world.

- The "White House Decision Center" at the Truman Presidential Library and Museum allows students to take on the role of one of President Truman's top advisors, recommending a course of action on a tough decision, such as the U.S. response to the 1948 Soviet blockade of Berlin. The Center is designed to help students acquire skills such as information gathering and analysis, group decision-making, and increased knowledge of American history and politics. Internet2 connectivity will enable students from all over the country to participate.

- The JASON project has exposed students to scientists on real research expeditions, who have "compared shallow and deep ocean habitats; pondered the mysteries of chemosynthetic life forms; studied bio-diversity, plate tectonics and volcanoes, geo-thermal hot spots, glaciology, human and animal migration; and compared conditions experienced in space and under the oceans." The JASON project currently uses a satellite downlink for distribution of high-quality video, but Internet2 will allow more students to participate.

Learning in the palm of your hand

Elliot Soloway and his colleagues at the University of Michigan argue that computers are likely to have little impact in a K-12 setting as long as computers are not "ready-at-hand."

"As long as the computer lab is down the hallway and up the stairs, teachers will consider them irrelevant to learning and teaching."[55] His proposed solution is to focus on palm-sized computers such as the Palm, the Handspring, and the PocketPC. He believes that providing every student with a $100 palm-computing device is a realistic goal; providing every student with a $1,000 PC is not.

The current focus of Soloway's group is on developing educational software that will run on palm computers, and would make it worthwhile for a school to invest in purchasing one for every student. For example, he has developed picoMap – software for creating and share concept maps that allow students to graphically represent the relationship between ideas. Commercial companies have developed add-on "probes" that allow palm computers to become mobile science labs, by, for example, collecting and visualizing data on the pH of a local stream. Other companies, such as Wireless Generation, have built tools for handheld devices that allow teachers to get a real-time graphical representation of each student's reading performance and skills.[56]

Given the likelihood that Soloway's goal could be achieved, developing a set of compelling educational applications that ran on palm-sized computers would be a worthwhile investment.

Next Steps

I believe that the case for making a major investment in the kinds of activities described above is compelling. In an ideal world, the Bush Administration and Congress would move quickly to pass legislation that would authorize a proposal similar to the Digital Promise proposal. However, policymakers may choose to move forward in a more incremental fashion, given the current fiscal situation and support for increasing expenditures on national security and homeland defense. Even under this scenario, there are a number of concrete steps that policymakers and the broader community interested in these ideas could undertake immediately.

First, all of the proposals for the creation of a digital "information commons" could benefit from greater debate and study. The recent Congressional call for a report by the National Science Board is an excellent first step, but a broader range of stakeholders should be engaged in wrestling with the policy and design issues mentioned above, including the Trust's mandate, structure of the organization, mechanism for the allocation of funds, intellectual property policy, sustainability of projects, etc.

For example, some experts believe that there are serious structural problems that prevent markets for educational software and content, particularly K-12, from being attractive markets from a commercial point of view. A RAND workshop on educational software concluded that the market is a "mess. The economics of the school market do not work for software developers…."[57] Participants in the workshop observed that schools spend very little per student on software, the review and adoption process is slow and expensive, the market is fragmented, and many schools have old PCs and Apples that are not capable of running the latest multimedia software. A report by the Software and Information Industry Association estimates that K-12 schools spend only $10 per student on software![58] Clearly, one issue that DOIT (R&D, development of prototypes, rigorous evaluation) will help address these barriers, or whether additional actions will be required.

Second, the Administration and Congress could set the stage for the creation of a Digital Opportunity Investment Trust by expanding some of the existing programs. Examples of existing federal programs that might be expanded include:

- The NSF's NSDL (National Science, Technology, Engineering and Mathematics Education Digital Library), which is currently funded at $25 million per year;

- The NSF's Digital Library Initiative-2, which is supporting the development of advanced digital libraries in areas such as digital music, the spoken word (e.g. Thomas Edison's first cylinder recordings), folk literature, and geospatial information;

- The Interagency Education Research Initiative – supported jointly by the National Science Foundation, the Department of Education, and the National Institute of Child Health and Human Development;

- The digitization efforts of agencies such as the Smithsonian, the Library of Congress, and the National Park Service, which can currently only show a tiny fraction of their holdings to the American public;

- The Defense Department's efforts to develop "advanced distributed learning" for the men and women of the Armed Forces; and

- IMLS (Institute for Museum and Library Services) grants for digitization projects at museums and libraries, and the National Endowment for Humanities "Online Humanities" projects.

One activity that would be particularly useful is identifying illustrative projects that deserve to be supported. An organization called the Learning Federation, for example, is seeking to develop a detailed research agenda for learning science and technology. Proponents of the Learning Federation wish to explore issues such as: maintaining the motivation and interest of learners; the relative effectiveness of different approaches to teaching and learning; tools for building simulation-based instruction for science and math; and tools for continuous assessment.[59] The National Science Foundation has also supported a series of workshops that identify important research topics related to learning technologies.[60]

One could also imagine disciplinary communities or other "communities of interest" helping to set the agenda for an information commons. Today, websites, specialized portals, and digital libraries have "hot lists," which are lists of resources that are <u>currently</u> available on the Web. Different disciplinary communities could create "wish lists" that describe what materials <u>should</u> exist online to support teaching and learning in a particular course or subject area. By publishing these lists, communities might (a) identify the gaps in what is currently available and (b) inspire people to contribute material that fills in these gaps, in the same way that open source developers contribute patches and improvements to software such as Linux and Apache. This wish list could be a useful device for "leveraging the small efforts of the many."[61] A simple example of this technique in action is the Stanford Encyclopedia of Philosophy, which has used a list of desirable entries to solicit volunteers willing to write a given entry. A logical extension of this idea would be to describe not only "entries in an Internet encyclopedia," but a broader range of learning objects.

Conclusion

As computers and the Internet become increasingly ubiquitous, it is appropriate to ask ourselves what kind of Information Society we want to live in. If we want to live in a society where everyone has an opportunity to prosper, then expanding access to high-quality education and lifelong learning is a must. An "information commons" will not magically eliminate the barriers to success faced by disadvantaged children in isolated rural communities or inner-city schools. Nevertheless, there is little question that it would help create a more level playing field and could very well spark a revolution in learning.

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