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The Role of Nonprofits in Educational Technology Innovation

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Abstract For decades, nonprofit organizations have played a vital role in educational technology innovation. *Sesame Street*, online high schools, probeware for science and mathematics teaching and learning, and many other innovations now widely used both in and outside schools were developed by nonprofits, including not only universities but also independent R&D organizations, such as the Concord Consortium. Within the federal budget, there has been a decade-long trend to reduce both the size and number of awards made specifically for innovation in educational technology. Small grants, including those for basic research, are less likely to lead to transformative innovations in teaching and learning than larger, targeted awards for innovation. At a time when digital tools continue to grow more useful and powerful, and when larger numbers of schools are using them effectively, it is time for federal agencies to focus additional resources on educational technology innovation.

Keywords Innovation · Digital tools · Nonprofit · Federal policy

The influence of digital technology in schools has grown enormously over the past 15 years:

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- Nearly every public school classroom in the United States is connected to the Internet (thanks in large measure to the federal E-Rate program).
- At least half the states operate their own online (or "virtual") high school.
- Maine and Pennsylvania have 1-to-1 laptop programs for students, as do hundreds of individual schools and districts.
- Millions of state tests have been delivered via computer and data-driven decision-making has become increasingly important in schools.
- Graphing calculators are ubiquitous and about half of all high school science teachers and their students make use of probes and probeware to digitally measure, display, and analyze temperature, motion, and other phenomena.

In short, it is clear that innovative changes in schools more often than ever involve computers, the Internet, and related tools.

If American schools are to be transformed into higher-performing organizations, as virtually everyone believes is necessary, leaders in education need to understand and support the process of innovation that involves technology. One starting point is to ask: Where do effective educational technology innovations come from? An important part of the answer is that nonprofit organizations have long played a vital role in the development of, and research about, educational technologies used in schools and homes:

- *Sesame Street*, originally developed by the nonprofit Children's Television Workshop, was built on a novel, powerful partnership among researchers, educators, and TV production staff. Since 1969, when *Sesame Street* first aired, the program has been adapted in 120 nations, and as a model it has led to countless other high-quality

television programs for children, as well as Web sites and computer games (e.g., www.sesameworkshop.org).
- The Center for Applied Special Technology (CAST) is one in a long line of nonprofit organizations focused on the needs of youth with disabilities. CAST has co-developed successful software products for schools, such as Thinking Reader, and is a pioneer in the development of national standards for making curricular materials more accessible to special education students.
- The computer languages BASIC and LOGO, each designed for students (and used by tens of millions of them at one-time or another) were both developed as part of grants awarded to universities by the National Science Foundation (Zucker 1982). (The for-profit firm Bolt Beranek and Newman also participated in developing LOGO.)
- The pioneering Virtual High School was started in 1996 by two nonprofits, the Concord Consortium and Hudson, Massachusetts, Public Schools.

Unfortunately, government funding for innovation by nonprofits, such as in the examples highlighted above, is dwindling at a time when further innovation is badly needed. The number and average size of awards for applied innovation provided by the US Department of Education and the National Science Foundation's Education and Human Resources directorate has declined. For example, as recently as 1996 the federal government awarded a five-year, $7.4 million award to start the Virtual High School. No comparable size award for new educational technology innovations seems likely in today's climate for federal funding.

Nonprofits and Innovation

Independent nonprofits—ranging from the American Red Cross, the Boy and Girl Scouts, to the Carnegie, Ford, and Gates foundations—have played a vital role in the United States for more than a century. These organizations use valuable approaches to identifying and solving problems that complement the approaches taken by government, universities, or for-profit organizations.

Nonprofits play important roles in education innovations of all kinds. At the state level, for example, nonprofit organizations have been created specifically to improve mathematics and science education, including the Vermont Institute for Science, Mathematics and Technology, the Maine Mathematics and Science Alliance, and the Connecticut Academy for Education in Mathematics, Science, and Technology. At the local level, the nonprofit Knowledge is Power Program (KIPP) supports a network of more than 50 locally run public charter schools aimed especially at helping low-income, minority, and other underserved students on the road to college (www.kipp.org). At the national level, organizations like the Biological Sciences Curriculum Study (BSCS), TERC, the Lawrence Hall of Science, the National Science Teachers Association, the Exploratorium, the American Chemical Society, the National Council of Teachers of Mathematics, and many others have, for decades, helped develop key education reform ideas (such as national education standards) and innovative instructional materials and move them into schools. Universities and private foundations are nonprofits that play important roles, too, but this essay focuses especially on the non-university operating nonprofits that are considerably less well known but are the source of much of the innovation around educational technology.

Unlike large technology companies, such as Apple Computer and Microsoft, nonprofits working in the field of educational technology are often unfamiliar. Nonetheless, many are unusually creative places with long and impressive track records. SRI International, for example, in addition to its work in educational technology R&D (described below), invented the computer mouse, was the second node on the Internet, and developed the original TTY technology[1] for deaf communications. Yet many people have never heard of SRI, or many other nonprofits.

Nonprofit organizations are among the most important sources of reliable, objective knowledge about the use of digital technology in education. Besides developing products and services, their staffs testify before congressional committees, are members of government advisory groups, pioneer many R&D methods, write books and journal articles, and conduct independent studies for the government and for corporations.

The independence of nonprofit organizations from pressure to make a profit for shareholders and increase stock prices allows them to focus their work differently than for-profit corporations working in the same field, and to be more independent. If developing an innovative product or service will make little profit, the private sector is not highly motivated to make the needed investments. To take an important example from another field, developing vaccines to treat diseases common in low-income countries offers little hope of bringing in billions of dollars of profit, which is why the Gates Foundation is investing billions, most of it in grants to universities and other nonprofits, to develop such vaccines. Conducting basic research—whether in education or the sciences—is another area in which the private sector, including wealthy corporations, is not motivated to make all the necessary investments;

[1] Originally TTY stood for teletypewriter. Later, people referred to TDD devices (telecommunications devices for the deaf).

government agencies make many of America's investments in research, usually by awarding grants to universities and other nonprofit organizations.

Independent nonprofits have some advantages over universities when it comes to innovation in education. Innovation requires teams of professionals with diverse skills. Universities focus primarily on research, teaching, and publishing. Few university faculty members are trained or expected to manage long-term applied development projects involving teams of experts with as wide a range of talents as are typically needed for educational technology innovation—from computer programmers to graphic designers, content experts, project managers, writers, and others.

To illustrate the vital role of nonprofits in educational technology, and because they illuminate valuable lessons about the *process* of innovation, this white paper focuses on the Concord Consortium and SRI International. The Concord Consortium concentrates heavily on technology development, including open source computer software, and SRI's Center for Technology in Learning (CTL) principally does research and evaluation, including large-scale national studies conducted for the US Department of Education. Together, these two organizations have been involved in a full spectrum of sponsored research, development, strategic planning, and consulting. Focusing on these two organizations allows certain lessons about funding and innovation to be illustrated concisely, but clearly many other nonprofit organizations also play important roles in educational technology R&D.

The Concord Consortium

For most of its life since 1994, the Concord Consortium (CC) has been a small organization, employing 25 to 50 people. But despite its size CC can point to many singular accomplishments. A partial list shows that CC:

- building on work its key staff initiated at TERC, has continued developing and promoting the use of "probes" in science education (devices attached to a computer that measure temperature, sound, motion, or other phenomena), an innovation that spread rapidly and after <20 years is used by about half of all high school science teachers (Hudson et al. 2002);
- in 1996 began the first online high school in the nation, which thrives to this day and whose successful practices have influenced many other virtual schools;
- disseminates hundreds of free online lessons based on complex but easy-to-use models and simulations of the interactions of matter at the atomic and molecular levels;
- is a leader developing open source science and math education software for schools; and,
- is responsible for a half-dozen books and dozens of journal articles about online learning, virtual schools, handheld computers in the classroom, and many other significant innovations involving educational technologies.

In short, CC has been an effective "skunkworks" (a small, loosely structured corporate research and development unit formed to foster innovation).

On its web site (www.concord.org), CC describes itself as an organization that "creates interactive materials that exploit the power of information technologies. Our primary goal in all our work is *digital equity*—improving learning opportunities for all students." The group's emphasis on innovation means that CC has resisted becoming a service organization. In 2001, for example, rather than enlarge its core mission, CC spun off the successful Virtual High School, which continues as an independent nonprofit organization (www.govhs.org) with more than 10,000 course enrollments annually, serving students in 30 states and more than a dozen foreign countries.

The Concord Consortium, which like the majority of nonprofits has no endowment, is almost entirely dependent on external funding. Two projects, the Virtual High School and Molecular Workbench, provide contrasting illustrations of how nonprofits obtain the funding needed to develop innovative educational technologies.

The Virtual High School

The Virtual High School (VHS) resulted from several strands of work and ideas being woven together in a creative way. In the mid-1990s, CC won an NSF grant for CC's first online education effort, a three-year project for nearly $3 million called the International NetCourse Teacher Enhancement Coalition (INTEC). INTEC created and taught online courses for middle and high school teachers to learn to use inquiry in their math and science classrooms. Using the Internet proved appealing especially to teachers who were unable to attend summer or evening courses.

Ray Rose, an experienced manager of educational R&D projects, was hired by CC to direct INTEC. In early 1996, Ray proposed that CC obtain funding to start an online school, most likely a high school. Shelley Berman, then an innovative superintendent of schools in Hudson, Massachusetts, and a founding member of CC's Board of Directors, proposed that CC team up with accredited schools to create a virtual high school. CC would provide the technical expertise for an online school, while accredited high schools would donate teachers' time in exchange for some of their students being allowed to take courses offered by *any* of the high school teachers in the online school's network.

CC's leader, Bob Tinker, who has a Ph.D. in experimental low-temperature physics from MIT, led the development of a compelling proposal. He and Shelley were proposed as co-Principal Investigators of the winning $7.4 million Technology Innovation Challenge Grant awarded by the US Department of Education late in 1996. The goal of the project was to create a national consortium of schools each of which would contribute to teaching one or two online courses (called NetCourses) and in return for each course would be allowed twenty seats for the school's students to enroll in any of the consortium's online NetCourses (almost always ones offered by other schools, not their own). This national consortium approach was and remains an unusual one for online schools.

In 1996, the concept of a national online high school was undeveloped and untested. VHS and its member schools were pioneers. Federal funding provided the seed money needed to convert VHS from an idea to a reality, including:

- bringing together a talented staff of educators, evaluators, and techies;
- developing standards of quality and principles of operation for an online school;
- adapting an existing technology (Lotus Development Corporation's LearningSpace, which was primarily intended for corporate training) to the needs of high school teachers and students;
- developing a syllabus and an online course to train experienced classroom teachers how to teach effectively in the new online medium;
- recruiting participating schools and teachers (including explaining the concept to principals and school boards and persuading them that the experiment would benefit their schools and their students); and,
- working with about 30 teachers to develop NetCourses for students in a wide variety of subjects.

As expected, creating and managing the Virtual High School was a complex job requiring a team approach. To manage the project the co-PIs turned to Bruce Droste and Liz Pape. Bruce was hired because he had been director of a private high school and had promoted educational technology to other private schools. Liz, who has an MBA degree and had worked in for-profit companies, was hired about a year later. Led by the CC team, VHS quickly became well known and received extensive publicity, including a full-page 1998 article in *US News and World Report*. Educators around the US and the world interested in developing their own online learning programs contacted CC for information.

Beginning in 2001, VHS, Inc. became an independent nonprofit organization in its own right, with Liz as CEO. She also helped to start, and serves on the Board of Directors of, the North American Council for Online Learning (NACOL), an international organization formed in 2003 "to facilitate collaboration, advocacy, and research to enhance quality K-12 online learning" (www.nacol.org/about/).

Many other talented people also were needed to make VHS a success, including its initial group of outstanding teachers, drawn from dozens of public and a few private schools across the US (Zucker and Kozma 2003). As a group, these teachers were extraordinarily hard working, creative, adventurous, and passionate about good teaching and their subject matter. Most continued teaching a course online for years, while devoting the majority of their professional energies to teaching face-to-face in their home schools. A number of this first cohort of teachers took on leadership positions within VHS.

At an early stage, VHS began to support itself. The departments of education in Georgia, North Carolina, and Ohio each paid for training programs. Nearly 60 local school systems also paid for additional training, beyond what was included in the federal grant, and Israel's ministry of education paid to train participants in a VHS workshop in 2000. Between the Challenge Grant and these additional fees for services, Concord spent more than $4 million starting VHS and providing services to students as part of the initial grant, and the Hudson Public Schools spent another $3 million plus.

Nonetheless, additional funds were needed to allow VHS to make the transition from federal funding to its current independent, nonprofit status. The rules governing use of federal funds are strict, and they may not be used to pay the start-up costs of a new organization. Fortunately, Bob was able to interest Penny Noyce (by then a member of CC's Board of Directors) and the Noyce Foundation, which provided the Concord Consortium a grant of $885,000. Penny had been a technology-oriented medical researcher and not only understood CC's work, but also its need for special funding to avoid the constraints of government grants.

Innovations that depend on venture capital typically require much more than the $8 to $9 million that it took to make VHS a self-sufficient organization. The state of Florida invested more than $25 million in public funds to develop and support the Florida Virtual School, which has more than 30,000 enrollments each year. In this context, the $7.4 million federal Technology Innovation Challenge Grant turned out to be a successful, relatively modest-sized investment that created a model from which many other organizations were able to learn. The Administrator of the Alabama Online High School, for example, said, "*[VHS]* *really jumped head over heels into the briar patch, and they came out clean and helped the rest of us see the way*" (Zucker and Kozma 2003). Just five years after the Challenge Grant was awarded, in 2001 Virtual High School won a prestigious international award, the Stockholm Challenge Award for Global Excellence in Information Technology (www.stockholmchallenge.se/index.html).

Fortunately, both VHS and the Florida Virtual School took seriously the responsibility to offer high-quality courses online, to develop standards for online learning, and to commission external evaluations of their pioneering ventures. In the case of VHS, a team of evaluators from SRI International studied the school for more than five years, which included doing annual surveys of participants (students, teachers, principals, and school superintendents) and hiring independent subject matter experts to assess the quality of online courses. A book, *The Virtual High School: Teaching Generation V*, summarizing the results of the evaluation and providing detailed information about the school, as well as a variety of other online schools, was published in 2003 (Zucker and Kozma 2003). VHS's co-Principal Investigators allowed the evaluators to gather reams of data and to make their own judgments based on those data. As a result, the evaluation and the book provide a balanced account of VHS, including both its strengths and its weaknesses. However, the continued success of VHS and the fact that half the states are operating their own online schools (often drawing directly on lessons learned by VHS) testify to the fact that the strengths of the new venture greatly outweighed its weaknesses.

Unfortunately, most successful innovations do not take place on such a rapid timetable. Even the now-ubiquitous computer mouse, which was originally developed at SRI International in 1964 (www.sri.com/about/timeline/mouse.html), didn't take off until about 1990! Development projects typically require many years to reach fruition, as demonstrated by a more typical Concord Consortium project, the Molecular Workbench.

Molecular Workbench

Being able to see or visualize a phenomenon is often an important key to understanding it (AERA 2007). Conversely, the fact that we cannot see molecules and atoms, for example, is a barrier to understanding heat, temperature, chemistry and chemical equilibrium, protein folding, and other important scientific phenomena and concepts. "Enabling students to observe the unobservable" is a major goal of developing computer models, which is an important strand of CC's work.

Although common sense tells us that being able to "see" otherwise invisible scientific phenomena will be useful, measuring more precisely the impact of computer simulations on students' learning requires research. According to a large-scale national study of science education, "Eighth-graders whose teachers had students use computers for simulations and models or for data analysis scored higher [on the NAEP science test], on average, than eighth-graders whose teachers did not" (NAEP 2000). These findings are based on data from tens of thousands of students but are not experimental. Smaller research studies with random assignment of students to the experimental and control groups have reached the same conclusion: simulations help students learn important concepts in science and mathematics.

Boris Berenfeld and Bob Tinker developed the original idea for Molecular Workbench. Boris, a member of CC's staff, holds a doctorate in radiation biophysics from the University of Moscow in Russia and has extensive research experience in biology, ecology and the application of technology to education. In May 1998 NSF awarded Boris and CC a Small Grant for Exploratory Research, "Hands-On Molecular Science," to elaborate their idea. Work under that grant led to a series of six additional grants. Grants in other R&D strands have also funded CC work with models, including a $7 million, five-year *research* project called Modeling Across the Curriculum, or MAC, focusing on the impacts of the use of models at the secondary school level.

The total amount awarded for the seven Molecular Workbench related grants was under $6 million, meaning that CC staff members invested much more time and energy writing proposals for these seven projects than they did for the Virtual High School—and yet received less funding for development than was provided by the single Technology Innovation Challenge Grant that launched VHS. In this respect, unfortunately, Molecular Workbench is more typical of CC's funding pattern and the educational technology funding of many other nonprofits. The average grant size is not large enough to allow many ideas to reach fruition with one or even two awards. For Molecular Workbench, seven awards have been needed, stretching over more than a decade. The innovation business, in schools as well as in R&D organizations, requires persistence!

Many person-years of effort by first-rate computer programmers (notably Qian Xie) have resulted in a molecular simulation "engine" that simulates the dynamic interaction of atoms and molecules according to physical laws. With the Molecular Workbench software, you can watch as atoms and molecules interact. The engine is a professional tool for generating model-based activities and for annotating and sharing them among students. Working with the tool, hundreds of lessons and activities have been developed for students, each focusing on one or more scientific phenomena (diffusion, liquid crystals, dissolving, distillation, etc.), and all are freely available to download and use (molo.concord.org/). These lessons help students learn by observing the behavior of simulated atoms and molecules and by interacting with computer simulations.

During a decade of work, CC carefully separated the expertise required to build the sophisticated simulation engine from the very different kind of expertise needed to develop interactive educational experiences for teaching and learning science. As a result, Molecular Workbench not only provides a powerful environment for creating interactive molecular models and dynamic simulations, but also an easy-to-use authoring tool for building user interfaces and writing guided student activities that use the simulations. Without becoming computer programmers, teachers and other curriculum developers can either use existing lessons or learn to create additional model-based lessons, including embedded assessments for measuring students' learning with simulations. All of Molecular Workbench's functionalities are integrated through a simple user interface, making it far easier than ever for educators to create sophisticated, realistic model-based student activities in which students can control and observe simulated atoms and molecules in action.

As an open source, extensible modeling platform, Molecular Workbench puts the products of millions of dollars of federal funding directly into the hands of teachers, students, and curriculum developers. One unit appropriate to a high school or college biology course, for example, is called "Shaping proteins: From DNA to amino acid conformation." Dynamic simulations in this unit allow students to observe and explore how proteins, the building blocks of life, fold into characteristic shapes with specific biological properties. A pretest, four activities, and a posttest are available online (workbench.concord.org/web_content/unitV/index.html).

Users from more than 60 countries have downloaded over 10,000 copies of the Molecular Workbench software, as well as more than 100,000 copies of models and activities based on the software engine. Because the scientific concepts in Molecular Workbench don't age, and because new activities keep being produced, these numbers will grow for many years to come. It is not clear that a commercial distributor would be able to sell as many copies of a specialized software title. Yet it is quite possible to combine open source and commercial distribution. The Linux operating system, for example, is available free of charge, but can also be purchased from commercial vendors who are selling not only a standardized version of the product but also technical support and documentation. There is no reason why textbook publishers could not make greater use of open source software, and some are beginning to do so.

Open Source

Open source is a philosophy, not a project. Perhaps the best-known open source software product is Linux, a computer operating system the first generation of which was developed by Linus Torvalds, then a Finnish university student. The computer source code for Linux and other open source software is made available for anyone to use, modify, and redistribute at no cost. People making improvements in open source software are encouraged to send them to special Internet-based committees coordinated by volunteer experts for broader sharing. This approach reduces software purchase costs, which is especially important to schools. The open source approach also allows a large community of paid and volunteer developers to add to or improve what was first developed. Wikipedia, an online encyclopedia with more than 1.5 million articles in English (as of 2006) applies this same idea to a different type of product.

CC is committed to developing open source software, as exemplified by Molecular Workbench. A Web site (source.concord.org/) makes available the great variety of open source software that CC has developed. Most of it is written in Java, a computer language that runs on many different computers and computer-based devices.

The development of the Internet and then the World Wide Web has resulted in a huge volume of free resources in many fields, easily available to anyone. But because *many* digital resources are available at no cost, it does not follow that *all* digital resources ought to be free of charge. For educational materials used in schools, it seems clear that in the foreseeable future teachers and students will want to use both materials that are free of charge and those that are sold or licensed. Each fills a niche. But without question, open source materials provide educators with exciting new possibilities. One web site alone provides access to the text of more than 19,000 free books, from Adams, Dante, and Dickens to Yeats and Zola (www.gutenberg.org).

The Concord Consortium has had substantial impacts in educational technology in the space of little more than a decade. In contrast, SRI, which was created in 1946, has been around for more than 60 years.

SRI International

The list of SRI's accomplishments is simply amazing. In addition to those listed at the beginning of this paper, among the 50,000-plus projects that SRI has conducted are: developing the machine-readable numbers on bank checks and other essential work on bank automation for Bank of America in the 1950s; project "Mickey" that helped found Disneyland; the first major conference (1956) on the capture and use of solar energy; the first digital fax machine; development of inkjet printing; the technology for modern air combat training ranges (such as shown in the movie *Top Gun*); anti-malarial and anti-cancer pharmaceuticals; and, groundbreaking work in speech recognition, including a spinoff company, Nuance Communications, formed in 1994 to commercialize the technology (Nielson 2004). This list could be expanded many, many times over.

SRI is a nonprofit contract research organization, sometimes called a "think tank." SRI's funding (more than $280 million in 2005, or about $400 million including the revenues of Sarnoff Corporation, a wholly owned SRI subsidiary) comes from contracts and grants awarded to the organization by its clients. With these monies, SRI supports a staff of 1,400 people.

SRI was originally a part of Stanford University. Because cooperation in R&D between universities and private companies is now common, it is easy-to forget that before World War II such linkages were unusual. SRI, first called the Stanford Research Institute, was created as a subsidiary to benefit the University, the western United States, and to contribute to "improvement of the general standard of living and the peace and prosperity of mankind." After nearly 25 years as part of Stanford, SRI International became an independent nonprofit organization in 1970.

SRI is entirely devoted to research, development, and consulting. As a recent history of the organization notes, "This type of environment has a distinct quality to it. Though immersed in a large organization, the researcher is, in a very real sense, working directly for the research client" (Nielson 2004). Although contract research has its challenges, such as the perpetual need to find money to support projects, many researchers are content to spend an entire career in this environment. As at the Concord Consortium, project teams, each with a great deal of independence, do the essential work. Quoting again from the recent history,

> …there is an unchanging essence that those who have spent meaningful time here come to know. To experience it requires your having been 'in the trenches,' so to speak: having lived with the excitement of forming a new concept, solution, or vision; having struggled to find the needed support; and having known the euphoria of bringing an idea to realization. Some of the magic of SRI is the creative atmosphere that pervades the Institute and becomes intensely personal for all principal investigators and those who support them. (Nielson 2004)

Education and Human Services

SRI has supported work in education R&D for more than 60 years. Although it is difficult to characterize a typical SRI education project, SRI has done many national evaluations of federal education programs, beginning with the Follow Through evaluation in 1969 (a program created to "follow through" on the Head Start program for early childhood education). That study involved nearly 10,000 children each year. SRI is far more likely to conduct large-scale R&D projects than a small organization like the Concord Consortium. For more than 25 years, SRI has played a central role in large-scale national studies, like this, of children with disabilities and their education. Mary Wagner and her team have conducted longitudinal studies following thousands of children, their parents, teachers, and schools for a decade, in the process producing some of the nation's best and most reliable data about special education and students with disabilities. Typically, national studies are conducted under contract to the federal government rather than under grants. At their best, contracts are productive partnerships between government and contractor, similar to the way that a successful building results from the creative interaction of an architect under contract to a client.

Because the organization has always been interested in solving problems that cross disciplinary lines, some of SRI's education-related projects have been unusual. Douglas Engelbart's pioneering SRI work developing personal computing (including the computer mouse, hyperlinks, online document editing, and cooperative real-time work with distant colleagues) was first supported by the Defense Advanced Research Projects Agency under the title Augmented Human Intellect, which sounds like the cultivation of human intellect, or education by another name. Engelbart, who won the National Medal of Technology in 2000, helped create the computer and networking revolution that makes technology a transformative force in education, as well as in other fields.

SRI's Center for Technology in Learning

The education and human services programs grew under Marian (Mimi) Stearns, who joined SRI in 1972 and later became a Vice President. Prior to joining SRI, Mimi had been the government's first program officer for Sesame Street, and then worked for the federal Bureau of Education for the Handicapped. At SRI, she fostered growth in many areas, including educational technology, and was known for thoughtful mentoring of staff. Mimi created the Center for Technology in Learning (CTL) in 1989 (ctl.sri.com). The close connection between CTL and other researchers in the same division of SRI, who work on education issues but not necessarily on educational technology, has been an important contributor to its success.

CTL employs about 70 psychologists, cognitive scientists, computer programmers, evaluators, project managers, experts in math and science, statisticians, and others. Its national studies included a qualitative study of technology and education reform conducted by Barbara Means and colleagues, published in 1995, that was disseminated widely and was frequently cited by educators interested in using computer technology to make learning more active and project-based and to increase the emphasis on teaching critical thinking skills, not simply rote memory (Means and Olson 1995).

The Evaluation of Educational Technology Policy and Practice for the 21st Century, completed in 2002, included several sub-studies, including the first formative evaluation of the federal E-Rate program (which has awarded about $20 billion to schools and libraries for connection to the Internet, based on fees collected on everyone's telephone bills), conducted by the Urban Institute, a subcontractor. The evaluation found that the program was accomplishing key goals of the authorizing legislation, notably by increasing access to the Internet among schools and libraries serving low-income populations (Puma et al. 2002). Internet access grew from 3% of all classrooms in 1994 to 94% in 2005, reaching nearly 100% of schools (Wells et al. 2006). Another part of the contract was a national examination of how teachers use and learn to use technology for instruction, based on a sample survey of more than 1,200 teachers nationwide, as well as many site visits and a literature review (Adelman et al. 2002). Among the important findings was that by 2000, more than half of all public school teachers were using digital technology as part of instruction at least weekly, indicating that the nation's investment in computers and the Internet for schools was starting to be reflected in classroom practices.

The No Child Left Behind Act mandated that the Department of Education sponsor an independent, long-term study of educational technology use. NCLB has also increased the demand for "proven" educational practices, notably programs that have been tested through randomized experimental studies. To meet these needs, SRI became a partner to Mathematica Policy Research for the congressionally mandated experimental study called the National Study of the Effectiveness of Educational Technology Interventions, a three-year evaluation of 15 popular technology applications (Dynarski et al. 2007). Dozens of districts and more than a hundred schools were recruited for the study, representing a diverse cross section of districts. There have been only a limited number of experimental, large-scale studies of education programs, technology-based or not, because they are expensive and require substantial expertise.

CTL's work has grown since 1989 to include many strands, such as the use of handheld computing devices in education (including "clickers," small devices that transmit students' responses to questions so they can be instantly aggregated and displayed anonymously at the front of the room), using technology to assess students' work (especially in mathematics and science), assessing design issues in creating technology-supported learning environments, and evaluating uses of technology to support community centers and families. The organization conducts some development projects; for example, since 1997 CTL has developed and hosted Tapped In®(tappedin.org), an online workplace incorporating a wide range of synchronous and asynchronous Web-based collaboration tools that now serves a community of more than 20,000 K-12 teachers, researchers, and other educators. CTL has a diverse set of clients; in addition to conducting work for foundations, and for federal, state, and local government agencies, CTL does consulting for private sector educational technology firms (e.g., CTL 2006).

Like other parts of SRI, a hallmark of CTL's work is its collaboration with a wide range of individuals and organizations. Its "ubiquitous computing evaluation consortium," for instance, included researchers from nearly a dozen organizations, each of whom studied and evaluated one-to-one computing programs (ubiqcomputing.org). Managing a project involving many organizations can be challenging, but it makes a wider range of projects feasible, including those too complex for one organization to do alone. Collaboration among nonprofits is increasingly common.

Lessons About Innovation

Because innovation is so important to business and industry, the literature on innovation is large. But even this brief set of examples of the role of nonprofit organizations in supporting innovation in educational technology provides valuable lessons for those interested in educational innovations. Successful innovation, including innovation using digital tools for education, requires vision, teamwork, resources, and time.

Vision

When persuading funding organizations to invest millions of dollars in a new educational technology application, such as the first online high school, or incorporating novel technological innovations in school systems, as leaders in Maine and Henrico County, Virginia did when they took a calculated risk and began 1-to-1 laptop computing programs, leaders must develop a compelling vision rooted in an understanding of teaching, learning, and educational institutions.

Communicating the vision effectively is vital, whether for a proposal to potential funders, a presentation to a school board or legislature, or a talk to parents, teachers, or students. More schools and school systems are beginning to incorporate visions of the role of digital tools into their strategic plans and goal statements. One public charter high school, the Denver School of Science and Technology, describes its vision as follows (Zucker and Hug 2007):

> Technology must not be a simple replacement or enhancement of non-technological methods of learning. Technology is too expensive to be a substitute for the pencil and the chalkboard. Instead it must invite and enable higher order thinking, more creative thinking, learning and expression. It must engender more intense investment and engagement by the student. It must enable collaboration, extrapolation, projection, analysis, demonstration, and closer, tangible interaction with the subject under study that is extremely unlikely or even impossible without it. It must transport the student to places, experiences, modes of thinking, cultures, and people otherwise impossible to reach for the normal high school student.
>
> Technology should empower and enable, and never replace or reduce the central human role of the teacher in a liberal arts education. The role of a liberal arts education is to enable and facilitate the creation of leaders who value community, individuals and the creation of a truly human society. Technology must serve this end.

A compelling vision for increasing the use of digital tools in schools helps persuade others of the value of the innovation. Change is often difficult and risky, but clearly schools need to change. Although history shows there are some extraordinary people whose visions and skills allow them to develop or implement innovations unusually well, the reality is that invention, R&D, and the implementation of educational technology innovations are rarely solitary pursuits.

Teamwork

Nonprofit R&D organizations like the Concord Consortium and SRI rely heavily on teams. It requires teams of people to develop and realize the visions for new projects. Like many other educational technology nonprofits, CC and SRI have been able to hire outstanding staff whose expertise includes computer programming and hardware development, knowledge of science and mathematics, teaching experience (including online teaching), cognitive science, psychology, graphics, project, and financial management, writing, editing, and other skills. The multi-disciplinary nature of projects and the use of carefully assembled teams (often five to ten people) to carry them out are hallmarks of the contract and grant work done by Concord, SRI, and many other organizations involved in educational technology R&D.

Similarly, changing traditional practices in schools needs to be a multi-disciplinary, team-based, long-term effort. Leadership is crucial, but leaders are needed at all levels, not just at the top of an organization. Former Maine Governor Angus King, who began the state's 1-to-1 laptop program, was under no illusion that he was an expert at using computers for teaching and learning. The state has relied heavily on local, regional, state, and national leaders to move from a vision to a successful program. Examples such as this illustrate that successful school systems, like businesses, are able to build, motivate, and support teams that can change the organizations in important ways.

Resources

Schools spend almost no money on research and development, despite the fact that these institutions need to adapt to a rapidly changing world—which, for most large businesses, would mean that R&D is required. Dozens of states have developed online high schools; in most cases, however, this has meant adapting R&D done elsewhere rather than beginning by building their own technology and knowledge base. Innovation requires resources, including time and money. Even for dedicated R&D organizations it is a challenge to find the necessary resources. In schools, resources are obtained in various ways. In Maine, the legislature provided a special infusion of funds for the 1-to-1 program. And, for better and for worse, many schools have become more adept at writing proposals to obtain funding from foundations or government agencies. One-time solutions, such as grants, can be important. But transforming schools is not a one-time event; it is a process that requires support for years. Schools need to create budgets that support technology over the long-term. Similarly, schools need to view innovation not as a one-time event but as a process of continuous improvement. For example, districts planning to make better use of assessment data to improve teaching and learning are putting together teams of people to work together for at least a year, and often much longer.

Time

Because we live in an era of rapid technological change, there is a tendency to believe that social and organizational changes happen as rapidly as technological changes. Yes, some technological change happens rapidly—such as the majority of households buying their first television sets at almost the same time in the 1940s and 1950s—and some social and organizational changes are rapid, too. But more often, significant changes take substantial time, be that the introduction and spread of kindergarten programs, or, as mentioned earlier, the increasingly pervasive use of the computer mouse, which took about three decades after the device was invented. Policymakers and the public should expect deep, broad changes in school systems to take time. Buying and installing digital devices may be accomplished quickly. Changing patterns of teaching, testing, communicating, and doing business will take much longer and require extensive training, teamwork, leadership, and public support. Transforming schools will be a long-term process.

Federal Funds for Innovation

The federal government spends more than $30 billion annually for research in the life sciences at the same time that companies in the private sector, such as pharmaceutical corporations, invest tens of billions more (NSF 2006). By contrast, the federal R&D budget in 2005 for education, training, employment, and social services; *and* administration of justice; *and* commerce and housing; *and* community and regional development; *and* income security; *and* international affairs; *and*, veterans' benefits and services was only $2.5 billion altogether. These many categories are reported together by the federal government because even combined they are so small—less than 10% of the federal investment for R&D in the life sciences. Compared to the $74 billion government investment in military R&D, the percentage is even less, about 3%. These figures tell us what federal R&D priorities are. Unfortunately, more and better education R&D is not high among them.

The private sector is not about to invest billions in education R&D. The total of *all* software sales to schools in 2004 was a little over $2 billion (Richtel 2005), far less than the sales of many prescription drugs (like Lipitor, which reduces cholesterol). The point is not that using software is like using medication. Rather, the materials used in schools simply have not, and as yet cannot, be based on the kind of R&D expenditures that medicine, agriculture, the military, and many other fields take for granted. The private sector cannot improve that situation substantially, given current market size. Nor are individual states and school districts in a position to support expensive, cutting edge R&D.

The federal investment for innovation in educational technology R&D is essential—but it has been diminishing. Programs like the Technology Innovation Challenge Grants, which funded Virtual High School and other innovations, take calculated risks. That is what innovation requires. There are fewer opportunities for federal funding of educational innovation than there used to be. "Our greatest concern," Bob Tinker has written, "is that the pipeline of educational innovations in math and science is drying up… causing us, and others like us, to dismantle our teams and reduce our capacity for innovation" (Tinker 2006).

The National Science Foundation (NSF), an independent federal agency, has been CC's primary funder. Since its creation in 1950, a core part of NSF's statutory mission has been to support "science education programs at all levels in the mathematical, physical, medical, biological, social, and other sciences" (42 USC §1862). The great majority of its 10,000 or so awards each year are made to support research by scientists, engineers, and mathematicians. NSF also supports a prestigious program of graduate fellowships for the education of the next generation of scientific researchers, as well as many other grant programs designed to support and improve science, mathematics, engineering, and technology education from kindergarten through graduate school. Materials developed by a limited number of federal education grants have turned into successful, money-making products. The nonprofit TERC, for example, licensed the *Zoombinis* series of educational games to a commercial company, which has sold more than a million units. More lucrative has been an elementary mathematics curriculum developed by TERC called *Investigations in Number*, *Data*, *and Space*, which has earned millions of dollars in royalties based on its popularity in schools.

Yet anyone imagining that large income streams are typical of education products would be badly mistaken. It is the rare company that has been able to make money developing and marketing educational software, for example—and this is one of the reasons why organizations like the Concord Consortium are essential. In fact, the market for such materials has declined dramatically, both in the schools and in homes (Richtel 2005), no doubt due in part to the growing expectation that interactive materials are freely available on the Web. Yet whether a product is commercially distributed or not, there is so little profit incentive in developing complex materials like Molecular Workbench that without foundation or government support, such materials very likely would not be created. As a report written by the RAND Corporation (Glennan and Melmed 1996) noted,

> The market for educational materials, as traditionally structured, offers limited incentives for entrepreneurial development of content software. The market is fragmented and governed by a variety of materials adoption practices. Even if a high proportion of schools acquires a product, the volume of sales is small. This is particularly true with the more

specialized subject areas characteristic of much of secondary education.

Even rigorous education research is expensive. The study of 15 software products referenced above will eventually cost about $15 million. Although such price-tags are the norm, or low, for many health-related studies that one reads about in the news and that help shape national health policies and practices, the nation has invested so little in education research that it may come as unwelcome news to realize that large-scale, high-quality education research is costly, too. The No Child Left Behind Act emphasizes the importance of so-called "scientifically-based research," including randomized field trials of promising practices. Research is certainly important but entrepreneurs and inventors rely on experience, intuition, and inspiration as well as research. Business and industry would have had to wait decades before adopting computers and other information technologies if their main criterion had been first-rate, peer-reviewed research. Research on the effectiveness of new practices lags behind innovation. There is currently an imbalance; innovation in educational technology is under-funded.

It is true that research and development is no substitute for good teachers, healthy families, or communities that support and nurture young people. But the R&D work done by hundreds of nonprofits—including universities, as well as organizations like the Concord Consortium and SRI International—is vital to understand, improve, and ultimately transform schools. Unless we are content with the schools we have, the nation needs to find a way to increase the inadequate federal allocation for these R&D efforts, as well as allocate money to support innovation in schools.

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