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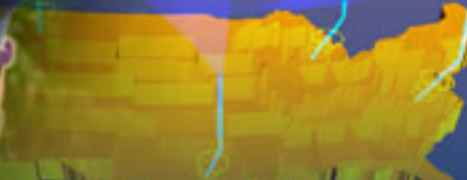


2020 VISIONS

Transforming Education and Training Through Advanced Technologies

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Through Advanced Technologies*



VISIONS 2020

*Transforming Education and Training
Through Advanced Technologies*



THE SECRETARY OF COMMERCE
Washington, D.C. 20230

Powerful new technologies now under development by U.S. businesses, universities, and government promise to transform virtually every industry and many human endeavors. These technologies could also be harnessed to transform education and training in ways previously unimaginable. Rapid advancements in the years ahead could enable new learning environments using simulations, visualizations, immersive environments, game playing, intelligent tutors and avatars, networks of learners, reusable building blocks of content, and more. The technologies that are coming could create rich and compelling learning opportunities that meet all learners' needs, and provide knowledge and training when and where it is needed, while boosting the productivity of learning and lowering its cost.

Successful development and deployment of these technologies in education and training could have a profound effect on American competitiveness and our standard of living. A world-class workforce is vital to the Nation's ability to compete. But staying on top in today's knowledge-based economy means Americans must have greater and more effective access to the knowledge and skills development they need to flourish as students, employees, and citizens in a rapidly changing world.

There are many challenges in the process of innovation that we must address to take advantage of these technologies to improve learning. For example, advanced technologies developed to meet other purposes must be translated into affordable tools for learners to use. Technical standards must be deployed to help guide the development of education and training content that will be drawn from countless sources throughout the world. The technology community must form stronger partnerships with the education community. Our education and training institutions need to prepare for rapid technological change.

We asked a number of distinguished individuals and teams from a wide range of technology and education fields to look out into the future, and describe what these learning experiences and technologies could be like. They responded with a rich collection of visions that offer a glimpse of a future in which learners could explore worlds and cultures beyond their own, in both distance and time as if they were there. Surgeons could hone life-savings skills in realistic settings without putting patients at risk. Students could interact with historical figures. Educators could have new high-wage job opportunities. And students, teachers, and parents could collaborate in productive new ways. A few of these visions offer cautionary tales that should serve to remind us that we must strive to apply the power of technology in ways that empower learners and teachers, enlighten the mind, and enrich all of our lives.

These visions are intended to contribute to our understanding of the potential of these technologies to foster innovation in our learning enterprise, the research that is needed, and the challenges that lie ahead.

A handwritten signature in black ink, appearing to read "Donald L. Evans". The signature is fluid and cursive, with a large initial "D" and "E".

Donald L. Evans



THE SECRETARY OF EDUCATION
WASHINGTON, D.C. 20202

September 9, 2002

Dear Colleague:

Everywhere one looks, the Internet and information technology are transforming every aspect of life in the United States. We are living, shopping, working, governing, and communicating in new ways that are enabled by technology. Organizations are learning how technologies streamline processes, enable real-time information transactions, expand markets beyond geographic areas, and customize service offerings to the needs of customers. These new capabilities have done more than simply make organizations more efficient – they have forced leaders to rethink markets and reengineer business structures and processes that led to dramatic improvement in quality.

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


The problem is not that we have expected too much from technology in education – it is that we have settled for too little. Many schools have simply applied technology on top of traditional teaching practices rather than reinventing themselves around the possibilities technology allows. The result is marginal – if any – improvement.

The visioning exercise facilitated by the Department of Commerce provides an opportunity to dream how technology can not only *improve* instruction, but also *transform* what we think of as education. These visions force us to question our traditional assumptions while stretching our minds with how technology can be used to reach *every* child with a quality education.

An old proverb says, “A vision without a plan is just a dream. A plan without a vision is just drudgery. But a vision with a plan can change the world.” These visions will be used to help shape the National Educational Technology Plan that is required by the *No Child Left Behind Act of 2001*. Together, these visions and the plan will shape the direction for a 21st century education that will meet expectations of excellence set forth by No Child Left Behind.

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To build a better, stronger America requires us to start first with ensuring that every child receives a quality education. I want to thank these visionaries for their commitment to that goal and for helping us to dream of what is not, but could be.

Sincerely,

Rod Paige

VISIONS 2020

Transforming Education and Training Through Advanced Technologies

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*The views expressed by the authors of these visions do not necessarily reflect the views
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TECHNOLOGIES AND LEARNING

Ruzena Bajcsy

*Director, Center for Information Technology Research in the Interest of Society
University of California at Berkeley*

The goal of technology, and especially information technology, must be to create an environment where every learner will have a series of resources and teachers in different discipline expertise and in different locations, with a teacher/mentor to help organize the information, and help the student pursue some areas in depth. This is currently too expensive, but there is hope that several upcoming technologies listed below can be deployed in the future.

As we know, the MOTIVATION of the learner is the most important factor in learning. Hence the question becomes - how can technology help and facilitate motivation during the process of learning?

We do not advocate replacing the human teacher with the technology! Future technology must live in a symbiotic relationship amongst teachers, students, parents and society at large. We view the technology as an ENABLER in a number of ways:

1. Help organize and provide structure for the teacher's material to students
2. Help students, teachers and parents interact (anytime and anywhere), in order to follow progress of learning in a given subject
3. Facilitate and assist in the authentication, search and prioritization of the digital material available on the WEB, which in this case serves as a world wide encyclopedia
4. Simulate and visualize structures and processes which are the result of physical, chemical, biological and engineering models and to interact in real time with them
5. Help in learning history, and /or future trends because technology can reconstruct life and, hence facilitate visualization of

going BACK and FORTH in time. A few examples might be: walk through old Rome, old Egypt, old Harlem, and their like or also a walk through FUTURE New York, or a devastated or polluted environment, etc.

6. A tool for the handicapped population, (this includes elderly). Technology can serve as an extension and enhancer for their missing capabilities, being either perceptual, physical or cognitive, so that they can equally receive the delivered information for a given subject, just as the normal population. Several examples might be, for the visually impaired, one can have brail lettered terminals and input/output devices. For paraplegic subjects there are several robotic customized devices for interacting with teaching material. For the cognitively impaired population, the teaching material must be adapted properly. Here the software enabler mentioned in example 1 will be of use.

Finally, this technology can be of great help among the multilingual population, with automated translators available both to teachers, students and parents.

The above enablers depend mostly on subjects which are sufficiently conceptualized and can be delivered through media, such as television or computer screens. Here the information is textual, verbal or pictorial.

However, there are skills to be learned that require physical interaction with the world, and/or carrying out an experiment. Here again, the ideal situation would be for each student to have their own experimental setup. However, in many cases this is not possible for a variety of reasons, not the least of which is the cost involved.

This technology can help again!

1. In order to have access to expensive laboratories and facilities, one can deploy tele-robotic technologies. With these tele-robots, students can interact with the physical experiment. They can see, hear and feel the affects of the interaction and ask “what if “ questions. These kinds of interactions not only help students to understand and embody the knowledge, but it also keeps student’s engagement active, which helps them to be motivated.
2. The most advanced and most desirable technology is the creation of a tele-immersive environment for teaching and learning. This is a three dimensional virtual space, which mimics the real space both visually, aurally and tactually. It is one in which both the student/apprentice and teacher/master can meet and interact. This technology does not exist yet but it is very feasible from what we know today.

The advantages of such an environment are many. First, the students and teachers do not have to be physically collocated. Secondly, the teacher can advise/coach several students and yet the student would feel that he/she is the only one getting the teacher’s full attention.

Third, this technology would facilitate demonstration/coaching of physical and/or mechanical skills (such as surgery, operating complex machinery, etc.), which require true spatio-temporal observations of the master. In turn the master can make the same spatio-temporal observations of the students and give not only verbal but also mechanical feedback. This feedback is critical for the apprentice since it will give him/her a sense of being in direct touch with reality, of being able to control events and get the perceptual feedback concerning how he/she is doing.

Finally, we can speculate on multi-site tele-immersive environments which may be needed

for the teaching and training of cooperative activities, such as playing in an orchestra, dancing in an ensemble, coordinated war games, coordinated manufacturing and their like. It is not too difficult to extrapolate the one teacher/student scenario to multi-students and one director scenario by deploying the distributed tele-immersive environments.

One open question remains – Can the tele-presence reproduce a sense of being there so that what is learned transfers to the real world?

All of this technology will never be used unless there is sustained and substantial investment into the necessary infrastructure covering not only schools, but libraries and homes, similar to the investment that was made in the past in electrification and later in telephone infrastructure.

* * * * *



Dr. Ruzena Bajcsy was appointed Director of CITRIS at the University of California, Berkeley on November 1, 2001. Prior to coming to Berkeley, she was Assistant Director of the Computer Information Science and Engineering Directorate (CISE) between December 1, 1998 and September 1, 2001. As head of National Science Foundation’s CISE directorate, Dr. Bajcsy managed a \$500 million annual budget. She came to the NSF from the University of Pennsylvania where she was a professor of computer science and engineering.

Dr. Bajcsy is a pioneering researcher in machine perception, robotics and artificial intelligence. She is a professor both in the Computer and Information Science Department

and in the Mechanical Engineering and Applied Mechanics Department at Berkeley. She is also a member of the Neuroscience Institute and the School of Medicine. She is also Director of the University of Pennsylvania's General Robotics and Active Sensory Perception Laboratory, which she founded in 1978.

Dr. Bajcsy has done seminal research in the areas of human-centered computer control, cognitive science, robotics, computerized radiological/medical image processing and artificial vision. She is highly regarded, not only for her significant research contributions, but also for her leadership in the creation of a world-class robotics laboratory, recognized world wide as a premiere research center. She is a member of the National Academy of Engineering, as well as the Institute of Medicine. She is especially known for her wide-ranging, broad outlook in the field and her cross-disciplinary talent and leadership in successfully bridging such diverse areas as robotics and artificial intelligence, engineering and cognitive science.

Dr. Bajcsy received her master's and Ph.D. degrees in electrical engineering from Slovak Technical University in 1957 and 1967, respectively. She received a Ph.D. in computer science in 1972 from Stanford University, and since that time has been teaching and doing research at Penn's Department of Computer and Information Science. She began as an assistant professor and within 13 years became chair of the department. Prior to her work at the University of Pennsylvania, she taught during the 1950s and 1960s as an instructor and assistant professor in the Department of Mathematics and Department of Computer Science at Slovak Technical University in Bratislava. She has served as advisor to more than 50 Ph.D. recipients. In 2001 she received an honorary doctorate from University of Ljubljana in Slovenia

In 2001 she became a recipient of the ACM A. Newell award.

TEACHING IN 2025: EDUCATION AND TECHNOLOGY TRANSFORMED

Vint Cerf

*Sr. Vice President for Internet Architecture and Technology
WorldCom*

and

Caleb Schutz

*President, MarcoPolo Education Foundation
President, WorldCom Foundation
Vice President, WorldCom*

Her students logged out hours ago, but the seasoned teacher is not quite ready to call it a day. Thirty years in the classroom has taught her the importance of being prepared. Staying one step ahead of her students has been a way of life for a long time. Yet, there is a rigor to her pace that suggests she is nearing the end, like a distance runner with a final burst of energy she wants to make the most out her remaining days in her classroom, although, *classroom* hardly seems an appropriate term anymore.

It is 2025, and traditional definitions and models in education have all been put to the test. She reflects on the hundreds of thousands of e-mail correspondences, virtual classrooms with students from around the world, data and e-mail from astronauts taking core samples on Mars, messages from frantic parents who are reviewing their son's or daughter's progress via secure databases. "We've come so far, or have we?," she ponders. This much is sure, technology has transformed classroom.

A knocking sound coming from her computer turns the teacher from her thoughts and labor, "yes," she says to the screen, "Come in." A visual of a *door* opens on her screen revealing the image of a young teacher half a world away, "Hello, I hope I am not disturbing you." "No, not all," says the veteran teacher.

"I heard yesterday you announced your retirement," the younger teacher says, "I want to say that I will miss working with you and your students. You've been a mentor and a trusted friend."

"Thank you, the pleasure is mine," responds the veteran. "In fact, I am glad you called."

Directing her computer to transcribe the conversation as they talk, she continues, "I was just thinking about the transformation technology has brought to the classroom in the last 25 years. You're just beginning your career in the classroom equipped equally with the blackboard and the keyboard. How important to you is the connected classroom?"

"I can't imagine it any other way," says the younger teacher.

"I thought as much, and that's just the way it should be!" replies the veteran. "You take for granted continuous and speedy access to data, integration of high-quality content, teacher training on-demand and mentor relationships online. It is a precious perspective; but one that did not come without discoveries, trials and frustrations of many who have walked before you. I gather for you, the Internet is simply there. It is no more amazing now than electricity or the telephone was for us at the very beginning of the third millennium. The very notion of *Internet* is disappearing for you because a world without it is simply unthinkable."

"Most certainly, but what sort of challenges did you face as an educator in earlier days and how were they overcome?" asks the young teacher.

"At the time," continues the veteran, "hardware and awkward user interfaces seemed the formidable foes. "Broadband access to information, wired or wireless, for the consuming public, was neither reliable nor affordable. Once technological and political barriers were broken, machinery and access costs dropped and the flood of information

began to rush in. The challenge was, and remains today, designing technical solutions that, however wondrous, contain a sustainable, scalable economic model and encompass easily used interfaces to access all the features of this rich information environment. Now, about two thirds of the world's eight billion people have anytime, anywhere, anyhow access at an affordable price."

"Let me pause to point out the obvious. For about 2 billion people today, the Internet is NOT a reality; it is yet a distant dream or perhaps entirely unknown. Electricity is still unknown or unavailable or unreliable. Sanitation, housing, food, water and education are in limited supply. For those parts of our global society, Internet and its benefits seem far beyond reach. We must not give up pursuit, however idealistic, of access for all.

"Running closely with these challenges was the whole notion of the proper training and use of content. Learning how to use technology turned out to be at least as challenging as building it. The first computers and online access arrived in my old style classroom back in the mid 1990's. We were all entranced: teachers, administrators, parents. Computers and access had arrived, golden days were ahead, or so we thought. We know it is never that easy. With all the focus on the technology and access, almost nobody was exploring what to *do* with the computers once access arrived. Where would we go for content and training, how would the Internet color education?"

"One early voice was MarcoPolo, an Internet content and teacher training program dedicated to providing free, top quality, standards-based online content coupled with teacher training focused on real application of Internet in the K-12 classroom. I was trained and then trained many others in the late 1990's on how to integrate Internet into the classroom. MarcoPolo, for all of us, was a revelation of sorts. In an instant, the power and potential of the Internet and connectedness with people places and machines around the globe made sense. We'd gather in a computer lab eagerly to observe delivery of an interactive lesson on building and understanding three-dimensional shapes. You'd have thought we were your grand parents eagerly awaiting the images on

television of a man walking on the moon! Technology has a way inspiring minds to dream big dreams."

"MarcoPolo and other early settlers of quality content on the Internet frontier began to transform education. Suddenly, standards-based content mattered, professional development mattered, assessment and databases mattered and teachers and their students, the final arbiters of success, would dictate and direct future use of technology in education."

"But how did you get from the early days of email and chat rooms to collaborative learning we have today?" inquires the young teacher. "My world and my role today as a teacher is very different from what you describe. I've been trained as a *facilitator* of information and critical thinking, I rarely lecture. And, the Internet is for me not just a collection of facts, but a living organism of ideas and experimental opportunity. Knowledge and understanding are derived from countless exchanges of information and collaborative explorations of concepts and experiments involving sources around the globe. Parent-teacher meetings are a regular occurrence because we correspond online or *meet* at the entrance of their daughter's online portfolio to review progress."

"And it has been a remarkable evolution of ideas, uses and technologies," says the veteran. "Internet and online education keep students engaged like nothing in the past. I know you and your students have participated with mine in our virtual engineering lab that allows students to enter the MUD (multi-user domain) lab as scientists with virtual tools of their choice to conduct experiments and participate in projects with others. Last week, one team of students was even successful at accessing and manipulating a probe in the virtual lab that was linked to a real satellite in space collecting data on the sun's rays. Data was sent back to the virtual lab for student analysis, and I was able to track their progress. In early days, this would have been a very expensive pilot program for *one* class while thousands of other eager students idled on the sidelines watching. Today, interactive collaboration is standard practice and just one of the required assignments designed to monitor the pace of a team's understanding. Our role now is not that of the keeper and provider of

all knowledge, but that of a guide and we can monitor student progress individually. Asynchronous learning, or self-paced online learning now allows students do most of their work outside of a standard, shortened lecture or presentation. Once equipped and capable to use core math and science principles, students were free to explore their world. This allows me to spend more time interacting with students individually to cover particular strengths and weaknesses.

“Of course tracking assessment and online portfolios that follow a student’s work through his or her school career are remarkable changes as well. I remember the policy battles necessary to allow state school systems to create secure online files for each student. But, with universities everywhere competing for students and engaging in borderless learning and companies around the globe all calling for demonstrable proof that tomorrow’s workers are equipped, action was necessary. As you can imagine, these tools also had major implications for privacy. If it were not for new encryption technologies and much better operating system designs focused at online education it would have been tough to do.

“The last driver of change,” she continues, “was the ability of quality programs to be able to scale-up and endure. In the early days, myriad pilot programs dotted the landscape. Distance learning programs of every shape and size, custom web sites for every conceivable educational issue, programs that all promised a lot, but were unable to deliver. Similar to the dot-com bust in 2000, the online education sector had to go through its own contractions. In the process, the lesson we’ve learned is that the best education technology solutions are those that can scale in terms of users and economics. Models that operate more like an isolated island run counter to the notion of a network and costs are driven down when programs can involve a million users as easily as they reach one class. One aspect became very clear: each individual student needed to be free to explore the information and experimentation space independently or in small collaborative groups. Scaling was a direct side-effect of the degree to which individuals and small groups could work more or less independently. We must recall also

that programs take time to build, we cannot give up on valuable programs, perseverance is key to success.”

“Collaboration with your class and teams of other students around the world is tremendous,” says the younger teacher. “It’s the primary reason I was drawn into teaching.”

“An image comes to mind,” continues the younger. “The notion is quite old fashioned, but I look at my classroom today and I see many of the variants of the classic *one-room schoolhouse*. Internet access brings information on a range of topics from around the globe, and even nearby planets, into the classroom. Wireless workstations allow students into a range of virtual environments to assemble research teams, collaborate, mentor and teach each other. Technology and the Internet make this possible. We’ve come full circle, but this time, the one-room schoolhouse has limitless windows to the world beyond.”

“You might be right,” says the veteran. “I think we can be assured that role of the educator is just as important today as in times past. Without guidance from teachers and essential navigation tools, our students have no more chance than a ship without a rudder.”

“Thank you,” says the young teacher. “I enjoy these conversations.”

“So do I,” says the veteran. “Thank you for your thoughts and please keep in touch.”

“I will,” says the young teacher, “and here come my students, so I’ll sign-off, goodbye.”

“Happy exploring,” says the veteran, “goodbye.”

The visual door on her computer closes and she is alone again in the classroom. “Computer,” the veteran says, “save this transcript in file memoirs-2025-4-10!”

Remarkable, she thinks, ten time zones apart, visiting and chatting online, in our own languages, and the intelligent network provided translation and transcription!

As she closes down her virtual workbook for the night, the veteran is warmed by the idea that half a world away a teacher is making a difference in young lives. Good teachers matter.

Where will education be when he retires?, she muses. The mind can only imagine.

* * * * *



Vinton G. Cerf is senior vice president of Architecture and Technology for WorldCom. Cerf's team of architects and engineers design advanced networking frameworks including Internet-based solutions for delivering a combination of data, information, voice and video services for business and consumer use.

Widely known as one of the "Fathers of the Internet," Cerf is the co-designer of the TCP/IP protocols and the architecture of the Internet. In December 1997, President Clinton presented the U.S. National Medal of Technology to Cerf and his partner, Robert E. Kahn, for founding and developing the Internet.

Prior to rejoining MCI in 1994, Cerf was vice president of the Corporation for National Research Initiatives (CNRI). As vice president of MCI Digital Information Services from 1982-1986, he led the engineering of MCI Mail, the first commercial email service to be connected to the Internet.

During his tenure from 1976-1982 with the U.S. Department of Defense's Advanced Research Projects Agency (DARPA), Cerf played a key role leading the development of Internet and Internet-related data packet and security technologies.

* * * * *



Caleb M. Schutz leads the WorldCom Foundation and the newly formed MarcoPolo Education Foundation, and serves as corporate vice president for WorldCom. Under his leadership, the foundation took a bold step forward in 1997 with the introduction of MarcoPolo to focus the country's teachers and policymakers on Internet Content for the Classroom. In partnership with leading educational and content organizations, MarcoPolo provides teachers with standards-based Internet resources designed for integration into the classroom curriculum. Today, MarcoPolo's top quality, standards-based K-12 content is enjoyed by 300,000 web-using teachers every month. In addition, 10,000 teachers are trained every month on MarcoPolo and the goal is to train 2.4 million teachers by 2005. With the creation of the new MarcoPolo Education Foundation, Mr. Schutz is focused on moving MarcoPolo into this public charity to broaden the funding base and continue providing needed content and training to the nation's teachers.

Mr. Schutz joined MCI WorldCom in 1996 as director of the foundation and was responsible for foundation strategy, operations and company-wide corporate contributions. Prior to joining WorldCom, he spent several years as a consultant to corporate and private foundations, educational institutions and associations. Previously, Schutz worked for more than 15 years at IBM corporation helping to reengineer and implement the company's worldwide contributions and community relations strategy.

A DAY IN THE LIFE OF A YOUNG LEARNER: A 2020 VISION

Milton Chen

Executive Director

The George Lucas Educational Foundation

and

Stephen D. Arnold

Vice Chair

The George Lucas Educational Foundation

Illustrations by Greg Knight

“Technology helps overcome the two enemies of learning: isolation and abstraction.”

George Lucas

Chairman, The George Lucas
Educational Foundation

July 15, 2020: On a foggy summer day in San Francisco, 11-year-old Malia is hard at work—in school. In 2007, her school district changed from the 9-month school calendar, recognizing that teaching and learning are year-round activities and that the long summer vacation was only an anachronism from a time when children were needed to bring in the crops. Her school looks and feels like a cross between a working office, a public library, and a movie set, with individual student cubicles decorated to express each student’s personality and interests, and 10 large multimedia production and research centers, enough for a whole class. Nearly all of the furniture is on wheels so that work areas can be easily reconfigured to adapt to the needs of particular student activities. The school’s design was inspired by Minnesota’s School of Environmental Studies, founded in 1995, but a pioneer in its time in new school architecture.

At the start of this school day, the classroom environment is brimming with student teams chatting about last night’s online exchanges and organizing to continue their work on the class earth science unit.

Malia and two of her classmates, Sahar and Osvaldo, are seated in comfortable task chairs at a multimedia production and communications station. Facing them is a high-resolution, luminescent display screen, viewable from front and back, where combinations of images, text, and digital video can be summoned by voice command.

Osvaldo, born blind, uses the assistive technology of a digital “visual prosthesis system” to see. The system consists of a minicamera mounted on eyeglasses with signal processors and electrodes stimulating his visual cortex, a technology first pioneered on Patient Alpha in 2002. Unlike blind students of previous generations, Osvaldo is able to participate fully in all activities with sighted students.

“Give us our team project on volcanoes,” Osvaldo asks the school’s server, enabling the team to review its progress during the previous week. Their research using the Global Learning Network has led them to the Hawaii Volcanoes



National Park website, where they have witnessed several hours of video footage of volcanic eruptions, observed volcanologists at work tracking and measuring lava flows, and watched interviews with them. The site included a 3-D time-lapse hologram of the 1983 Mount Kilauea eruption on the Big Island. Through the time compression of time-lapse photography, they were able to witness lava flows over the past 40 years. They had made a copy of the hologram and left it in the classroom for use by other students.

Yesterday, donning special virtual reality headgear, they had gone on a simulated trip to the lava fields, giving them an on-the-ground sensation of hiking across acres of older lava formations to arrive at a scene of bright orange lava flowing towards the sea. “How cool was that,” Malia grins. “You could hear the lava crackling.” Last night, from their homes, they had brainstormed some questions in preparation for an interview with a volcano expert, scheduled for today. “Last night’s interview questions,” requests Sahar. The system promptly displays the students’ work on the screen.

Their teacher, Kavery Dutta, stops by to observe their discussion as they prepare for their videoconference. “You know,” she advises them, “it would be great to also look at what volcanoes meant to the native Hawaiians centuries ago. They believed in a goddess of fire, Pele.” She gives them some resources to search and access from the University of Hawaii Digital Library. She also suggests they look up the pioneering work of MIT geologist Thomas Jaggar, who founded the Hawaiian Volcano Observatory in 1912 and persuaded Congress to preserve the area as a national park.

Ms. Dutta strolls over to check in with another group of students. One of them is holding a sample of volcanic rock, while another examines it under a handheld digital microscope, with the magnified image projectable on a large screen behind them. A third student is examining the volcano hologram left by Malia’s group.



“OK, we’re ready for our appointment with the volcanologist at Hawaii Volcanoes National Park,” Malia announces. The face of Harold Levitt, the Park’s chief of interpretation, appears in the familiar green uniform of a National Park Service Ranger. Responding to their questions, Ranger Levitt leads them through several more screens of images showing video news clips and data sources dating back to the Mount Kilauea eruption; the science and chemistry of volcanoes (including dangers such as the release of sulfuric fumes); and the human impact on local communities, from devastation of homes to increased tourism. Malia and her classmates are also able to observe today’s lava flows in real time from cameras trained on the site, enjoying the chance to watch the creation of black sand when hot lava meets the cold ocean water.

Malia asks, “A few weeks ago, we had a small earthquake here. We felt it but it didn’t damage anything. How are earthquakes related to volcanoes?” On another screen, Ranger Levitt calls up a simulation of plate tectonics and shows them cross-sections of the Earth, as well as aerial satellite photos from different elevations, with overlaid graphics indicating earthquake fault zones in the Bay Area and then San Francisco. For other

experts, he refers them to the U. S. Geological Survey offices in the Bay Area. Malia and her classmates make a voicenote in their ongoing project record to ask their teacher about making a field trip and to look up the USGS website.

After their 20-minute interview with Ranger Levitt, recorded on the school's server to become a part of the project archive, the students quickly review the video transcript and earmark some of his comments for possible use in their final multimedia report. At the end of the two-hour session, they make a multimedia summary of their work, calendar next meetings, and assign themselves homework before their next meeting. They each place a copy of today's workfile in their digital backpack, a rugged mobile personal computer and communications console "checked out" by each student at the beginning of the school year, the way textbooks used to be issued.

Malia's "digipack" allows her to spend some more time on her volcanoes project later in the afternoon after walking a few blocks to her father's office. As she waits for him to finish his work, she uses it to connect to the school's library information system and the now-widely-available wireless network. Searching links and browsing through references on Hawaiian mythology, she watches a short video clip on the Goddess Pele on her viewscreen, recording some voicenotes to share with her project partners at school tomorrow.

Later that night at home, Malia is practicing her Chinese in the family room. She hopes to visit China one day and has been using an online language learning system to gain proficiency in basic Chinese conversation, reading, and writing. Her younger sister, Sonia, likes to look on and sits by her side as they face a multimedia screen similar to those in their schools. They both hold handheld digital devices serving as Chinese-English dictionaries for looking up words and phrases in both languages, in text and audio. They can also store their own spoken phrases.

Malia requests, "The lesson on soccer, please," which begins with a scene of Chinese soccer star, Chen Mingde, dribbling around a Brazilian defender and scoring with a precise kick into the corner of the net. The play-by-play commentary is heard in Mandarin, with both the romanized phonetic system and Chinese characters shown as captions at the bottom of the screen. The individual words and characters light up as they are spoken.

As Malia practices her pronunciation of the scene, the system provides feedback, allowing her to hear her rendition and then a digitally corrected version, ensuring that she improves her pronunciation of the four tones, a typically difficult task for English speakers.

Through this online system, she is also able to converse with students with similar interests in other countries and engage in mutual language tutoring. "I'd like to talk to Xiaoyan," Malia says, asking the system to call her online friend, Xiaoyan Zhao, an 11-year-old girl who lives in Shanghai and goes by the nickname of "XYZ." XYZ appears on screen at lunchtime in her school cafeteria, speaking in English while Malia practices her Chinese as they help each other with vocabulary and pronunciation. They promise to make short videos introducing their family members to each other and send them in the next week.



Malia mentions she's working on a volcanoes project at school, and XYZ recalls that her geography class had studied Mount Fuji, named after Japan's ancestral Fire Goddess. Malia captures XYZ's comment as a voicenote and mails it to her classmates as a suggestion for extending their research.

As Malia finishes her conversation and logs off, her father enters the room and asks her the age-old question parents have asked their children for generations: "So what did you do at school today?" As Malia enthusiastically recounts her day, and her excitement about returning to school tomorrow, he shakes his head in amazement. "And to think," he recalls, "20 years ago, all we had was the Internet."



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VIGNETTES ABOUT THE FUTURE OF LEARNING TECHNOLOGIES

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In a decade or two, three complementary interfaces will shape how people learn:

- *The familiar “world to the desk top” interface*, providing access to distant experts and archives, enabling collaborations, mentoring relationships, and virtual communities-of-practice. This interface is evolving through initiatives such as Internet2.
- *Interfaces for “ubiquitous computing,”* in which portable wireless devices infuse virtual resources as we move through the real world. The early stages of “augmented reality” interfaces are characterized by research on the role of “smart objects” and “intelligent contexts” in learning and doing.
- *“Alice-in-Wonderland” multi-user virtual environments interfaces*, in which participants’ avatars interact with computer-based agents and digital artifacts in virtual contexts. The initial stages of studies on shared virtual environments are characterized by advances in Internet games and work in virtual reality.

The vignettes below are images of plausible futures that depict how applying these interfaces might reshape teaching, learning, and the organization of educational institutions. The objective of these vignettes is not to detail blueprints of an unalterable future, but instead to show the range of possibilities enabled by emerging interactive media and the consequences—desirable and undesirable—that may flow from their application in pre-college and higher education settings. Such visions suggest decisions that researchers should make today to explore the potential of these technologies while minimizing unintended and negative outcomes of their use.

* * * * *

First are two vignettes that illustrate the types of learning technologies young learners might routinely experience before they attend high school and college.

* * * * *

Vignette 1. “Take a deep breath,” Maria told her mother, “then blow it out into the balloon.” Deftly, as soon as her mother had finished, Maria used a plastic clamp to pinch the neck of the special balloon, then measured its circumference. “All done, Mama!” she said, writing down the number in her notebook. Her mother sneezed, then sank back on the couch with a smile of approval. Even though her sinuses ached—and that deep breath had not helped—she enjoyed helping Maria with her daily homework. After all, participating in the allergy study project not only involved her child more deeply in school, but also subsidized the Web-TV box that provided the family access to sports and entertainment websites. Maria was navigating to the appropriate site, then logging her mother’s lung-capacity figure into the national database. Her little brother watched, fascinated by the colored visualizations displaying the complex ecological, meteorological, and pollution factors that predicted today’s likely allergic responses in Maria’s region of the city.

Maria’s teacher, Ms. Grosvenor, was also sighing out a deep breath at that moment, but not into a balloon. While eating a Ho-Ho for breakfast, she was using her home computer to access a different part of the allergy study website, a section with guidance for teachers about how to cover today’s classroom lesson on regional flora. Her preservice education a

decade ago had provided some background in ecology, but—now that fifth grade students were mastering material she had not learned until the end of high school—Ms. Grosvenor frequently used the website to update her knowledge about allergenic plants. Sometimes the sophisticated multi-level model scientists and doctors were developing, made possible by micro-regional data supplied by learners all across the country, made her head ache for reasons other than sinuses! On the other hand, at least the students were quite involved in this set of science activities. Discussions in the “Teachers’ Forum” of the website reaffirmed her own feeling that most teachers would rather have the small hassle of keeping up with new ideas than the constant struggle of trying to motivate students to learn boring lessons.

At the same time, in her elementary school’s computer Lab, Consuela was threading her way through a complex maze. Of course, the maze was not in the Lab, but in the “Narnia” MUVE (a text-based Multi-User Virtual Environment developed around the stories by C.S. Lewis). Her classmates and fellow adventurers Joe and Fernando were “with” her, utilizing their Web-TV connections at their homes, as was her mentor, a small bear named Oliver (in reality, a high school senior interested in mythology who assumed a Pooh-like “avatar” in the virtual world of the MUVE). Mr. Curtis, the school principal, watched bemused from the doorway. How different things were in 2009, he thought, students scattered across grade levels and dispersed across the city, yet all together in a shared, fantasy-based learning environment a full hour before school even starts! (The school building opened at the crack of dawn to enable lab-based Web use by learners like Consuela, whose family had no access at home.)

“The extra effort is worth it,” thought Mr. Curtis. Seven years into the technology initiative, student motivation was high (increased attendance, learners involved outside of school hours), and parents were

impressed by the complex material and sophisticated skills their children were mastering. Even standardized test scores—which measured only a fraction of what was really happening—were rising. Most important, young girls such as Consuela were more involved with school. Because of their culture, Hispanic girls had been very reluctant to approach adult authority figures, like teachers—but the MUVE had altered that by providing a “costume party” environment in which, wearing the “mask” of technology, children’s and teachers’ avatars could mingle without cultural constraints. “I wonder what this generation will be like in high school—or college!” mused Mr. Curtis. (Dede, 2000)

* * * * *

Vignette 2. Alec and Arielle strolled through Harvard Yard on their way to the museum, to collect data for their class assignment. Each carried a handheld device (HD) that softly pulsed every time they walked past a building in the Yard. The vibration signaled that the building would share information about its architecture, history, purpose, and inhabitants, using interactive wireless data transfer. Sometimes Alec would stop and use his HD to ask questions about an interesting looking location. Today, he was in a hurry and ignored the pulses.

Inside the museum, Alec and Arielle split up to work on their individual assignments. When Alec typed his research topic into the museum computer, it loaded a building map into his HD, with flashing icons showing exhibits on that subject. At each exhibit, Alec could capture a digital image on his HD, download data about the artifacts and links to related websites, and access alternative interpretations about the exhibit. His HD automatically supplied information about Alec’s age and background to ensure that the material he received was appropriate in native language, reading level, and learning style.

While the museum-supplied information was interesting, Alec always enjoyed the

comments posted about each exhibit by other kids. Sometimes, he added a few remarks of his own to the ongoing discussion. Seeing a cool artifact related to Arielle's topic, Alec paused to link to her HD, sending a digital image of the exhibit and information on its location.

Alec's favorite exhibits were those augmented by virtual environments. For example, at a panorama showing the bones found at a tar pit, Alec's HD depicted a virtual reconstruction of the dinosaurs that were trapped at that prehistoric location. In the virtual environment, he could assume the perspective of each species and walk or fly or swim through its typical habitat. Other types of exhibit-linked virtual environments enabled "time travel" to show how a particular spot on the earth's surface had changed over the eons. For each epoch, Alec used virtual probes on his HD to collect data about temperature, air pressure, elevation, and pollutants.

Walking back from the museum, Arielle and Alec shared what they had found. Both wondered what learning was like before augmented reality and ubiquitous computing, when objects and locations were mute and inert. How lifeless the world must have been! (Dede, 2002)

The next vignette depicts types of educational technologies some secondary students might experience before college:

Vignette 3. In a rural area about sixty miles from the city, high school student Karen sits down at her information appliance (notepad device with the power of today's supercomputers), currently configured as an electronics diagnosis/repair training device. When sign-in is complete, the device acknowledges her readiness to begin Lesson Twelve: Teamed Correction of Malfunctioning Communications Sensor. Her "knowbot" (machine-based agent) establishes a telecommunications link to Phil, her partner

in the exercise, who is sitting at a similar device in his suburban home thirty miles away. "Why did I have the bad luck to get paired with this clown?" she thinks, noting the vacant expression on his face in the video window. "He probably spent last night partying instead of preparing for the lesson." A favorite saying of the community college faculty member to whom she is apprenticed flits through her mind, "The effectiveness of computer-supported cooperative work can be severely limited by the team's weakest member."

"Let's begin," says Karen decisively. "I'll put on the DataArm (a manipulatory device that incorporates force-feedback to its user) to find and remove the faulty component. You use the hypertext database to locate the appropriate repair procedure." Without giving Phil time to reply, she puts on her head-mounted display, brings up an AR (artificial reality) depicting the interior of a TransStar communications groundstation receiver, and begins strapping on the DataArm. The reality-engine's meshing of computer graphics and video images presents a near-perfect simulation, although moving too rapidly causes objects to blur slightly. Slowly, she grasps a microwrench with her "hand" on the screen and begins to loosen the first fastener on the amplifier's cover. Haptic feedback from the DataArm to her hand completes the illusion, and she winces as she realizes the bolt is rusty and will be difficult to remove without breaking.

Dr. Dunleavy, the community college vocational educator who serves as mentor to Karen and Phil, virtually monitors Karen's avatar as she struggles with opening the simulated device. He notes approvingly that she seems as comfortable with the physical, hands-on parts of the job as well as the intellectual analysis; both sets of skills are important in a future engineer. "Documenting a strong recommendation for Advanced Placement college credit via the Educational Testing Service will be easy in her case," he thinks, "but Phil is in danger of failing this

unit. Maybe Ms. Tunbridge (the TransStar communications repair expert also serving as mentor for this experience) will offer him a job right out of high school, giving him some time to mature before he heads for college.”

At his information appliance, Phil calls up the hypertext database for Electronics Repair. On the screen, a multicolored, three-dimensional network of interconnections appears and begins to rotate slowly. Just looking at the knowledge web makes his eyes hurt. Since the screen resolution is excellent, he suspects that a lack of sleep is the culprit. “Lesson Twelve,” says Phil slowly, and a trail is highlighted in the network. He begins to skim through a sea of stories, harvesting metaphors and analogies, while simultaneously monitoring a small window in the upper left-hand corner of the screen that is beginning to fill with data from the diagnostic sensors on Karen’s DataArm.

Several paragraphs of text are displayed at the bottom of the screen, ignored by Phil. Since his learning style is predominantly visual and auditory rather than symbolic, he listens to the web as it vocalizes this textual material, watching a graphical pointer maneuver over a blueprint. Three figurines gesture near the top of the display, indicating that they know related stories. On the right hand side of the monitor, an interest-based browser shows index entries grouped by issue, hardware configuration, and functional system.

Traversing the network at the speed at which Karen is working is difficult, given his lack of sleep, and he makes several missteps. “Knowledge Base,” says Phil slowly, “infer what the optical memory chip does to the three-dimensional quantum well superlattice.” The voice of his knowbot suddenly responds, “You seem to be assuming a sensor flaw when the amplifier may be the problem.” “Shut up!” thinks Phil, hitting the cut-off switch. He then groans as he visualizes his knowbot feeding the cognitive audit trail of his actions into the workstations of his mentors. He cannot terminate those incriminating records

and cringes when he imagines his mentor’s “avatar” delivering another lecture on his shortcomings. Mentally, Phil begins phrasing an elaborate excuse to send his instructors via email at the termination of the lesson.

For her part, Karen is exasperatedly watching the window on her AR display in which Phil’s diagnostic responses should be appearing. “He’s hopeless,” she thinks. Her knowbot’s “consciousness sensor” (a biofeedback link that monitors user attention and mood) interrupts with a warning: “Your blood pressure is rising rapidly; this could trigger a migraine headache.” “Why,” says Karen with a sigh, “couldn’t I have lived in the age when students learned from textbooks?”

(Dede, 2000)

* * * * *

The next vignette presents a portrayal of how emerging information technologies, if unreflectively applied, could enrich some aspects of higher education while also exacerbating some of its weaknesses. This depicts the daily routine of a faculty member a couple decades from now and illustrates some potential implications for colleges and universities of artifacts with embedded intelligence. [The ideas and situations in this image of the future draw heavily on a scenario from Weiser (1991).]

* * * * *

Vignette 4. Vesper is driving to work through heavy rush hour traffic. She is a faculty member in computational engineering at a university located far from her home in the suburbs. Despite the long drive, the position was irresistible because the campus is noted for its usage of advanced networking technologies. She glances in the *foreview mirror* to check the traffic. {Commuters' automobiles are hooked into a large network that uses data sent by cars and highway sensors to monitor and coordinate the flow of traffic. The “foreview mirror” presents a graphic display of what is happening up to

five miles in front of her car on Vesper's planned route to work.) Noticing a traffic slowdown ahead, Vesper taps a button on the steering column to check for alternate routes that might be faster. A moment later, she cancels the request for rerouting as the foreview mirror reveals the green icon of a food shop on a side street near the next exit from the freeway. The foreview mirror helps her to find a parking space quickly, and she orders a cup of coffee while waiting for the traffic jam to clear.

While drinking her coffee, Vesper calls up some work on the screen of her *information appliance*. {This device has the approximate processing power of supercomputers a decade from now and is about the size of a notepad. It is linked via wireless networking and fiberoptic cable to a large web of other information appliances, including those at Vesper's campus.} The university's diagnostic expert system for debugging prototype ULSI designs can handle the routine misconceptions typical of most senior engineering majors, but occasionally is stumped by an unusual faulty procedure that some learner has misgeneralized. {At this point in history, a computer program trained to mimic human experts can handle many routine aspects of evaluating student performance, but complex assessments still require human involvement.}

Vesper has an uncanny ability to recognize exotic error patterns by quickly scanning a complex schematic. She diagnoses three sets of student misgeneralizations before resuming her trip to school. Her knowbot (semi-intelligent agent) automatically sends this new "bug collection" to the national database on design misconceptions to be entered into its statistical records. Her knowbot also forwards her diagnoses to the university's expert system on ULSI design, which incorporates the new bugs into its knowledge base and begins preparing intelligent tutoring systems modules to correct those particular errors. Later that day, this instructional material will be forwarded to the

appropriate learners' notepads to provide individualized remediation.

As Vesper walks into the engineering complex on campus, her personalized *identity tab* registers her presence on the university's Net of security sensors. {In a clip-on badge displaying her picture and name, a small device is embedded that broadcasts information about Vesper's movements. Such an identity screening procedure is part of the university's security system. In this future world, these elaborate precautions have unfortunately become necessary.} A moment later, the machines in her office initiate a log-in cycle in preparation for her arrival. She realizes that she has left her car unlocked, but does not bother to retrace her steps; from her office, she can access the network to lock her car via a remote command.

As Vesper gets to her desk, the *telltale* by her door begins blinking, indicating that the department's espresso machine has finished brewing her cafe au lait. {A telltale is a remote signaling device that can be triggered to blink or make a sound, advising people in its vicinity of some event happening elsewhere.} Vesper drinks a cup of cafe au lait every morning on arriving. She heads down the hall to get the coffee; the espresso maker's brew will be much better than the vile stuff she had consumed at the food shop. On returning to her office, she instructs her knowbot to remind her not to stop there again. A copy of her evaluation is automatically forwarded to the food shop's manager and to the local consumer ratings magazine.

In the hour before class, as her senior students "arrive," they congregate in their various engineering labs to work on projects for their exhibition portfolios. (Of course, many of these students are not physically located on Vesper's campus; instead the facilities used by her students are geographically scattered all over the world, linked via broadband communications.) Vesper will "join" them in about half an hour to begin instruction. She takes a break from viewing her videomail to "surveil" their

activities on their individual notepads. Valerie is still dallying too long before getting down to work; Vesper will have to speak with her. Ricardo has not arrived at his engineering complex, but no message has come in to indicate why he is later than usual.

Skimming an engineering education journal, she notices a case study that resembles a problem student in one of her colleague's classes. His apprentice appears to have a rare type of learning disability that interferes with developing a spatial sense of geometric relationships, an important skill in his branch of engineering. Vesper sends an excerpt from the article to her colleague's machine with voice-mail appended explaining its significance. She tends to avoid videomail, even though its greater bandwidth empowers more subtle shades of meaning. It is too much trouble to assume a professional demeanor just to send a simple message. The knowbot in her journal-reading application notes that she found the article useful and reinforces the pattern recognizers that triggered its selection.

A small light on the edge of Vesper's glasses begins blinking. A phone call is coming in; must be from someone not on the network. "Activate," says Vesper (the only word her glasses can recognize). A voice begins speaking in her ear; Ricardo's girlfriend, informing her that he is sick again. With a sigh, Vesper makes a note to prepare hardcopy homework that will be sent off by snailmail—what a hassle! She will be glad when all governments finally recognize that home access to basic network services is a fundamental right, even if that does mean subsidizing subscriptions for the poor.

Across campus, two graduates of local high schools are waiting their turn for individual consultations at the Admissions Office. Both have equivalent, above-average transcripts and want to attend college in this city, but Nick has no money to offer beyond the minimum subsidy this State provides, while Elizabeth has \$150,000 from her parents to use on her postsecondary education. Nick will be offered four years of predominantly

large-group classes, most from other higher education institutions taught by lecture/discussion across distance or via computer-based training software. However, he will have some local seminar classes in his junior and senior year, this campus will arrange for an unpaid internship with a regional employer., and he will receive a degree from this university. In contrast, due to her financial contribution, Elizabeth will be offered mostly small-group classes, predominantly local (although many fellow students in those classes will attend across distance, as in Vesper's instruction). Elizabeth will also have a tele-mentoring relationship with a nationally recognized expert in whatever major she chooses and a senior-year apprenticeship guaranteed with one of her five top choices of employers.

Down the hall, the university's president chairs a meeting on their forthcoming re-accreditation. Since the last accreditation a decade ago, major shifts have occurred. Many students who enroll in this university's courses live outside this region and will graduate from other colleges, while most local students take the majority of their courses across distance from other institutions, then have these counted toward their graduation from here. Due to excellent teaching, strong scholarly reputations, and distributed collaborations with industry, the faculty are better paid and have smaller classes—they command high fees in the competitive national market for distance course enrollments. However, determining "institutional quality" in this situation is a little confusing to the group preparing for accreditation: How does one describe this type of distributed virtual organization? Who counts as students? faculty?

Before walking down to the lab to join her students, Vesper decides to have a conversation with her colleague Dimitri. Both received notifications last week about next year's salary. Vesper got a 15% raise because the spirited bidding nationally for the limited distance-based enrollments in her classes

drove up the university's revenue and thus the teaching part of her wages. Unfortunately, the opposite happened to Dimitri; his salary dropped 10%, as comparable faculty across the country showed greater increases in research visibility, student performance outcomes, and learners' ratings of teaching performance. All this led to reduced fees being paid by prospective applicants to his classes and lower wages for him. Vesper is trying to cheer up Dimitri by suggesting ways he can reverse this trend. This being subject to the laws of supply and demand is upsetting to both instructors, but that is the price of progress... (Dede, 2000)

As discussed earlier, this vignette's purpose is not to suggest that Vesper's world is the only possible future for higher education, but instead to illustrate the types of smart devices that will permeate society in the future and the human and organizational capabilities—and challenges—they enable. The final vignette below is deliberately crafted to suggest a type of dystopian future we could create if we mindlessly apply advanced technologies to teaching and learning.

Vignette 5. Disgusted and dismayed, Marcie stared out the window. Ms. Taylor, the human teacher, had once again bowed to the will of Hal, the classroom's machine-based 'intelligent' tutor. Despite student protests, the two co-instructors had raised the quota of worksheets to be completed each hour. "One more brick on the load," Marcie thought, "the more you do, the more they want."

Superhighway Secondary School was the envy of the city, the magnet program in which every family tried to enroll their children. Nothing but the best computers and telecommunications: ultra-fast workstations, high-speed digital connections to the Internet, the latest presentational multimedia applications, even neural-net filtering software to keep porn away from the nerds. Why even

Howie, the best technical wizard in the school, was able to defeat the filtering system only to the point of viewing the marble breasts on statues. "Get a life," thought Marcie.

Her best friend, Shelley, returned to the cubicle next to her. "You look mad," Marcie whispered out of the corner of her mouth. Her workstation's microphone was very sensitive, and she did not want to spend more time in detention. "I got scolded by the monitor-bot," fumed Shelley, "because I did not take the most direct path back from the restroom. What a drag!"

Just then a tone sounded in Marcie's earphones. Her five-minutes-per-hour break was over; time to get back to the worksheets. "If I see one more cute virtual figure dancing around the screen," she muttered to Shelley, "I'm going to puke all over the keyboard and short out this loser." "I agree," Shelley whispered back. "I'm so tired of multimedia, I can't even stand to watch TV at night."

Meanwhile, Ms. Taylor patrolled among her five classrooms. While the school board appreciated the cost savings with a pupil/teacher ratio of 150-to-1, maintaining order with that many students was hard even with the ever-vigilant Hal-tutors monitoring each classroom. The teacher thought about the disturbing news she'd heard that day. While standardized test scores of "Superhighway High" graduates were the best in the city, many were dropping out of college in their second or third year. "Don't they appreciate the value of a fine high-tech education?" thought Ms. Taylor. (Dede, 1998)

The important issue in effectiveness for learning is not the sophistication of the technologies, but the ways in which their capabilities aid and motivate users.

The author's recent testimony to Congress (Dede, 2001) presents a list of devices, media, and virtual contexts enabled by sophisticated information technologies, along with the

estimates of a conservative timeframe for their technological and economic feasibility. That testimony also indicates that the fundamental barriers to employing these technologies effectively for learning are not technical or economic, but psychological, organizational, political, and cultural. Powerful methods for scaling-up and transferring pilot implementations and for evolving the public's conceptions of learning and schooling are essential to take full advantage of the opportunities new technologies pose.

* * * * *



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grant from the Joyce Foundation to use Internet-2 interactive media for guidance and mentoring across distance.

Chris recently served as a member of the National Academy of Sciences Committee on Foundations of Educational and Psychological Assessment and a member of the U.S. Department of Education's Expert Panel on Technology. He is on the International Steering Committee for the Second International Technology in Education Study spanning approximately thirty countries. Chris is a member of the Board of Directors of the Boston Tech Academy, an experimental small high school in the Boston Public School system, funded by the Gates Foundation. He serves on the Advisory Boards of ThinkLink, FreshPond, bigchalk, Celt, and World Book, as well as several U.S. Department of Education Regional Educational Labs and Regional Technology Centers.

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A Vision for Life Long Learning – Year 2020

Introduction by Bill Gates

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Introduction

Computing has already enriched and enhanced people's lives in countless ways, but we've only begun to see how it will transform our businesses, our governments and our communities. In the next few years – a time I call the “digital decade” – we'll see computing become a much more significant and indispensable part of all our lives.

The pace of innovation is accelerating in all the core technologies of computing – from processing power to storage to network bandwidth – making it possible for computers to become better connected, easier and more intuitive to use, even less costly, and capable of handling all kinds of information. While this will create countless opportunities for business, entertainment and communication, the application of these technologies to the way people learn is the most important – and exciting.

By giving students access to a new world of information, sparking creativity, and facilitating rich communication and collaboration across vast distances, computers have long been a powerful tool for education. At the same time, the Internet has brought an unprecedented level of great educational content to a wide audience, encouraging teachers to share curriculums and resources worldwide. E-mail has facilitated improved communication among administrators, teachers, students, parents and educational researchers, and emerging Web services technologies will create further opportunities for collaborative learning. Increased industry and government funding in learning science promises to vastly improve the ways technology is applied to learning. And in the years ahead, a whole generation of kids will leave college and enter the workforce with a broad understanding of the ways they can use technology effectively in their jobs.

But we've still got a long way to go before we see how much technology can really do – particularly in education. Solving business problems with computers looks easy when compared to the often complex and little-understood process of learning. And technology is only part of the solution. All the computers in the world won't make a difference without enthusiastic students, skilled and committed teachers, involved and informed parents, and a society that underscores the value of lifelong learning.

Finding effective ways to use technology to enhance learning is a challenge that educators, academics, policymakers and the technology industry must work together to solve. The ideas and concepts outlined in this paper are just one step towards a better understanding of how technology can help everyone – from preschoolers to lifelong learners – to realize their full potential.



Bill Gates
Chairman and Chief Software Architect
Microsoft Corporation

Overview

Technology in education has two faces: one of transformation and one of hype. The printing press revolutionized access to education, and in the process an explosion in scientific inquiry was born. Teachers could finally produce and communicate content to a growing number of students entering an industrial revolution. Classrooms emerged as a great solution to disseminate content and augment interaction with faculty and other students. Traditional apprenticeships with experts polished the student to perfection.

Within a short period of time, the industrial workforce ballooned and with it the student body. The need to scale student to teacher interactions encouraged us to turn to other technologies: radio, television, computers, and the World Wide Web. Individually, these technologies couldn't increase the ratio of experts to novices, or significantly add to their real world experience. The "educational transformation" hype emerged around these technologies and they didn't deliver as their evangelists claimed.

"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 textbooks." (Thomas Edison, 1913).

"Radio may come as a vibrant and challenging textbook of the air". (Benjamin Darrow, 1932, Founder and first director of the Ohio School of the Air).

There won't be schools in the future.... I think the computer will blow up the school. ... but this will happen only in communities of children who have access to computers on a sufficient scale." (Seymour Papert, MIT, "Trying to Predict the Future", Popular Computing, October 1984)

One thing Mr. Papert got right was that access to computers, especially ones that are connected to communities would have an impact on education. The transformative differentiator for the next generation is the programmability of our interconnected networks. With increases in software programmability, we increase interactivity, increase communication, increase learner adaptability, increase shared visualizations, increase shared laboratory access, and increase experiential learning. In 20 years, we're going to see an impact equal to the printing press. This time we'll see a global, diverse, educated workforce deliver on dependable innovation, shared vision, and collaborative creativity.

The sweet spot for the use of technology in education may clearly be that software personalizes the learning experience, connects all the components, and emancipates publication for targeted and effective interaction. In the future, no one owns content as an end product. It is molecular at its origin. MIT will give away their content for free, other institutions will follow with interactivity innovations, and quality content will be consumed in chunks by whoever needs it. Through a filter of standards, tools and personalization templates (both for individuals and groups) we'll be able to aggregate learning content, the relationships between the content, and our context for using the content in such a way as it becomes part of our own personal value proposition when

studying or working with others. The objective: obtain and create knowledge at the right time, in the right place, in the right way, on the right device, for the right person.

Learning 2020 – Innovative, Creative, Collaborative Workforce

Let's imagine where technology will be in 20 years to help us set a vision for taking advantage of this new power for education. Such an exercise will allow us to visualize a roadmap for getting there.

It Begins at Birth – Intelligent Toys

From the first few months of life, children play with toys that teach them various concepts. In 2020, toys begin capturing children's learning experiences by using embedded technology that records information about the child's habits, preferences and progress to provide parents with a better understanding of their child's development. Toys provide parents with the child's learning profile, sending private information to the parent's information appliance so they can use the information in the selection and purchase of additional toys that will enhance the child's motivation and experience.

Preschool – Game Based Learning

Over the course of the preschool years, children increase their play in Learning 2020 by engaging in supportive virtual reality games in which they build on their psychomotor, reading, writing and math skills they learn in school. Interaction with other students and teachers in the environment helps identify learner strengths and deficiencies. The environments individualize around the children's content preferences, and create classroom activities that encourage children to expand their abilities through problem solving environments, complete with on-line personalized mentoring by parents and teachers. The games build critical thinking skills using simulated, situational environments that engage other members of the family and community to play along.

Because the parent is more involved, the access to outside content is monitored and manual personalization of student interest can be adjusted accordingly during prescribed home activities as well. The technology objective is to construct a safe environment for the child while engaged in technology driven learning experiences. For real world interactions, video playbacks of children engaged in learning activities are frequent and reviewed by student, teacher and parent.

The Early Years – Social Collaboration and Filtering

Auto-Recommended Group Formation

Since many parents send their children to kindergarten and traditional K-8 schools, while others home school their children, Learning in 2020 focuses on creating learning environments that facilitate communication and collaboration. Technology networks kids together in groups to learn and practice their combined skills. Whether children are working on art or science, they work with embedded technology that measures their performance. Capture technologies record student interactions, teacher guidance and parent profiles to provide individualized and group feedback. Continuous personalization ensures each participant brings something unique and cooperative to the group keeping membership optimal. Children communicate with ubiquitous devices that provide

targeted feedback to each other while working in groups, identifying compatibilities and suggesting what questions to ask. Group communication is the core objective, with shared activities as the principal methodology.

Student Generated Interactive e-Books

Students use wearable technologies to exchange, collect, communicate and present information either posted to large screen displays, or holographic 3D environments. As they collect information, it automatically maps to the learning objectives for their skill group and displays cumulative data about the group's success in onscreen graphics for easy monitoring. Anonymity is crucial, as performance indicators supplant grades. The focus on learning is group accomplishment of tasks, with individual contributions sent to the teacher and the student. The environment queries the student when it doesn't receive adequate information and works to help students draw similar inferences that other kids drew during similar exercises. Videos are served up to the students when they don't understand how to do something.

Students complete most of their projects by designing reusable e-books rich with simulations to share their work with others, creating long-term digital portfolios to be shared throughout the years. Teachers help students enhance screen literacy skills by building interactive multimedia for reuse among other learning populations worldwide. Sharing is the key objective, and working in diverse populations is preferred.

Teachers share their activities, thoughts, and technology ideas with a virtual team of experts in business, higher education and other institutions. A strong focus on integrating workflow and student activities throughout the community is enhanced by technology communication systems and easy to use large screen displays that encourage teachers to work together in distances to align industry, institution and schools together in real time knowledge construction and practice.

Virtual Mentors

Teachers are mentors, still using their nurturing techniques in the learning spaces to socialize children. In addition, each child has their own virtual mentor that can be accessed anytime. The mentor follows the children's activities on-line, suggesting new ideas and dialoguing interactively to understand the student's emotions and competencies. When children go on-line, the experience is secure and private. On-line content is filtered by the virtual mentor, who constantly reports noteworthy events to the parents, teachers and other interested parties. Embedded assessment is constantly sent to the teacher, parent and mentor. The virtual mentor consistently maps to performance goals and adjusts student activities to keep kids more focused on learning rather than relying on test taking. Parents can participate in their children's activities wherever they are via wireless mobile video computing and emerging communication technologies.

Kindergarten 2020 Scenario

Alicia wakes up this morning excited about what the day will bring. Today, she gets to meet with her discovery group. This group of students has been pre-selected through learning traits collected by toys that she used prior to entering kindergarten and shared with the school upon enrollment. The group has similar interests and meets 3 days a week. Today, they are going on a virtual safari to Africa.

Alicia likes animals a great deal and the group is going to experience how elephant families are similar to her own. Upon entering the virtual safari, she immediately experiences the size and weight of the elephants as they are presented in a 3-D environment where she feels as if she could reach out and touch them. During the safari, the virtual mentor points out how elephants are similar to our families and how important the mother is to the survival of the babies. Alicia gets to name one of the baby elephants and she and her teacher send a message to her mom telling her of Alicia's new friend.

During the day, Alicia demonstrated two acts of kindness towards another student. She received a personalized award at the end of the day. A copy of the award was immediately forwarded to her parents. Her dad, while traveling, received notice on his cell phone that Alicia was recognized in school and calls up a video interface to share his excitement with her. When Alicia arrives home she finds balloons waiting complete with her mother's outstretched arms.

High School – Increased Community Communication

Personalized Digital Libraries in Project Based Learning

Once children become more familiar with study and communication habits, they need content to be served up to them even more effectively. Learning in 2020 combines the student personalization with the virtual mentor and sends the information out to coordinated work projects designed for community learning. Secured broadband video conferencing appears on every device, digital cameras capture visual content, workspaces grow more complex, and collaboration tools are linked directly to personalized digital libraries. These libraries stay with a learner for life. Digital highlighting, digital conversations, group note-taking and other personal annotations make the asset active throughout the individual's life and can be shared with colleagues at any time.

No longer the dusty box of papers in the basement, learners collect a kind of “clipping service” so that a trip back through memory lane becomes an updated re-immersion in the subject matter, a kind of academic band between learning experiences. As students work on building a motor, for example, large screen displays coordinate visualizations for them to work together. They see the visual designs, on their devices and they build the motor from graphical components that simulate what they'll be doing in the laboratory. All their notes, their conversations with other students, their workflow, their graphics and video captured during their research period are all recorded and stored for student review.

Internet in Your Ear

Since students are working more often in distributed groups, they need to be able to get information more effectively. Students work in groups and ask questions aloud, receiving information through earpieces that feed constant information and personalized entertainment upon request. As the students work on an experiment trying to figure out how electromagnetism works, for example, they talk through their devices to ask for definitions of words, or ask for a simulation to show them how something like Faraday's law works. Sometimes explanations don't work, so calling up a simulation can help them grasp a concept better. Once they think they understand, they apply the principle to the design and ask for feedback from teachers and co-workers.

Teachers can listen into conversations as well, and they control input when necessary for group messaging or for helping students stay on task. Centralized visualized displays are constantly updated to project student progress, tasks to be performed, and provide guided instructions for learning more about a topic and to help with task completion. Experts are available on-line to evaluate the engineering quality of the students' projects. They are also available to students when they are presenting results, so they can help them deliver their results more effectively. If students are buying materials for their products, the transactions are integrated into their digital financial records, approved by the appropriate person and delivered to the laboratories immediately.

Ubiquitous Student Controlled Interfaces

Voice recognition is the standard method of both input and output, occurring mostly outside the classroom where students spend much more time. Students work in laboratories communicating with devices that record student interactions, record hypothesis, previous student engagements, and direct communication links to communities that specialize in the use of the equipment and in the history of effective construction.

Underlying the user's experience is a ubiquitous interface that launches content based on what the student is working on. The interface is a 3D visual bar that can be visually refined to map to the user's experience. For example, if a student begins studying Computer Science, the visual bar identifies his learning objective, his location, his tools, his co-workers, his relevant e-mails, his notifications, the videos, related lectures and text, the experiments, the simulations, the top 10 reading lists, the polls, and the alerts for participating class members. Underneath, like an assessment tool that reminds the students where to focus attention.

Students work in sophisticated visual environments deconstructing and constructing objects on the screen allowing them to question why things work the way they do. Imagine students using intelligent reusable visual components to build a plane that flies, a bridge that spans a ravine, or an electronic device that can actually be built by another team. As students work in simulated environments with smart learning objects, they begin to understand the underlying scientific principles, and each principle is measured and displayed to allow students to know where they are and what they need to work on next. Force feedback devices provide input that simulates real world instrumentation. Students develop a reason to learn math, and they enhance their communication skills by documenting and annotating their work for review by others.

Learning Style Adaptation

As students work in collaborative environments, the learning objects adapt immediately to their learning styles in 2020. The tools model the user throughout their learning career. It maps their preexisting knowledge to the kinds of learning objects that are useful to them for rapid learning, much like the toys they used as preschoolers. Now, in this stage of their learning careers, their emotional responses are being tracked to help them refine their ability to interact even more effectively with others.

So many automated processes have been built in for them: inquiry style, learning style, personalized activity selection, multimedia preferences, physical requirements, and favorite hardware devices. For example, if the student is in research mode, natural dialogue inquiry and social filtering tools configure a working environment for asking questions and validating hypotheses. If students like rich multimedia and are working in astronomy, they automatically connected to the Sky Server which accesses all the telescopic pictures of the stars, introduces an on-line expert talking about the individual constellations, and pulls up a chatting environment with other students who are looking at the same environment.

If the student is struggling with a concept, the intelligent tutoring services turn on automatically. If the student needs to practice a psychomotor skill or is restricted because of physical limitations, hardware devices are immediately recommended to assist the student, and locations at various schools nearby are identified for the student to use the equipment. If the student is having difficulty with complex processes or principles either assisted or augmented reality is initiated and the student jumps into a virtual world scenario that gives them an enhanced perspective of the problem and allows them to play the actor solving problems. This is especially useful in engineering and scientific solutions because they also reveal the math behind the phenomena, giving the student real world examples, with the theoretical supporting math. Discovering the visualizations of math can be highly contagious.

High School 2020 Scenario

Eddy's day starts when his Internet earring goes off at 6:30 with his favorite music playing. He wakes up, and sees his schedule for the day on his wall screen. He notices that he has early lunch today so he makes sure to bring a snack along with him. After getting ready, Eddy returns to grab his learning tablet and notices that he has received a bus alert with an exact GPS location. His bus is running 15 minutes late so he has some extra time to get ready. He tells his virtual mentor to identify his daily learning packet that he has received from school which contains all of his work projects, meetings and notes for the day. They are read to Eddy via voice in his earring.

Eddy has team deliverables due to be presented in his first class period. He will review the presentation with his team through his two way video tablet on the way to school. He compares his schedule to his teacher's schedule and picks a time he can log in for the remote meeting for a 1 on 1. His calendar is automatically updated with the new appointment and a message is sent to all the team members, including the teacher. Eddy's virtual mentor checks the bus online and announces to Eddy that it is just turning down his street. He gathers his tablet and his gym bag and heads out the door.

Upon entering the bus, Eddy's clothes scan his student number and the school is immediately notified that he has made the bus and will be conferencing in en route. Eddy arrives to school 15 minutes late, but has been in constant communication with his team going over last minute details for the presentation and they're good to go. His music comes up and he listens to his favorite song as he walks across campus. He arrives and joins the project team who are reviewing details about the Persian Gulf War that are

relevant to Eddy's school mates in Egypt on this project. Eddy reviews a vision of the history of the discussion and watches as personalized information puts the discussion into context for him. A set of questions are automatically configured for him to review and a green light goes on indicating it's his turn to engage.

An alert appears on his tablet right before the end of the period, reminding him that he is to meet his science team outside today. Today in science, Eddy is completing his personalized learning project. This project was designed especially for Eddy's learning style and allows him to use an observation-based instructional process. While outside, Eddy works on the effects of light on plants, using his virtual biosphere to experiment. He collects real-time data from various laboratories throughout the world, helping him manage his unique ecosystem.

He begins a dialogue with plant specialists whom he encountered over the Internet. The software recognizes that Eddy struggles with some terminology as his interaction rate seems too low. His questions don't seem to map directly to the content. His virtual mentor immediately provides support resources and appears on his screen ready to show and tell. The virtual mentor asks Eddy some questions and explains some of the concepts that he is having trouble with. After finishing the tutoring session, Eddy submits his project for team review again and receives an A, the standard grade of all high school students.

Eddy heads to the cafeteria where he picks up his pre-ordered lunch and debits his student account. After lunch, Eddy has 3 more projects to check in on and then a free period. During his free period, Eddy has signed up to learn Chinese from a school in Beijing. Eddy signs in to the course and begins talking to his classmates via embedded cameras and a virtual interface for picking objects up. Students walk through the video/virtual city talking and discussing the environment around them. When Eddy doesn't pronounce his words right, a voice monitor appears and shows Eddy the right lip and tongue movements. He repeats and one of his virtual classmates tells him "most excellent".

After school is over, Eddy has basketball practice. Eddy's basketball is hooked to sensors that monitor the pressure on the ball, his trajectory and his travel speed before he makes a shot. During his bench time, his video glasses show him professionals making shots and highlights past games that he has played that he reviews during his next warm up. Eddy receives an alert that his mother has to work late today and that she's arranged for Eddy to go home with another mom, whose virtual mentor leaves Eddy a message, a picture of the car, and a time she'll meet him at a GPS designated location. Eddy arrives home after practice and calls his girlfriend. His snack is awaiting him in the refrigerator, calories, carbs and protein all listed in his personal health indicator. Eddy spends the rest of his event going over movie reviews with his girlfriend for their weekend date.

College and Lifelong Learning

College has changed a lot in twenty years, as college students work more often with industry partners, co-working on projects. College has benefited from improving the learning process over twenty years and students are ready to take on much more

sophisticated experience working on their own rather than sitting in classes listening to lectures. They are more responsible for finding a person to work with to create solutions to real world problems. Industry and non-profit community organizations are excited about working with students as they share their workloads and help prepare students to gain work experience. Similarly, industry workers who want to learn more about various topics are happy to join teams of eager students with great ideas.

Scholastic reputation management might begin at the high school level, but it gets serious in college. Students study broader and deeper and require much more concentration and time on applying learning. All the tools for personalization, collaborating, communicating, and building are still available. The dominant technologies revolve around great visualization and programmability, laboratory tools, project management and ubiquity of tool access. Students are required to attend only the right lectures and can receive them in their ear or watch them on 2-way interactive video tablets; in addition, they utilize immersive visual environments in which they work on long term projects with customers who are actually working citizens.

Student projects are monitored with real time assessment monitors that map to the workflow metrics in the companies. Students are evaluated by their successful deliverables, their timeliness, their ability to work on teams, and their communication styles that have been monitored in process. Virtual mentors continuously adapt student interactions with their lifelong digital profiles, and map the effectiveness of their contributions to published company goals. Industry takes careful steps to identify recruiting requirements and detailed reports are shared between institutions to ensure student learning and return on investment.

Super Simulations and Sensors

Simulation technologies and powerful sensor technologies provide scaleable models for engaging in the learning by doing. Simulations allow students the opportunity to build integrated environments with objects in one environment that serve similar purposes in another environment. This level of programmability across multiple visual environments is the metric for successful development. As students move from the visual world to the real world, sensors in laboratories provide students with feedback as they reconstruct and deconstruct various objects in real time, with real materials. The laboratory environment becomes ubiquitous, and students spend the majority of their time working on projects.

Intelligent Laboratory Objects

Embedded technology now designs learning into any object used in education. Students receive physical components that instruct the student how to design, test, and connect them together. Students build robots frequently to perform various functions to prove their concepts. If the student fails to create a solution, he automatically remediates to a visual environment for practice and better visualization of key concepts. If the student still struggles with the content and actions, he is sent back to the original set of instruction and exercises through an on-line video conferencing environment. Internet based laboratories are the norm where students are able to run laboratory experiments wherever they find them, meaning that not all schools don't have to budget to build

exactly the same capabilities. Instrumentation is managed remotely and students work together in laboratory groups to learn how to use equipment effectively.

Project Management

Students write more software in 2020, not least because all scientific disciplines require increasing amounts of computing sophistication. So, they must be taught to identify opportunities and customers, manage their requirements, provide effective documentation, and manage source code, release management, testing and usability. Students manage several projects with outside customers through internet interfaces, virtual conferences, and shared workspaces. Task analysis software is personalized and everyone who is responsible for an action item is automatically notified, as well as all the related collaborators. Voice technology eases communication as students wear technology in their clothing allowing them to access both content and people wherever they are. Students are finally getting a grip on how to program software, teach programming to their coworkers or team members, and manage software projects.

Higher Education 2020 Scenario

Sumi wakes up in the morning, talks to her visual display on the wall and her virtual mentor brings up a visualized schedule for the day. Sumi has a videoconference meeting with her advisor at 10:00 and an economics project review to log into at 10:30. She logs into her project review venue from her room at 10:30. As the team leader (in this case the professor) moves from one key concept to the next, a Q&A session appears on the screen to check to see if Sumi understands the concepts.

The video session pauses as Sumi answers the questions, messaging to her coworkers for clarification. Sumi is struggling with one concept and her virtual mentor appears with more detail and a short video that was served up on the topic. The virtual mentor knows that Sumi is a visual learner and responds better to video with examples. After further explanation and follow-up questions, Sumi is still struggling with the topic, so a teaching assistant is notified and automatically schedules a meeting to help Sumi understand the material.

After 10-15 minutes Sumi reenters the video conferencing meeting. The system summarizes the key points that she missed real time, including all student questions. She pauses the video and submits a question and a series of discussions return on topic. The answer she is looking for comes from one of the industry members that she has worked with before. She returns to the video. The session ends at 12:00 and Sumi heads over to campus for a lunch meeting.

As she bikes over to the restaurant, an audio notification sounds from a chip in her sun hat. The Health Sciences department announces a blood drive, and she sends a voice command signing her up for it. Her online schedule is automatically updated for a future reminder. Sumi eats lunch with a couple of friends, and conducts a virtual meeting with classmates in her Urban Planning project team. She's promised herself not to multitask like this when she's with friends, but she's got a deadline and it can't be helped. Sigh! Time is still the currency of the 21st century.

Her virtual project manager, a professional urban planner from a local firm, sends her great feedback on their combined project, including customer notes, a marketing video and graphical simulator showing the park improvements in the new housing development she's been working on. All of the voice commands she sends to the project manager are automatically logged and distributed to her co-workers.

Architecture class begins at 1:30 and Sumi attends in person as they are handling real building materials today. 3-D simulation software is provided at a study kiosk that allows Sumi to tweak her design and model and experiment with different physical materials before spending time in the studio. She finds the name of a materials expert in her ubiquitous working interfaces, asks a quick reference question, makes a change to her virtual design and sends the list of materials to the studio. To help herself prepare, Sumi calls up previous projects through her course interface and reviews comments from her instructors, both in ink-written format and through personalized video feedback. She's such an overachiever. Some things never change.

Lifelong Learner 2020 Scenario

Caramela registers for an advanced circuit board design course. She's having a problem in her response time and needs to learn more about crystallography. Based on her learning requirements and the course objectives, personalized academic material is downloaded into Caramela's choice of form factors (one for the car, one for reading on her tablet, one for her graphical environment). Her wallet receives the transaction receipts and her expense reports automatically reports to her company and the bill is paid instantly.

A mandatory session on campus is available via teleconference, and although Caramela is on her way to the airport at the time, the session is recorded and sent to her wireless audio device which she'll interact with on the plane. As she reviews and interacts with the material, she watches information automatically populate into her assessment monitor that she filled out with information on why she's taking this course. She identifies which content is useful to her, examines the auto-generated goal maps and aligns the information with her current projects. An e-mail is automatically generated for her to send to her co-workers, customers and teacher to update them on new ideas she has that could be related.

A notification from her instructor arrives on her cell phone with a reminder of the first online project he wants to discuss. Along with it come a research project outline, suggested contacts, and an analysis of how her current project that she identified as the reason to take the class relates to this project. The instructor reviews her task list and makes a few suggestions on how to work best with her virtual team.

A couple of days later, Caramela returns from Chicago and emails her boss with some suggestions for a decrease in resources for their project. She's figured out a clever way to solve one of their problems as a result of the first course interaction and evaluation of workflow for the project. She's seeing results already, cool! She decides to take a Q&A exercise to see how to best move through the rest of the material rather than watch the movie. She decides to work together with a couple of colleagues, who always

share information on the topic she's reviewing. She returns home and spends the weekend with the kids.

Two Mondays later, she discovered that she did so well on the timed exam that the assessment tool suggests to her, the instructor and her colleagues, that she should probably move on to another interaction level. Caramela is quickly able to advance to a simulated work experience via shared applications from a real-world 3-dimensional toolset accessible from her laptop. It's a lot easier to work on something you can see, she thinks to herself. She starts to take apart the virtual circuit board she's been working on, and the 3D environment explains what functionality has been eliminated. She inserts a new chipset that she programmed from working on her project in class, and the circuit board reflects much faster response time. She is enjoying this first week of her semiconductor course.

In only the first week of her online class, Caramela has already demonstrated a level of skill to advance her to reach her career potential through a fully customized learning experience—accessible at her personal convenience and choice of device, personalized level of learning, and length of time to complete. She thinks she'll sign up for another.

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Principal Author's Background



Randy Hinrichs is Microsoft Research's Group Research Manager for Learning Science and Technology. He manages a large scale Learning Science and Technology research project at MIT called iCampus, and runs a team of research developers who are building an Internet 2, mobile learning research platform called the Learning Experience Project. He is Microsoft's industry board member on the Accreditation Board for Engineering and Technology, IEEE Learning Task Force, the National Science Foundation's Corporate Foundation Alliance, ACM's eLearning Board, a Director of the Corporate Member Council of the American Society of Engineering Education and the International Network of Engineering Education and Research. He is one of the pioneers and a board member of the Learning Federation, a consortium of industry, government and universities focused on an international research agenda for LST.

He has been working as an educational technologist researcher for 25 years. He developed and delivered one of the first World Wide Web courses at Sun Microsystems in the early 90s. He wrote two ground breaking books on using the web for education: *Web Page Design: A Different Multimedia* (cognitive and interactivity design), and *Intranets: What's the Bottom Line* (creating learning organizations with intranet technology). He has testified before Congress for the Web Based Education Commission, participated in the PITAC Subcommittee on Learning, keynoted at many international web education conferences and appeared in many articles both as an intranet strategist and visionary on the web in education. His own penchant for technologies is simulation-based technologies that enable activity based learning, discovery learning and game based learning.

Introduction



William (Bill) H. Gates is chairman and chief software architect of Microsoft Corporation, the worldwide leader in software, services and Internet technologies for personal and business computing. Microsoft had revenues of US\$28.37 billion for the fiscal year ending June 2002, and employs more than 50,000 people in 78 countries and regions.

PLAYING GAMES TO LEARN COMPLEX SKILLS: COMPUTER SIMULATION FOR MEDIC TRAINING

Gerald A. Higgins, Ph.D.

SimQuest International, LLC and The Federation of American Scientists

The military medic and the civilian Emergency Medical Technician (EMT) must be prepared to perform difficult, life-saving procedures, often in the face of traumatic injury and danger. These challenges have been increased with the emergence of Weapons of Mass Destruction (WMD), and the realization that civilian healthcare personnel in the United States may have to cope with mass casualties requiring prompt and effective medical care under difficult environmental conditions.

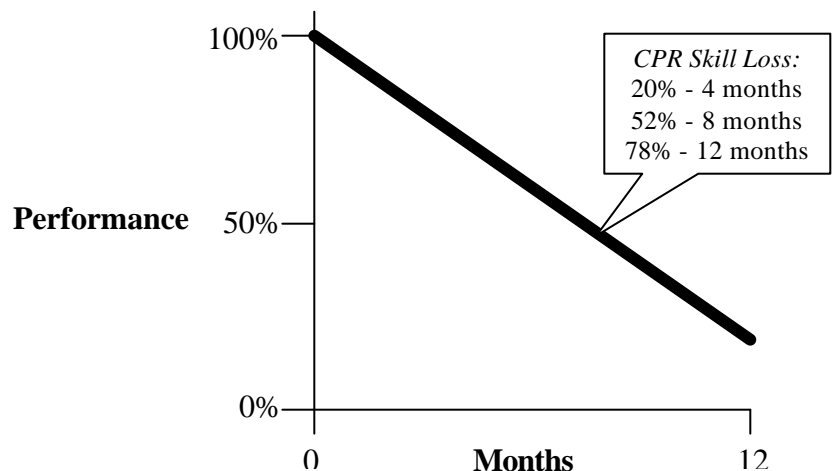
Like playing a musical instrument or flying a plane, medical procedures involve both cognitive and technical skills that demand frequent rehearsal for proper execution. Treating a patient in crisis with the added burden imposed by dangerous settings such as the combat battlefield may produce a stressful experience for the medic, sometimes leading to faulty decisions and medical errors. Unfortunately, skills such as Cardiopulmonary Resuscitation (CPR) are easily forgotten (see Figure 1), and there is little opportunity for medics and other healthcare personnel to refresh their skills through practice on real patients in settings that approximate the dangers of the battlefield or the mass casualty event.

Simulators Can Train Complex Skills and Provide Objective Measures of Performance

Computer-based simulation has been used extensively in the airline industry and in the military for effective training of cognitive, perceptual and motor skills. More recently, simulators have been used for training medical personnel in procedures using manikins and virtual reality systems. Medical simulators may include both three-dimensional (3D) models of human anatomy displayed on a computer monitor coupled with a “haptics” device that conveys a sense of touch to the user. Thus, a paramedic inserting a chest tube or a surgeon cutting into a ‘virtual’ patient can visualize anatomy and feel the forces associated with the actual procedure using a force feedback device similar to the controllers used in computer gaming.

In addition to the value provided by simulators for skill training, these systems can also provide an ongoing assessment of the performance of the trainee, including metrics such as judgment, timing, sequencing of procedural steps, spatial accuracy, errors, etc. In medicine, the development of performance metrics and the objective assessment of performance is a difficult and complex process, because it requires decomposing the medical procedures into their elemental parts using a process called task analysis, depends on ‘buy-in’ from experts in the medical community, and requires

Figure 1: The ‘Curve of Forgetting’. Decline in the number of soldiers able to perform CPR at an adequate level without refresher training. Adapted from Hagman and Rose (1983).



validation using rigorous scientific methods. The performance can be displayed to the user in a debriefing session, and compared to the user's past performance and to the performance of other users. When properly configured and validated, computer-based simulators can provide objective assessment of performance to be used for certification in medicine, as they have been used for certification in aviation.

Pilots, Surgeons and Race Car Drivers: Computer Simulation for Training Dangerous Tasks

One approach for refreshing and sustaining technical skills is to allow the medic and other healthcare personnel to practice procedures in simulated environments that reproduce many of the difficulties found in real world, emergency settings. An advantage offered by simulation in all domains is the ability to expose personnel to unusual settings and situations where practice improves performance and reduces error in real world tasks. A comparison between the simulation requirements for training combat pilots and trauma surgeons is shown in Figure #2. In flight simulation, pilots are exposed to dangerous scenarios such as broken engines, difficult settings such as night landings on aircraft carriers, and unusual situations such as flying a B2 bomber at treetop height, all of which would be difficult or impossible to perform in the real world without repeated prior exposure on a simulator (Higgins et al, 1997). Similarly, surgeons can safely practice difficult procedures on simulated patients under life-threatening conditions, medics can stabilize injured soldiers while simulated bullets whiz by, and Formula One race car drivers can learn new circuits at high speed in 3D computer simulations.

The combination of a compelling 3D computer graphics simulation with a competitive game-like environment

Figure 2 Characteristics Shared Between Air Combat and Trauma Surgery: Skills and the Simulation Environment

- Multidimensional skills, with an emphasis on perceptually-tuned cognitive performance in a complex spatial environment
- Cognitive skills are critical for negotiating decision pathways
- Requirement for a continuum of motor performance, ranging from precise ballistic movements to steady-hand maneuvers and continuous perceptual-motor tasks
- Requirement for intense visuo-spatial navigational skills, including 3D visualization
- Need for trajectory guidance and minimization of collateral damage
- Stressful, time-dependent performance requirement
- Operator must adjust behavior in response to rapidly changing environmental cues
- 'Mission-critical' - Failure has grave consequences (e.g., death)
- Operator commands immediate mission environment with ultimate responsibility for success or failure
- Performance cannot be easily trained using other methods
- Virtual reality can be used to provide a stressful training environment

produces an engaging tool for training and sustaining medic skills. The simulation game can be configured like a spirited contest in which players can test their skill against other players, comparing results tracked by the software. Profiles of idealized 'model' users, such as experts, can also be stored in the simulator for comparison to the player's profile. Like other computer games, the players can work in different mission modes. In career mode, the medic trainee can climb the ladder of medical expertise in a progression that presents increasingly more difficult cognitive challenges. Single player mode can allow the user to practice the procedure while playing the simulator, practicing cognitive and technical skills without "leaving tracks".

On-Demand, Adaptive Case-based Simulation Game for Medic Training

The ideal medic training system would provide refresher training both in the field and at dedicated training centers, be deployable on a variety of hardware platforms, ranging from PDAs and laptops to full-blown immersive virtual reality training systems, be networked into larger simulations such as wargames and into hospital information systems to provide updated medical information, allow for retrieval of the user's past performance in relevant patient cases including replay of video, and be available for testing and skills certification. However, in the short term, an optimal simulation game for medic training should at the very least, encompass the latest in learning technologies within the constraints imposed by medical training. The goal is to embed skills, judgment and knowledge so deeply into the central nervous system of the medic that diagnosis and therapy are promptly and effectively executed for point-of-wounding care even in the most dire and stressful of circumstances.

Figure 3 shows some of the features of a simulation game for combat medic training. Patient case-based scenarios are a common tool for differential diagnosis and therapy in medicine. Providing the medic with a choice of case studies, retrieved by user input or automatically as part of the learning process, greatly enhances the training value of the simulation. Thus, if the simulation determines that the student is having trouble placing an intravenous line, additional cases are called up from the database for training in venous access. In some cases, the trainee should be able to successfully perform the medical procedure by any number of alternate, valid pathways. This is often critical in medicine, since many procedures can be successfully performed using different approaches, many of which may arise as a consequence of the specific complications, anatomical anomalies, or combination of procedural elements that are

Figure 3: Selected Features of a Simulation Game for Training Combat Medics

1. Automated patient case scenario retrieval based on the location, training need and circumstances as indicated by the user, or generated from the software program, including automated reach back functionality to select appropriate cases for training;
2. Recording of student state for on-the-fly adjustment of training resources;
3. Intelligent tutoring that can track the performance of each individual's progress during instruction and encourage trainees to formulate questions when they're confused, providing context-sensitive answers when appropriate, and summon human instructors when needed;
4. Performance assessment based metrics validated by the medical community, resulting in automated debriefing providing interpretation of cognitive skills and technical skills as part of the After Action Review (AAR).
5. Scalable training with SCORM (Shareable Courseware Object Reference Model)-compliant content modules, including different versions for field and training center applications;
6. Competitive and engaging computer graphics-based game environments, allowing trainees to compete against each other and expert users, including single player and career modes, in the context of appropriate combat settings including specific ground warfare sites;
7. Distributed, networked capabilities supporting multi-player including team training capabilities and allowing interface with other systems;
8. Learning Management System, including event recorder and common administration database containing user performance ratings;

Support for hardware interfaces and functionalities, including compatibility with laptop delivery platform, video capabilities for student state recording and playback modes, and extensions to immersive virtual reality devices.

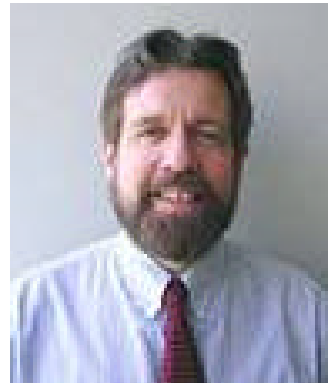
(from SimQuest International LLC)

presented by the specific patient case. The simulation should not only be able to track the student's progress through the content, it should also be able to determine the cognitive and emotional state of the student, determined by how the user behavior in the simulation, or by more direct physiologic measures of the student state such as EMG or video analysis, and adapt the instructional content to suit the needs of the trainee. Intelligent tutors, programmed into the simulation, or available as live experts accessible online, should provide remedial help when needed. Automated debriefing can list and score the correct and incorrect choices, for review by the trainee and his/her superiors.

The Digital Human: Bringing Medical Simulation to Life

Although great progress is being made in the development of computer simulation for skills training, the next generation of medical simulators will greatly extend the benefits of this approach through advances in technology. Today, we can envision the value of simulation training by providing medics with the opportunity to refresh their skills with engaging gameplay and validated medical content. In the next few years, not only will visually realistic simulators run on the desktop, they will also support sophisticated functions such as the integration of physiology to create realistic "breathing and bleeding" human simulations, predictive human models that can integrate diagnostic image data and laboratory tests to forecast disease within specific patients, simulations that can serve as testbeds for new therapies, drugs and interventions, and simulated surrogates that substitute for actual humans in dangerous settings (Higgins et al, 2001). The eventual goal of research and development efforts will be the development of a coordinated "Digital Human", consisting of models, simulations and databases spanning molecule to organism. The challenge posed by this work is that a valid and accurate

model of human structure and function can be built to serve as the standard for medical diagnostics, therapeutics and education.



Gerald Higgins, Ph.D., has experience in corporate, federal and academic sectors. He is an anatomist and computer scientist who develops medical simulators and computer-aided surgery systems. He serves as Principal Investigator and Co-Investigator on several medical imaging and simulation projects from the National Institutes of Health (NIH), U.S. Army and Defense Advanced Research Projects Agency (DARPA). He is co-founder of SimQuest International, LLC, a company that develops simulators for medical training. He also serves as the Director, Digital Human Project at the Federation of American Scientists and as secretary for the Washington, D.C. Computer-Assisted Surgery Society. He is a recipient of the Mallinckrodt Scholar Award for Excellence in Science. As Director of Imaging Applications at Hoffman - La Roche, he helped to develop AutoCyte, a computer-aided diagnostic system. At HT Medical Systems (now Immersion Medical), he was involved in the development of the first medical simulator products that are now achieving market entry. Dr. Higgins has an extensive background in biomedical research, with an emphasis on imaging techniques applied to biology and medicine. He previously held the position of Chief of the National Institutes of Health's world-recognized program in molecular neurobiology. He has authored over two hundred publications in anatomy, neuroscience, molecular biology and computer science.

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NEXT GENERATION LEARNING SYSTEMS AND THE ROLE OF TEACHERS

The Learning Federation

Given an aggressive national investment and skillful management, technologies achievable by the year 2020 could transform learning – making it more productive, more personalized and more compelling for learners of any age and with any background. These technologies will make it possible to implement a range of powerful new instructional strategies long recommended by experts in cognition, but which were previously unaffordable. The instructional strategies enabled by these new technologies will more closely resemble some of the earliest forms of instruction based on tutors and apprenticeships than today’s factory-like classrooms. For example, new tools will permit learners to explore and test their skills in simulated environments unaffordable or unattainable in any previous learning system. These new learning systems will change the process of learning, redefine the role played by the teachers, and create an enormous range of challenging new teaching occupations. What they will not do is replace the need for human teachers, tutors and counselors who can provide expert instruction, provide inspiration, encouragement and discipline, and serve as exemplars of the kinds of expertise a learner can aspire to achieve. Teaching and other related occupations in education and training systems will become much more like other “knowledge economy” professions, having more opportunities for professional growth and more support from technology and specialists.

In many sectors of our economy, skillful use of technology has resulted in an increase in the quality of products and services, greater personalization of services, increased efficiency and reduced costs. Realizing these benefits required coupling information technology with careful rethinking of the processes, management structures and job

descriptions of the people and institutions involved. There is no reason to believe that education will be any different. Consider what has happened in medicine. As little as a generation ago the occupations in medicine were largely limited to family doctors and nurses. But today, modern physicians can draw on an enormous array of medical professionals to provide specialized expertise, develop and maintain sophisticated medical equipment and software, and perform elaborate testing. It would be down right frightening if your medical care was limited to what your family physician could perform in his office – but that is largely the situation teachers find themselves in today.

The discussion that follows will explore changes possible to the teaching profession in post-secondary education because the Learning Federation has concentrated its efforts on research and development for post-secondary learning environments. However, many, if not most, of the changes in teaching professions, instructional tools and management innovations discussed here will undoubtedly also apply in K-12.

Next Generation Learning Systems

By the year 2020, teachers will routinely work with teams of people with expertise in many different areas and draw upon a variety of learning products and services. New learning systems will enable teachers to create challenging assignments that can close the gap between the world of instruction and the world of work and tailor instruction to increase the efficiency of learning. New learning systems will make more productive use of both the teacher’s and learner’s time and talents and provide useful, multi-dimensional assessments of each learner’s expertise and ability to accomplish complex tasks. For example:

- **The process of learning will dramatically extend from “teacher push” to “learner pull.”** With future learning systems, human instructors and a robust array of software tools will shape

the instructional path in ways that can be most efficient and most motivating for each individual. In the right time and place, lectures will still be critical, but current learning environments too often consist of sitting passively in a room with a hundred people and little expectation of being an active participant. Next generation learning systems will allow learners to access live and recorded lectures from multiple sources. Performance-based assignments will allow learners and small groups to demonstrate levels of expertise in tasks where they are strongly motivated to succeed.

- **Learning systems will be built from a set of powerful tools allowing instructional designers to go from concept to operational systems quickly.** They will also permit continuous upgrades and improvements as problems are discovered and new concepts are proposed and tested. The tools will include systems for: continuously evaluating the learner's approach to expertise in critical areas; providing quick, context-sensitive, individualized responses to questions by dispatching questions to automated systems and human tutors and experts; rapidly building networks of learners and teachers; monitoring a user's level of interest, anxiety and motivation; adapting to specific learners (language of instruction, cultural background, learning abilities); and systems for building simulations reflecting the state-of-the-art in science, engineering and other fields.
- **Robust simulations will make possible assignments in which learners learn and test their expertise in addressing compelling assignments and problems.** Coursework could include being turned loose in a virtual representation of Renaissance Venice and asked to find the secret behind the legendary blue coloring of their glass, engineering and building a (virtual) bridge over a (virtual) Mississippi River, navigating the interior of a (virtual)

pancreatic cell to determine why signals reaching it do not stimulate insulin, or being given a broken (virtual) avionics system from a Boeing 777 and asked to repair it.

- **Teachers and learners will be able to call on a variety human tutors, counselors and experts and summon a variety of automated help systems** for addressing routine questions. Learners will work face-to-face with teachers and tutors and be able to call on a worldwide network of subject-matter experts and other specialists when interesting questions arise. Sophisticated tools will help diagnose sources of confusion and suggest new learning strategies based on analysis of the experience of large numbers of learners facing similar situations.
- **A combination of automated monitoring tools, tutors and other specialists will make it possible to continuously adjust the pace, nature and style of the learning process** to ensure a learning experience optimized for each learner. Instead of being forced to move all learners forward at a uniform rate, teachers will be able to move each individual forward at a rate consistent with his or her measured performance in each area. No one will be forced forward before demonstrating comfort and confidence in the concepts being learned.
- **This combination of automated and human observers will enable continuous measures of competence** integral to the learning process that can help teachers work more effectively with individuals and leave a record of competence that is useful and informative to learners, future teachers and employers. (If you succeed in flying a simulated airplane or cure a simulated patient in an assignment, there should not be much argument about what is being measured.)

Implications for Teaching and Related Education and Training Occupations

The systems just described can make the learning process more productive and more rewarding for each learner and teacher. However, as in every other sector of the economy that learned to make effective use of new information tools, these gains will require dramatic changes in the organizational structures and management systems

of the institutions that deliver education and training services. Education and training institutions and their supporting industries must dramatically improve the way they invest in innovation, manage innovation, invest in capital equipment (including software) and assign responsibilities to different occupations.

These changes will reshape the nature of employment in education in a number of ways:

- **Teaching will become much more personalized** because teachers will be able to spend much more time in dialogues with individuals and small groups.
- **The roles bundled in the job of today's teachers are likely to be "unbundled"** (lecturer, tutor, counselor, subject-matter expert, administrator, disciplinarian, record keeper, evaluator, curriculum designer) with many tasks performed by experts or automated systems with specialized expertise. (See box).
- **As a consequence, teachers and tutors working directly with learners will work as a part of sophisticated and continuously changing team** involving specialists and specialty firms. Professionals may specialize as subject-matter experts, expert teachers, instructional designers, courseware developers, applications designers, or a variety of other occupations, and they may concentrate on the roles at which they excel and find most rewarding. Individuals may undertake several roles simultaneously and are likely to move between jobs for career advancement or because an inspired opportunity defines a business opportunity.
- **The new supporting industries will generate an enormous number of new occupational opportunities.** Many of these will be in firms that produce tools and services sold to a large number of education and training institutions (and in some cases to individuals) worldwide.

Since many of the skills involved will be required by other businesses, movement into and out of education professions is likely – a process that will ensure that education takes full value of innovations occurring throughout the economy. Online instruction will make it much easier for individuals to build new skills that would allow individuals to change specialties during the course of their careers.

- **Professionals at all levels will need to continuously upgrade their skills** and use an array of tools for professional development throughout their careers. This can include keeping abreast of developments in the field being taught, understanding advances in the theory of cognition, pedagogy and assessment, and understanding innovations in software design, standards and communications. Fortunately teachers and other professionals will work in an environment allowing easy access to high quality instruction in all areas—sometimes using tools they themselves have developed. Demonstrations of expert teaching will be readily available over the high-speed internet, and the new information tools can let teachers see discussions on how other teachers have approached a subject or dealt with a difficult situation and facilitate dialogues with their colleagues as they struggle with similar issues.

Summary

The improvements in teaching and learning just described will require a major national investment in research and skillful management of these innovations by education and training institutions. The needed research will require large, persistent, well-managed research programs and partnerships drawing on industry, government, foundations, universities and schools. New learning systems will only be affordable if these research insights are used to build robust, reliable, well-evaluated tools that allow investments to be amortized over a large number of users. It may, for example, cost several million dollars to build a powerful biomedical simulation, but the investment can be returned quickly if the product and interaction model can be used by hundreds of thousands of course designers and teachers worldwide. It may seem expensive to employ specialists in specific types of learning

disabilities, but if the specialists can work online to quickly diagnose and advise teachers and learners in a large region the amortized cost will be affordable. Making effective use of these tools and redefining the roles of teachers and other professionals needed to use them to achieve real gains in learning will require creative management by education and training institutions and supporting industries.

In the end, it is likely that the challenging new occupations of teaching, tool building and support services will give education occupations the same respect, and same remuneration, enjoyed by other knowledge

professionals. There will be much more room for professional growth and mobility, and more time to learn from colleagues and specialists. Society will need to make a choice about whether the efficiency gains will be used to cut the cost of delivering high quality education and training or whether to use it to deliver more and better education and training services to more people. We suspect that both will happen and that markets and political leaders will recognize that increased investment in professionally delivered learning services is a key to a prosperous and just society.

Future Education and Training Occupations

Occupation	Notes
These jobs may be performed onsite or offsite and the services may be provided by the institution or purchased from other providers	
Gifted lecturers and experts in various fields capable of giving outstanding and unique presentations that can motivate and inspire	Some individuals may be some superstars used widely by teachers and learners
Teachers and tutors gifted in working closely with individual learners	May work face-to-face with learners or exchanges may be via online exchanges *
Counselors sensitive to the individual needs, interests, abilities, and cultural background of each learner	May do site visits but generally will work with learners online*
Learning specialists who have specialized expertise in assisting learners with particular learning difficulties and disabilities	May do site visits but generally will work with learners online*
Subject-matter experts who define instructional requirements for courses and propose strategies to evaluate whether appropriate expertise has been reached	Will work with professional societies, certification organizations and employers
Curriculum designers who work as part of a design team to translate objectives into creative courses of instruction. Alternative, creative strategies are likely to emerge as groups design innovative assignments and ways to provide initial information	Competing firms may specialize in instructional modules or entire suites of instruction
Simulation and virtual environments engineers who build and maintain the components for synthetic environments, including specialized scientific software, e.g. a digital human that can be used for a variety of learning situations	Specialists in building the components of simulated towns, instruments, landscapes, biological systems, or physical phenomena
Software engineers who work in teams to develop and maintain systems that can track individual learner progress, help provide accurate automated answers and summon instructors	Developers of tools for continuous evaluation of a learner's expertise, "user models" of motivation, state of confusion, diagnose confusion and take approximate action
Evaluation and certification experts who ensure that the knowledge and expertise measured match instructional goals	Independent measures of expertise or certification of embedded assessments
Management and support occupations that provide a variety of services including record keeping, IP management, repair, MIS systems, micropayments, etc.	May be provided by the institution or services and software tools may be purchased or licensed from specialty firms

* This could mean everything from email, personal videoconference or having the counselor take control of an avatar in a simulation.

The Authors

The Learning Federation is being formed as a partnership with businesses and government to build a strong research consortium that unites funding, talent, expertise and momentum to accelerate R&D of new learning environments to dramatically improve education and workforce training. The Learning Federation's focus is post-secondary (2 year and 4 year colleges and universities and industry training functions) and lifelong science, math, engineering and technology education, directly addressing workforce development needs. The Learning Federation's research efforts will help all businesses by speeding the introduction of techniques that can make corporate investments in training more productive, and it will provide early access to advanced concepts for educational products and services with potentially enormous markets. The Learning Federation's work is conducted under the direction of a senior Steering Committee, comprised of the following members:

Dr. Ruzena Bajcsy is the Director of the Center for Information Technology Research in the Interest of Society (CITRIS) and a faculty member of the Department of Electrical Engineering and Computer Science at UC Berkeley. She is the former head of the Directorate for Computer and Information Science and Engineering at the National Science Foundation.

Dr. John D. Bransford is the Centennial Professor of Psychology and Education and Co Director of the Learning Technology Center at Vanderbilt University. He is an internationally renowned scholar in cognition and technology and author of seven books and hundreds of articles and presentations.

Randy Hinrichs is the Group Research Manager for Learning Science and Technology group within Microsoft Research within the University Relations Group.

Prof. Edward Lazowska is the Bill & Melinda Gates Chair in Computer Science in the Department of Computer Science and Engineering at the University of Washington. He serves on the National Research Council's Computer Science and Telecommunications Board and the Committee on Improving Learning with Information Technology.

Elliot Masie is Head of the MASIE Center, an international e-lab and ThinkTank dedicated to exploring the intersection of learning and technology.

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Dr. Henry Kelly is President, Federation of American Scientists and Executive Secretary for the Learning Federation. He served as Assistant Director for Technology in the White House Office of Science and Technology Policy from 1993–2000.

2020 CLASSROOM

Ulrich Neumann and Chris Kyriakakis
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Imagine a group of students from around the nation in the science classroom of the future as they embark on a mission of exploration. The room is transformed into a fully immersive aural and visual environment that makes them feel like they are really in the same place together. Like deep-sea divers, they move through a compelling landscape of continuous activity. Together they begin to travel through a human cell. As they move through this beautiful yet unfamiliar landscape of curious objects, the immersive environment entices them to ask questions of each other and their teacher, to explore fundamental principles, and to form robust models of complex processes. They interact with each other and with the environment in a natural way with language and gestures. For them, from this moment on, “science” and “learning” will never be the same.

A new paradigm for K-12 education will evolve over the next 20 years as innovative information technology and pedagogy are integrated into the learning environment. This process is being fueled by two factors: broadband Internet capability and the emergence of immersive technologies. When these technologies are combined, the Internet as we know it today will be transformed from a low fidelity medium for browsing information to a high fidelity medium that delivers rich and immersive experiences.

These new remote immersion systems will bring interactive and stimulating classroom experiences to all student populations – regardless of location. Classroom boundaries will fade as students and teachers are brought together by high-resolution video and immersive 3D shared environments that allow natural discussion, collaboration, and interaction among physically distant participants. With remote immersion, students and teachers will investigate, play, explore, and learn together in an environment that dynamically adapts to the content – from a biology laboratory to a visit to the aquarium.

The transformation of the Internet into a system for rich experiences will bring about the creation of

massive distributed on-line archives of past lectures, interactive presentations, simulations, proficiency testing, and problem presentations. This new content, designed specifically for these new technologies, will replace current textbooks and workbooks with a national resource of high-production and content quality materials, cross-indexed and customized for individuals or classes. Once created, the archives will be updated and further improved by continuous contributions and links from teachers, production groups, and authors anywhere.

Advances in information management technology will be integrated with both the delivery and content creation technologies to address the critical need for meaningful learning assessment. Rather than relying on current periodic testing results, automated tracking of students’ progress will provide statistical models of presentation sequences and paths, providing instant feedback to the student, the instructors, and administrators on progress or problems in the curriculum and its presentation.

There is a great need within the education community for such innovations and the pressure to make changes is being felt by schools at all levels. While information and digital media technology has been progressing at breakneck speeds over the past decade, unfortunately little has changed in the delivery and the design of the curriculum. The majority of efforts involving technology in education have focused on CD-ROMs or web sites containing little more than digitized versions of textbooks, or broadcast lectures with poor quality audio and video. Little has been done to design the content to take advantage of the potential of new delivery mechanisms. Technology up to now has been viewed as a way of reaching a larger audience, and not as the enabler of new learning paradigms.

We envision a new partnership evolving between technology and pedagogy—a partnership that will result in a new education paradigm. Teachers and students might be thousands of

miles apart, yet they will appear and sound to each other as if they are in the same classroom. Facilitated by unobtrusive picture and sound display devices, the infrastructure will give them a strong sense of presence, as if they are actually in the room together. Students will be able to “touch” objects in a faraway museum or “feel” forces in a virtual physics experiment through the use of haptics (touch-based technology). Teachers will be able to search for past lectures that best suit the needs of the session at this time. Data acquired automatically from the student’s interactions in this immersive environment will be captured and used to optimize the lesson progression. The term interactivity will be transformed from mouse-clicking and instant messaging to realistic, life-sized representations of teachers and classmates sitting next to you and talking. Imagine students interacting with avatars of James Watson and Francis Crick tutoring and guiding them on the discovery of the DNA structure. Imagine students immersed in a role playing experience at the Continental Congress during the Revolutionary War era. This is what remote immersion can do for education.

As appealing as this vision may sound, the truly revolutionary transformation will take place at the core—the dramatic reformation of our teaching methods themselves. New approaches will be developed for content authoring and modeling for simulation and for creating models of learning and assessment to measure the progress of students and guide them through the learning and problem-solving process. Students will interact with content material, explore challenges and perform inquiry-driven collaborative investigations, using an array of virtual laboratory tools and simulations. This new education environment will incorporate 3D computer animation and graphics, real-time image rendering, multichannel immersive audio, video, text, and haptics. Techniques that promote a high degree of student attention, goal attainment motivation, and satisfaction will be adapted from approaches already much better understood and employed by the gaming industry.

New multimedia and Internet technologies are creating novel ways to teach and learn through this very process of creating new ways to see, hear, and

touch. From an educational viewpoint, the use of sensory immersion has never been investigated. There is evidence from learning and psychology research indicating that memory is significantly enhanced by spatial associations. For example, optimal recall is achieved when an experience is not only captured as a set of sound and image streams, but when these are reproduced in such a fashion that the replay experience preserves the spatial relationships among the various elements.

How will this paradigm of bringing remote teachers and students together improve our standard classroom where the teacher and students are already in one place? It extends the classroom, opening it up to a vast treasure trove of educational experiences beyond the physical room walls and delivered in specific ways designed and crafted to enhance learning and understanding. Clearly, when the teachers and students are physically in the same classroom, the technology will still deliver experiences and materials in a way that enhances learning. This will also open the door to consistent and continued education for children with disabilities, or those in medical institutions, or those with difficulties traveling to a classroom.

The new paradigm of K-12 education we envision will evolve steadily over the next decade. As the technologies are introduced, we also envision the transformation of society in countless other ways, including the ways we communicate socially, conduct business, produce goods, and entertain ourselves.

The Integrated Media Systems Center in the School of Engineering at the University of Southern California has pursued scientific research and the application of information technology to K-12 education since its inception in 1996 as the National Science Foundation’s Engineering Research Center for multimedia and Internet research. Through its “2020 Classroom” project, IMSC is developing a prototype that integrates remote immersion with tools for creating pedagogically

sound curriculum for such environments, as well as novel methods for learning assessment. IMSC also carries out a successful cross-disciplinary program of research, education, community outreach, industry collaboration, and technology transfer. The Center has developed such unique immersive technologies as 3D face modeling and animation; streaming media servers; multichannel immersive audio; and Immersivision™ panoramic video. Other research areas include speech processing, haptic devices, data compression, and wireless communications.



Ulrich Neumann is the Charles Lee Powell Professor of Engineering and an Associate Professor of Computer Science at the University of Southern California. He earned an MSEE from SUNY at Buffalo in 1980 and he completed his computer science Ph.D. at the University of North Carolina at Chapel Hill in 1993 where his focus was on parallel algorithms for interactive volume-visualization. His current research relates to immersive environments and virtual humans.

He won a National Science Foundation CAREER award in 1995 and the Jr. Faculty Research award at USC in 1999. He was an Associate Editor for the IEEE Transactions on Multimedia from 1999-2002. Dr. Neumann is currently Director of the Integrated Media Systems Center (IMSC), the only National Science Foundation Engineering Research Center in multimedia and Internet technologies. IMSC includes over twenty-five faculty participating with more than twenty corporate partners pursuing media

systems research. In his commercial career, Dr. Neumann designed multiprocessor graphics and DSP systems, co-founded a video game corporation, and independently developed and licensed electronic products.



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A CURMUDGEON'S VISION FOR TECHNOLOGY IN EDUCATION

Randy Pausch

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I am both a technology enthusiast and a technology curmudgeon. Before I lay out my grand vision for what technology will do for education in the future, I'd like to assert that there have only been two major technological impacts on mainstream U.S. K-12 education in our country's history. I'll give you a moment to guess what they were ...

Ready?

- 1) The use of blackboards.
- 2) Mass-produced textbooks.

Blackboards took the "personal slate" and made a large, communal display at the front of the room. This allowed the teacher to display large amounts of information, and to allow students to "work problems at the front of the room." These are both large social changes.

Mass-produced textbooks provided for the standardization of curriculum, shifting power from the individual teacher to the centralized authors and purchasing boards. Currently, the most powerful forces in American education are the textbook selection committees of Texas and California.

So technology is important when it shifts the social power regarding who makes what decisions about education, as well as in the actual education itself. Having said that, here are some of my visions for the impact of technology on education:

Printed textbooks will disappear in favor of electronic books, and economically force a nationwide textbook market. Not because of all the advantages of the

electronic medium (animation, interactivity, etc.) -- but because electronic books will simply become cheaper than paper textbooks. This will further centralize the decision-making, and in order for the profit motive to work, there will need to be national standards for e-books that require royalties to be paid on a per-student basis for all content. So e-books will move power from the states to the federal government.

In general, the area of cognitive modeling of individual students will bear large fruit. John Anderson and other researchers at Carnegie Mellon have already shown that their geometry tutoring software can substantially improve student test scores on standard geometry exams. By a combination of infinite patience and a model of what the individual student's difficulties are, the software can tailor problems and explanations of solutions to address the current conceptions (and misconceptions), much as an experienced teacher would. This will move the social power from the teachers to the developers of the software.

Multi-tasking will become more common. For better or for worse, children are already becoming comfortable time-slicing at a fine granularity: They work on a computer screen and IM (that's "Instant messenger" for the non-hip) their friends, and talk on the cellphone, rapidly moving their attention back and forth between those tasks. Education will learn how to inject itself into this workflow, and eventually the technology will learn enough about the user's cognitive state to assist in the presentation of interruptions in a more elegant way. This will move the social power from the teachers to the students, and you can already smell the future debates about what technologies will be banned by schools, much as pagers were originally banned.

Biofeedback will be used heavily, especially with younger children with behavioral disorders. The current approach of "medicate first, ask questions later," will probably not work in the long run. Instead, some researchers have shown initial results with hyperactive children by allowing them to play videogames while hooked up to sensors measuring the child's heart-rate and other vital signs. As the child becomes calmer, the video game controls become more effective, and the child is completely unaware that he/she is being conditioned to learn to calm him or herself. It's a sort of technology-driven kind of meditation/relaxation exercise.

Virtual Reality will (finally!) arrive, and we won't use it very much. While the experience of being perceptually immersed is extremely powerful, the cost (not in the technology, but in the content matter) of developing these experiences will remain prohibitive. How often does Hollywood spend \$100 million on a film to teach history to 3rd graders? In certain niches, (physics, driver's ed), VR will become used heavily, but only when there is an opportunity to deploy the subject matter over a large enough number of students to defray the cost.

Programming will become something that every child learns, both as potential vocational training, and as a mode of thought. This education will move younger and younger. Early systems such as Logo paved the way for current efforts such as the Alice project (www.alice.org) at Carnegie Mellon, where young children can be introduced to the basic concepts of programming in playful, "story authoring" environments. This will be an important cultural change, much as requiring every student to take art, or physical education, is a cultural decision as much as an educational one.

Geography will become less relevant. (Okay, most kids don't think Geography is relevant now :-). But what I mean is that

one's physical location is going to be less important than it used to be. The ability to send video and audio, in real time, from one place to another, means that students will develop a cultural notion of telepresence, where when something interesting is happening, a student will instantaneously broadcast it to his/her peer group. This will move the learning experience to be "anytime, anywhere," as opposed to the 8-3 M-F notion. Remember: students learn more from their peers than anyone else, so we if we capture this peer-to-peer communication and reward it with grades, we can "capture that turf" and inspire it.

Language will become less relevant. Within the next 15-20 years, real-time, usable translation technology should exist. This will enable a number of fundamental shifts in education, not the least of which could be a huge increase of the number of students who spend time abroad, and huge changes in the kinds of countries they visit. Currently, needing to learn the language of the host country to some degree heavily constricts travel abroad.

Big Brother will arrive. My favorite use of technology in education is the truancy-frustrated administrator who set up the school computer to dial the homes of absent children and leave a message telling the parent that the kid was not at school. (Naturally, the kids' counter-measure was to clear the message off the machine before the parent got home). But soon, parents will be able to geographically track where their children are: this will begin with GPS+transmitter in wristwatches, but will soon become the kind of under-the-skin technology that is used for expensive pets. Don't believe it? In 1950, would you have believed that we would scare every kid in America at the breakfast table by putting missing kids' faces on milk cartons? This is a paranoid country, and we'll put trackers on our kids. And we'll give the schools permission to track the kids from 8-3 M-F, since they kids should be in school then. Also, parents will be able to "tune in" to their child's classroom via remote video/audio technology. Teachers will resist that, but they will lose. Some day care centers are advertising this as a value-added capability already! Finally, parental "review" software will allow a parent to "fast forward" through everything that their son/daughter has viewed on a computer screen

during the day, compressing it down to several minutes. This will allow the parents to confirm that there's no pornography: more interestingly, this might actually spur conversations between the parents and children about what the kid has been studying.

What's most important is what won't happen. Technology will not allow children to access the world's experts on a given topic. The technology will be there, but the experts won't have the time for it. Telepresence won't take over: children will still physically go to schools, because there's just so much of us, as primates, that requires physical touch and general proximity. Children won't learn to reason, or make judgments, or become good citizens any better because computers and other technology is in the loop: that will still be up to the adult role models around them, in school and otherwise. Oh, and the kids won't be flying to school in personal helicopters, either.

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Randy Pausch is a Professor of Computer Science, Human-Computer Interaction, and Design at Carnegie Mellon, where he is the co-director of CMU's Entertainment Technology Center (ETC). He was a National Science Foundation Presidential Young Investigator and a Lilly Foundation Teaching Fellow. He has consulted with Walt Disney Imagineering on the user interface design and testing of interactive theme park attractions, and with

Google on user interface issues. He is the director of the Alice project, which makes it possible for high school children to author interactive virtual reality worlds.

ENCOMPASSING EDUCATION

Diana Walczak
Artistic Director
Cofounder, Kleiser-Walczak

Broad dynamic content will feed future education technologies. We will integrate motion and haptic interfaces, display and sound sciences, computer simulation breakthroughs, and next-level communication and information technologies. The vast possibilities created by these merging technologies make it crucial to bring together great minds from every discipline to begin building a foundation for the development of massive amounts of evolving content simultaneously and in collaboration with the design of next-generation education technology. In an effort to illustrate one small but powerful possible piece of the future education puzzle, this conceptual paper includes a vignette set in the 2020's showing a twelve year old girl engrossed in a highly comprehensive though very personal learning experience. To create such a functional education system for the coming century we must find ways to break down long-standing educational shortcomings:

Problem Set 1:

- Faster and slower students are alienated because teaching is aimed at the average student
- Less aggressive students learn less
- Teachers don't have time to give individualized instruction

Solution 1:

Customize the learning process

Problem Set 2:

- Students don't experience enough
- Students have trouble visualizing abstract concepts
- Students don't utilize enough of their senses
- Students don't utilize balance and coordination when learning

Solution 2:

Utilize the senses and experience more

Problem Set 3:

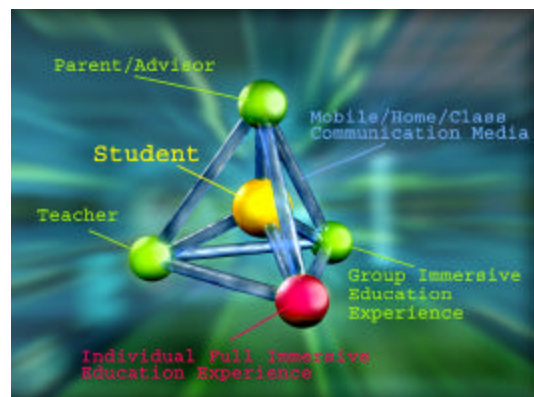
- Disciplines are too separate
- There is too much emphasis on grades, rules and directions rather than creativity
- The arts have taken a superfluous position in education
- Too few students are interested in learning

Solution 3:

Foster a heightened sense of curiosity

ADVENTURE LEARNING

The drawbacks listed above can be resolved by customizing the learning process, allowing students to experience more, and fostering a heightened level of curiosity. Students should pursue their own inspiration and learn at their own levels. It is a well-known fact that we learn more by doing. But how can we be individually exposed to many different ideas or places? By developing a system for students to experience more through increased usage of their



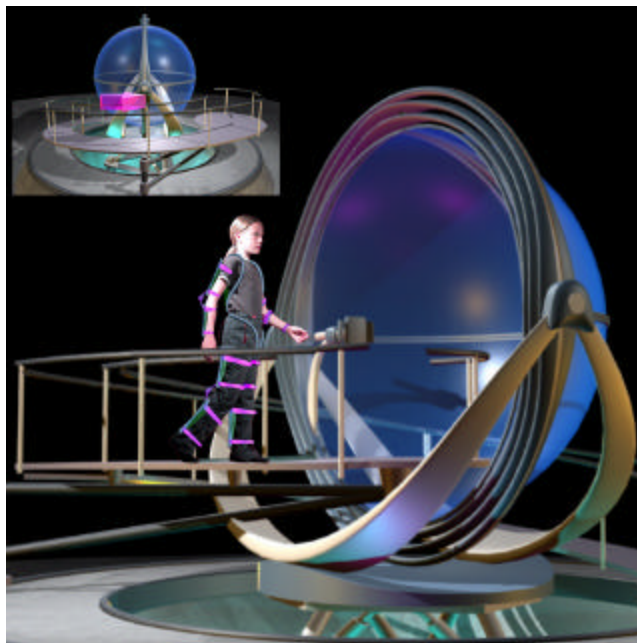
Though this paper highlights the individual full immersive education experience, a complete, stable, and discrete student learning structure includes teacher, parent/advisor, and group immersive experience nodes. All nodes are interconnected with mobile, home or class communication media.

senses. Students should be compelled more toward seeking creative solutions than merely following instructions. Let's allow rivers of subjects to mingle in a confluence of endless possibilities and in the future, incorporate rather than separate the arts. How can technology help us overcome past educational problems including those caused by technology itself?

We will evolve into a more productive society through Adventure Learning. Picture an Adventure Learning structure in which the student is surrounded by four essential education nodes, each of which is connected to the others and to the student. The four surrounding nodes are teacher, parent/advisor, group immersive education experience, and individual full immersive education experience. Mobile, home, or classroom communication media link the nodes to establish a unit of stable and discrete education.

Communication media will become the glue that holds together a more customized and far less simplistic education system. The technologies that will vastly change information and communication are autostereoscopic display systems, 3D sound, augmented reality, virtual reality, and portable or wearable ubiquitous information machines. Through any or all of these technologies, a teacher can guide or a student can present projects within the node or beyond. And all have access to "cybraries" and other information databases.

The group immersive education experience can be an actual or virtual laboratory where students can work together to solve problems and achieve common goals. Telepresence with student avatars would allow students to work closely with other colleagues around the world or beyond. The group immersive experience could also be a variation of the individual immersive experience, placing the group in a larger display dome or providing retinal scanning or other virtual reality eyewear in combination with full body force feedback systems.



Iona enters the Tangitrek. With a force feedback exoskeleton, motion base, gimballed harness and autostereoscopic display, a student can go anywhere and do anything.

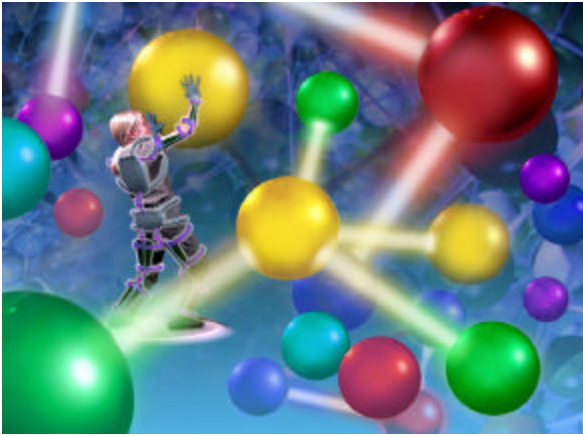
This discussion will highlight the individual immersive experience portion of the overall system because of its tremendous potential impact on customization, experience and creativity.

Customize the Learning Process

Fast-forward to the 2020's. A 12-year-old student walks up a curving entry platform and enters a Tangitrek, which biometrically identifies her as Iona Sole. A 10-foot sphere envelops her after the entry platform rotates out of the way. Iona, who has two years of Adventure Learning experience, makes some selections. The system will accommodate and keep track of her preferences and skill levels in different areas. Like many students, Iona's focus used to be more on getting good grades than learning. Now that she's developed a strong desire to learn, she is already several years ahead of turn of the millennium educational standards for her age.

Utilize the Senses and Experience More

As we continue to increase our knowledge through an accelerating number of virtual techniques, we rapidly lose touch with the tangible world. By further advancing our simulation



On her virtual mobile scaffold, Iona surfs through a giant chemical model whose surfaces and atomic bonds she can feel.

capabilities we will actually bring real world challenges back into the virtual experience.

The sphere Iona is now inside is the inner of a three-ring gimbal system that allows her complete freedom of rotation. The outer ring is attached to a three-degree-of-freedom motion base that enhances her sense of acceleration by moving up and down, side to side, and forward and back. Iona sits on a small seat and is gently enveloped by a body harness whose sensors make minute size adjustments and lock into place. The body harness is an intelligent force feedback exoskeleton. Twenty years ago this haptic, or touch technology was used for digital sculpting and surgical simulation. Now Iona can feel objects, step on surfaces, and fly through spaces.

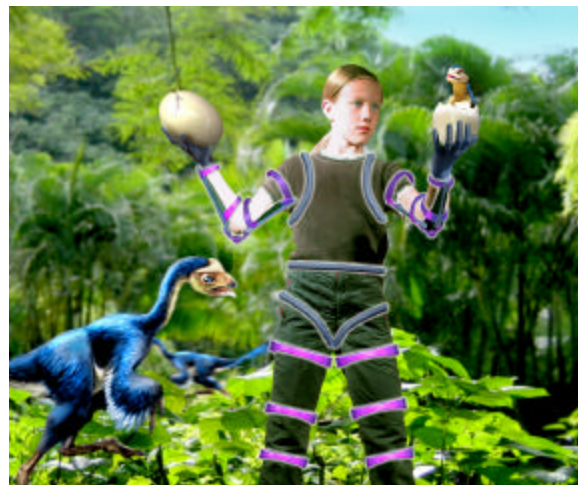
Like all students, Iona eagerly begins her adventure with her ongoing individual exploration project. From there she will traverse research branches which help to solve problems for her personal project or enlighten her to related subjects. Iona, an enthusiast of ancient mythology has been studying the theoretical genetics of creating a winged horse. In her visualization class where students are coached in picturing imagery in their heads, Iona worked out a DNA protein configuration that her teacher was able to analyze from her brain scan. These days teachers expect a lot of the work to be done in

the student's head in an effort to exercise more of her brain and to avoid over-immersion. Iona begins where she left off by selecting and boarding a virtual mobile scaffold—not unlike a surfboard—on which she navigates through a giant model of DNA.

She deftly arranges and rearranges the chemical model whose surfaces and atomic bonds she can actually feel.

The photo-realistic autostereoscopic computer-generated imagery surrounding Iona appears to jump right off the inner surface of the plasma display sphere. Though the spherical display surface is never more than 10 feet away from Iona, she perceives apparently distant images reaching to infinity. This adventure system has access to all the imagery and information in the entire US Public Cybrary; a student can access information without the commercial intrusions of general cyberspace.

When Iona reaches a juncture relating to bird origins which requires further research, she quickly traverses the Theropoda branches of Dinosaur classification and selects Caudipteryx > Hatchlings > Reality Simulation. Suddenly, Iona is standing in a Caudipteryx nesting grounds in an Early Cretaceous landscape. This world even smells different, as a function of the flora, fauna, and climate. The nanoaromatic system delivers and deletes aromas based on the biochemistry of objects in scenes. Aroma levels can be dialed up or down by the



Iona closely observes a prehistoric youngster cracking its way out of the egg. She is able to see, hear, smell, and touch simulated objects and environments.

Tangitrek user. All around Iona, the small flightless theropods forage among the ferns. She picks up two eggs, feels their shape and weight, and vocalizes a few observation notes for future reference. Iona hears the slightest of cracking sounds that seem to come from exactly inside one of the eggs. A binaural 3D acoustics system accurately positions simulated or recorded sounds with respect to objects that she sees in the spherical display system. Iona closely observes a prehistoric youngster cracking its way out of the egg.

Foster a Heightened Sense of Curiosity

The industrial revolution, with its inventions and factories, by necessity bred a society in which following sequences of instructions was imperative. This approach has lingered through 20th century education even though we've been transitioning into a society where humans become more creative and machines perform manual or repetitive tasks. Adventure Learning allows students to navigate, investigate and determine their own solutions. Endless interdisciplinary combinations discovered in immersive environments will lead to new kinds of specialists with strong diverse backgrounds.

Iona studies horse anatomy and works on a concept design for the mythical flying horse. Before allowing her to set out on a flying trek to ancient Greece, the system prompts her to solve problems involving English words with Greek origins. Reacting to Iona's inadvertent avoidance of language, the system ensures a balanced set of disciplines is reached in each adventure. Flying over the Acropolis, Iona can see the structures as they originally looked. Simple hand gestures provide navigation as she observes Synthespians in ancient dress going about their business. She lands on the hill to browse the culture a bit. She makes herself visible and speaks with the simulated Greek townspeople. Recognizable highlighting allows her to see that there are a few other Tangitrek users in the area. In any cultural recreation, local Synthespians see Iona as one of them and are eager to discuss ideas relating to their era. Iona experiences the original



Iona flies over the Acropolis as it may have looked in ancient times. She can converse with synthetic townspeople about their era.

language and can turn translation on as needed. She is directed to a temple full of sculptures of interest. She touches the sculptures to enhance her visual study of them. As she moves her hand over the neck of a marble Pegasus, the Tangitrek informs her to prepare to disembark. Though it's difficult to leave the simulator, she smiles with satisfaction knowing information from today's adventure will be accessible from her personal media system.

REWINDING TO THE PRESENT

We should note that though the above-illustrated system demonstrates the exploration of a twelve-year-old girl, the concept has use in education or training for people of all ages. It's especially important to awaken the senses of the very young to the underlying structure of nature through geometry, color, and sound. The basics: reading, writing and arithmetic will come quickly and easily after a rich, explorative foundation. Kindergarten as we know it today is a diluted version of the original 1830's invention of Friedrich Frobel which intended children to use their natural ability to discover, reason, and create through the universal language of geometric form. Adventure Learning technology can help us reinvent the nearly lost, yet highly innovative teaching system.

We know that with the development of content to drive a combination of technologies—haptic, autostereoscopic display, 3D computer simulation, data management, harness and structural materials, personal media communication systems—we will be

able to realize a profoundly valuable education system. The customized approach improves student self-esteem, intellectual development, and vocational planning. “Physical” experience increases retention, balances the psychological with the intellectual, and brings tangibility to ever-increasing virtual worlds. We will see a transformation in the workplace whereby a person’s focus shifts from the pursuit of a paycheck to a daily quest for knowledge and creative solutions when we finally develop education content and technology powerful enough to reawaken the natural curiosity of our students.

© 2002 Diana Walczak. Computer-generated imagery created by Patrick Finley. Images composited by Io Kleiser and Diana Walczak. Text and images are intended for demonstration use only.



Diana Walczak is Artistic Director and co-founder of Kleiser-Walczak.

In recent years Diana Walczak has begun to focus on directing fully CG-animated projects. Walczak’s directing credits include the short film Little Miss Spider: Lost and Found, (a winner at the 2002 New York International Children’s Film Festival) and two stereoscopic projects: Corkscrew Hill (a 2002 Thea Award-winner) and Santa Lights Up New York (created for The Radio City Christmas Spectacular). Writing about Santa Lights Up New York in the New York Post, Liz Smith said, “This is the best short film of

the year!” Walczak’s directing credits also include The Amazing Adventures of Spider-Man (for Universal Studios Florida), the film for the Philip Glass/Robert Wilson digital opera Monsters of Grace and the Clio Award-winning commercial Trophomotion.

Walczak is a computer graphics pioneer. She developed the first digital stunt doubles for Judge Dredd and co-directed the creation of two of the first digital human characters, Nestor Sextone and Dozo. In 1988, she and Jeff Kleiser coined the term Synthespian to describe the 3-D characters that they bring to life.

In the early days of Kleiser-Walczak, Walczak contributed to the animation and visual effects of Stargate, The Luxor Trilogy and The Astronomers. In 1995, she sculpted Michael Jackson and created a digital representation of the artist for his HIStory album cover.

Prior to founding Kleiser-Walczak in 1987 with Jeff Kleiser, Walczak worked as a sculptor and medical illustrator. She studied engineering and computer science at Boston University, finishing with a degree in sculpture in 1985. Walczak’s traditional sculpting skills have been utilized in much of her work as a digital artist and director of computer animated characters. In recent years, she has moved from sculpting characters in clay to designing and sculpting characters with virtual clay, in the computer, using a haptic force feedback tool by SensAble Technologies.

Diana Walczak serves on the board of directors of the Norman Rockwell Museum. She is also on the board of the SEE Fund, an endowment that supports innovative extra-curricular educational projects for the Mount Greylock Regional School District. She lives in rural Massachusetts with her husband and three children.

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FUTURE OF EDUCATION = TECHNOLOGY + TEACHERS

R. Stanley Williams

H-P Fellow

Hewlett-Packard Laboratories

The future of education will be profoundly affected by forthcoming information technology. But even more importantly, it will be affected by how educators and students use the technology to prepare for life-long learning in the face of unrelenting change. Human beings have been slowly evolving along with their tools for millennia, but we have now entered an age in which revolutionary transformations take place every few years. This makes it difficult for most people to even imagine what technology will be available in two decades, let alone for institutions to plan its effective use. Exponential change presents the danger that people will be swept away by an irresistible flood of new technologies that supplant all that they have learned, making them irrelevant to society and incapable of contributing to it. However, in the hands of skillful and dedicated teachers, new information technologies have the potential to greatly improve the educational process. People of any age with access to them may learn to embrace change as an exhilarating part of life and adapt as rapidly as the world about them transforms. The responsibility for determining whether technology overwhelms or elevates future students belongs to everyone, not just the developers and marketers of products. More than ever, the joint efforts of concerned teachers and involved parents will be needed to ensure the proper use of technology in the classroom so that education becomes an integral part of living.

Extrapolating from historical advances in electronics, we can roughly predict some of the tools that will be available in 20 years:

- Hand-held (or wearable) computers will be able to calculate 10,000 times faster than they can today, and will thus begin to rival the data processing capability of the human brain. They will be the hubs of digital assistants that could store more textual information than a human could read in 10 lifetimes. Such assistants will combine the present functions of telephones, web browsers, and recorders and players of both audio and video. Through wireless web access, they will be able to download far more video information than a human could watch in a lifetime.
 - Digital assistants may be capable of real conversation, responding to verbal requests with questions to clarify the requester's intent. A third party wouldn't be able to tell if a person is conversing with his or her digital assistant or with another person, using the assistant as a telephone.
 - Display technology will also have advanced tremendously. In 20 years, we'll have eyeglass displays that will be able to project virtual or recorded images that the wearer will perceive as immersive three-dimensional reality. Such glasses will be able to overlay or blend telemetry, virtual images and the real world almost seamlessly. A person will be able to see someone seated across a table, and – in the next “seat” – another person physically located halfway around the globe.
- If we accept these projections, what can we guess about the future of education and learning? We can imagine two extreme scenarios following from present trends: the first a distinctly bleak but all too possible future and the second a vision in which teachers and technology work together to help students realize their full potential.

A blind acceptance and inexpert use of information technology in future classrooms could lead to a generation of people with no ability to interact with each other or with the unpredictable surprises and accidents that occur

in everyday life. Judging from the way in which computers are often used in schools today – by teachers who don't understand technology or are intimidated by it – we can easily envision a future in which teachers in elementary school use immersive technology as digital Ritalin®, to keep young students quiet and docile. The students themselves could become addicted to the virtual worlds they are presented and prefer them to the real world. This scenario projects that children in the future will have very little contact directly with each other and would become social misfits. This is not all that far-fetched, since all too often today young children come home from school to turn on their computers rather than going out to play with each other.

It could also mean that tomorrow's students will have too little experience of the real world: if they are given a steady diet of prepared scenarios and virtual models, they will be totally unprepared and unable to deal with new problems that arise. A model can only have built into it the types of behaviors that people understand or have already experienced; however, Murphy is a lot smarter than any programmer, so a student brought up on canned solutions to problems may be completely overwhelmed by a unique experience or interaction.

Furthermore, if education software is an extension of current computer games, then all children will have homogenized backgrounds and will react to the same stimulus in the same fashion. Technology used in this improper fashion has the capacity to crush the creativity out of young people and turn them into obliging responders to prepackaged stimuli, such as advertisements or political propaganda.

Does that mean that children under a certain age should be banned from using computers, rather like today's youth are denied cigarettes? That's not a desirable (nor practical) objective, since highly capable computers can and should be used to encourage and enhance the creativity of a person. However, teachers and parents must carefully consider how to introduce and stage students' work with computers as one component of their educational experience.

In the optimistic scenario, new technologies properly utilized in the classroom have the potential for encouraging differentiation and creativity. Very few people have the skill with a brush to craft a great painting or the facility with the musical scales to compose a symphony. But with appropriate technology and software, it should be possible to digitally create any image or sound that a person can imagine. This possibility dramatically expands the range of assignments that young learners can tackle and the ways in which they can express themselves. The key is that the tools are used as an extension to creativity, not a set of fixed restrictions on what a student can do.

Traditional classroom learning involves experiencing new material at least five times: previewing a textbook, listening to a lecture, reading the text for comprehension, performing directed problem solving and reviewing the information (usually for an examination that is intended to gauge how well the student mastered the material). This paradigm can be adapted for highly capable digital assistants, where new material is introduced gradually over a period of time by presenting it within meaningful contexts, the lecture could be a recording of a great master teacher, the reading for comprehension could be done with an active tutor that senses when the learner is having difficulties, etc.

All of this presupposes that real people with a strong sense of social responsibility become involved in creating the software and the environments that are used in the learning experience. This will require that we better comprehend human cognition and use that improved understanding in designing our tools to establish a sound pedagogy. Thus, improved technology provides greater imperatives for performing research in areas that will help us to be more aware of ourselves. The daily experiences of teachers must be incorporated into any new approach to curricula, so that they will work with digital assistants to customize lessons according each pupil's aptitudes and interests. Above all, we must understand that there can be no substitute for direct human contact, even with all of the imperfections and misunderstandings that can arise. People have

always learned best through their mistakes or the mistakes of others, and no technology will change that.

Given these considerations – the need to use technology appropriately and not attempt to substitute it for human interaction or experience with the real world – future technology could provide qualitatively new types of learning. The human aural system is similar to a serial communications channel, which is greatly afflicted by noise and transmission errors. Normal human writing and reading emulates this serial process. However, vision is inherently a parallel information communication system. People with sight can see everything within a two-dimensional frame simultaneously, and, moreover, that frame can be updated frequently. That means learning and comprehension may benefit greatly from the development of a universal visual language. Such a language is in a sense already developing – it appears in a wide variety of media and it is also evolving through viewgraph presentations, where a presenter can mix aural and visual stimuli to convey large amounts of complex information in a short time. Future book equivalents may actually be written in a visual language, in which more information-rich symbols are used, perhaps something like hieroglyphics as clip art. A U.S. student studying South Africa could not only attend lectures and discussions, read books, listen to music, see the art and cultural artifacts, watch TV and films, and access a wealth of factual information on the Internet, he or she could also meet and communicate in a universal language directly with a South African student studying the U.S. to appreciate different perspectives and world-views.

In short, tomorrow's educational environment should be greatly enhanced by future information technology, which can engage more of the senses in the learning experience for vastly improved comprehension. The ubiquitous availability of information could abolish the constraints of time and place for education, which should become a part of the fabric of everyday life. And everyone should have equal access and be able to contribute to the continual flow of new information, which in

turn must be verifiable or subject to review and rebuttal!

This approach to education recalls the universal truth attributed to both Chinese and Native American wisdom: "Tell me and I'll forget. Show me and I may remember. Involve me and I'll understand."

We must all become involved, not only in understanding future technologies but the ways in which those technologies will be put to use. Technology can never be a substitute for excellent teachers and involved parents, but it can enable a more enriching and effective educational experience for those fortunate enough to be in an environment where it is used properly. The future begins today.



R. Stanley Williams is an HP Fellow at Hewlett-Packard Laboratories and founding Director (since 1995) of the HP Quantum Science Research (QSR) group. The QSR was established to prepare HP for the major challenges and opportunities ahead in electronic device technology as features continue to shrink to the nanometer size scale, where quantum mechanics becomes important. He received a B.A. degree in Chemical Physics in 1974 from Rice University and his Ph.D. in Physical Chemistry from U. C. Berkeley in 1978. He was a Member of Technical Staff at AT&T Bell Labs from 1978-80 and a faculty member (Assistant, Associate and Full Professor) of the Chemistry Department at UCLA from 1980 – 1995. He is

currently Adjunct Professor of Chemistry at UCLA and of Computer Science at the University of North Carolina at Chapel Hill, as well as a frequent lecturer at the Pepperdine University School of Business Management. His primary scientific research during the past twenty-five years has been in the areas of solid-state chemistry and physics, and their applications to technology. This has evolved into the areas of nanostructures and chemically-assembled materials, with an emphasis on the thermodynamics of size and shape. Most recently, he has examined the fundamental limits of information and computing, which has led to his current research in molecular electronics. He has received awards for scientific and academic achievement, including the 2000 Julius Springer Award for Applied Physics, the 2000 Feynman Prize in Nanotechnology, the Dreyfus Teacher-Scholar Award and the Sloan Foundation Fellowship. He was an advisor to the Defense Science Board for the project "Achieving an Innovative Support Structure for 21st Century Military Superiority" in 1996 and a co-organizer and co-editor of the workshop and book "Vision for Nanotechnology in the 21st Century", respectively, that led to the establishment of the U. S. National Nanotechnology Initiative in 2001 at a funding level of \$418 million per annum and in 2002 at a level of \$600 million. He has been awarded seven US patents with twenty six more pending, has published 201 papers in reviewed scientific journals, and has written general articles for technical and business publications. One of his patents was named as one of five that will "transform business and technology" by MIT's Technology Review in 2000.

http://www.hpl.hp.com/features/stan_williams_interview.html

<http://www.forbes.com/tool/html/99/jun/0614/feat.htm>

See the following links for further information and interviews:

<http://www.hpl.hp.com/research/qsr/index.html>

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A VISIT TO THE SPRINGDALE SCHOOL SYSTEM IN 2012

John I. Wilson

Executive Director

National Education Association

The National Education Association (NEA) welcomes the opportunity to offer our vision of the future for education technology. We commend the Department of Commerce for initiating this thought-provoking exercise.

We are not here as technologists or futurists, but as educators. Our goal is not so much to define the intricacies of technological developments or their future evolutions, but to explore the potential outcomes and opportunities for our students.

In theory, technology offers endless possibilities to enhance the educational experience.

Educational technology can offer students expanded academic opportunities as well as critical employment skills necessary for entering the workforce of the global economy.

Technology may have the potential to transform from a goal to a reality the ideal that every child will succeed academically. In practice, however, what we do in the present will define our future. And, as in space travel and medicine, technological advances in education will require major national commitment and resources.

THE VISION: A VISIT TO THE SPRINGDALE SCHOOL SYSTEM IN 2012

By the next decade, technology could bring students to exciting new worlds, enhance teaching and learning strategies, and facilitate effective parental involvement. Twenty-four hour access and pervasive technology will be the norm. Students will require both technological fluency, and whole new levels of media literacy skills. Educational employees will have a vast array of tools to tap the potential of every child, but will also face the significant challenge of managing these new responsibilities.

For example, on a typical day in the year 2012 in Springdale U.S.A...

Students find new ways to study content and develop analytical skills: Ms. Fuentes and Mr. Jackson are debriefing her students on their virtual participation in historical events. In Ms. Fuentes' class Joshua and Alice have just finished participating in the Founding Fathers' debate over the approach to states' rights in the founding of the Constitution. The opportunity to question Jefferson and Hamilton has given them much to contemplate on how to develop national unity and which decisions are best made at the state versus the national level. In Mr. Jackson's class Nathan and Jennifer are reflecting on their experiences on the virtual Underground Railroad. Jennifer, as a run-away slave, and Nathan, as a provider on the Underground Railroad, faced complex moral and practical dilemmas. Cynthia is sharing her perspective from a fascinating biography of Harriet Tubman she borrowed from the school library.

Educators use technology to inform and improve their approach to individual students:

Mr. Jackson and the technical support staff are reviewing technology requirements for each first grade student to meet his/her needs and learning style. They fine-tune the technology for Lamar and Teresa to ensure their dyslexia doesn't slow their progress in reading. They also look at how the software they ordered has helped Timmy and Lee learn to better organize and synthesize their ideas. They note that Janey's articulation skills have improved significantly since technology has helped her better understand verbal communications. They also agree that she would benefit from a shift in her schedule allowing for more classroom discussion time and fewer hours working alone on her digital portfolio.

At the same time, across the hall, Ms. Alfonso is spending her daily two hours of planning time reviewing the regular digital diagnostic assessment from each of her student's

work and crafting approaches to help each of them. Her feedback tools indicate that a new approach is helping Darren understand multiplication better, but exponents still seem to be a problem. Ms. Alfonso is working with colleagues to identify the best way to help Darren with this lingering problem. The feedback also shows that the program allowing students to virtually build and touch three-dimensional objects appears to be helping Jennifer's understanding of geometry, and allowing her to study solid geometry at a relatively young age. Ms. Alfonso begins studying some new tools recommended by her technical support staff person that might work particularly well with Jennifer.

Students with disabilities find instruction fully accessible: Stephen is working in a small group searching the Internet for background about human cells. Although he is blind, voice description software allows him to participate fully alongside his sighted classmates. Another class down the hall is watching a video about Abraham Lincoln's life. Even though Denise is severely hearing impaired, she easily follows the video through embedded captioning and sign language interpretation. Stephen and Denise's teachers know their textbooks and instructional materials are fully accessible for all of their students – even those with significant disabilities.

Classes thousands of miles apart learn together: Ms. Ginsburg is co-teaching a bilingual course with Ms. Blanchi in Poitiers, France. Every morning the two groups learn together in a technology-connected bilingual classroom. Many of the students continue conversations after school with their transatlantic classmates. Because the students have participated in this program since the early grades, it is often difficult to distinguish between the French and American students.

Schools find new ways to ensure safety and discipline: Down the hall Tracey and her parents are meeting with Assistant Principal Grabowski. Tracey has had a series of discipline problems in school and had been caught through the school's ubiquitous, seamless screening mechanisms with a knife. As a result, Tracey has been attending

school through an alternative virtual school program, which ensures she maintains her academic program while receiving counseling to return to the physical school setting. Tracey has been maintaining her grades, regularly meeting with her counselor, and performing her community service requirements. While she has kept up academically, she believes she would be happier now back in the physical school setting, and they are developing a plan for her return

Educators and students explore new strategies for learning: Mr. Parsons is having a conference with Melissa's parents, who had been concerned about her decision to take physics. Their own experiences with high school physics years ago had proved frustrating, as neither were terribly good at abstract spatial relations. When Mr. Parsons demonstrates the simulation software and virtual reality techniques he uses, they understand Melissa's success. Mr. Parsons also shows Melissa's parents how 24-hour wireless access to the technology and materials lets Melissa revisit concepts at a time and pace that best suit her. Melissa's parents think about taking a physics class themselves, with the new tools now available.

Mr. Jhori is using a 3-D printer to instruct his earth science course. Students utilize special software that digitally slices a 3-D model into hundreds of cross-sections. Each section is printed using starch- or plaster-based powder and a binding chemical, piling the layers atop one another until the object takes shape. In two hours, the students create a full-color, 3-D model of the earth.

Home and School Connect: Mr. Monopolis is finishing up a conversation with Jessica's mother. He has noticed that Jessica appears distracted in class and her work shows a lack of concentration. Jessica's grandmother is ill, and the family may have to travel to a neighboring state to see her. Jessica is worried about her grandmother, as well as about falling behind in schoolwork and not seeing her friends. Mr. Monopolis is outlining for Jessica's mom how she can attend school through wireless video conferencing while she is away, and even visit with her classmates during lunch break. The materials already online

describe what the class is studying this semester, and Jessica's parents plan to review it in more depth so they can monitor Jessica's work while they are out of town. They also plan to communicate regularly with her teachers.

Students and educators explore new worlds:

Guidance counselor Dawn Williams is going over Kim's workstudy project. Kim plans to study biochemistry in college and wanted to work with a team at a pharmaceutical company as a workstudy project. Although there are no pharmaceutical companies based in Springdale, Ms. Williams was able to establish a virtual internship with a pharmaceutical company downstate. While Kim hopes to make a couple of actual trips to meet with her new colleagues, technology will allow them to work together "shoulder to shoulder" on a daily basis.

Mr. Jenkins' class has been doing research on the Basque independence movement. The technology they use allows them to access new resources and information from around the world at any time, but some have become discouraged by the enormous amount of information available. Mr. Jenkins is helping them navigate through the materials they have found to identify the most reliable and insightful resources. He coaches them on their responsibilities regarding the use of materials created by others, and how to best publish and present their own findings. Among the best resources are forums allowing conversations with actual Basque citizens that allow the students to grasp the nature of the dispute and the issues to be resolved. Virtual tours of the region have also helped them understand how even the topography of the region affects the political situation.

Ms. DeMarco and Juan are reviewing opportunities for a specialized course on medieval architecture – a subject he became interested in last year when he joined a virtual construction project with a group of international students. While Springdale doesn't have a course on this exact topic, Juan is considering a course offered by his state, as well as a course provided through European Economic Community Schools. Ms. DeMarco is helping him research

which course would best serve his curricular needs and learning style.

New students have help integrating into the school:

Ibrahim has just moved from across the country to Springdale and is getting settled in his new school. All of his records and the electronic portfolio of all his work have followed him to his new school. His new teachers are meeting to review his work, see the electronic comments and reports of his former teachers, and learn what approaches and technologies appear to best suit his learning style. They have had video meetings with some of his former teachers, and now they will begin to prepare his individual learning program. While teachers expect him to assimilate socially, he has opted to remain in his former school's technology club through virtual contact for the next few months.

Su Cho has just transferred to the school from Seoul, South Korea. Portable technology that instantly translates verbal and written communications between English and Korean is helping her keep pace in her courses while facilitating her learning of English. The software also translates materials from her former school for her teachers in Springdale. While time differences make conferencing difficult, the Springdale teachers and the Seoul instructors have been able to communicate asynchronously and, with the help of translating software, to facilitate Su Cho's assimilation into her new school site.

Educators enhance their skills: Mr. Sandoval is using his weekly three hours of professional development to take an online course on new technologies to assist physically impaired students. While he has studied this area before, the constant technological breakthroughs necessitate regular updates of his knowledge and skills.

Ms. Chen is video-chatting with one of her mentors on the West Coast. They're reviewing videos of her classroom activities, and her peer mentor, Mr. Barry, is sharing some tips and advice with her. Ms. Chen has found her first year of teaching stressful, but the guidance of mentors, both in her school and in other

locations, has proven invaluable. She has found Mr. Barry particularly helpful because he is an effective teacher whose instructional style is similar to hers. The extra time they are both allotted for this interaction and reflection improves both their capabilities as educators.

MAKING THE VISION A REALITY

Much of this exciting vision rests not on new technologies, but on applying existing technologies fully to improve the academic experience and performance of every student. Yet, even applying existing technology in this manner will require considerable commitment and resources.

For example, the Springdale experience outlined above assumes modern, well-equipped schools; well-trained teachers and support professionals; small class sizes; ample teacher planning and preparation time; and families with access to technology at home.

Unfortunately, the presence and use of technology in our schools is sporadic. While some schools are saturated with technology, others have a sparse, isolated technological presence. In some schools, teachers have technology mentors to explore the panoply of tools and resources and apply them to individual students. In others, teachers remain overwhelmed and unaided. In some schools, educators and support professionals have time to plan and collaborate to devise the best use of technology to impact student achievement. In others, such planning is done in isolation in the wee hours of the morning or on the commute into work.

In addition, some students go home to state-of-the-art technology and have 24-hour access to technology via hand held devices, while others may not even have a phone at home. According to a 2001 report by the U.S. Department of Commerce, **students from the lowest income families are 10 times more likely to have their technology access limited to school than their highest income peers.**

Unless students and parents can access technology beyond the school day, their ability to

benefit from the exciting technological advances imagined above will be severely limited.

In the Springdale example, Ms. Fuentes and Ms. Ginsburg's students will have a very different experience in 2012 if Springdale schools lack extensive technology and the resources and library materials are decades out of date. Mr. Jackson and Ms. Alfonso will be unable to provide individualized strategies tailored to specific students if they have 30 students in a class and no preparation or planning time. Melissa and Jessica will be left behind if their families can't afford a computer at home, or their parents don't have the time or the skills to help them use the technology. Mr. Sandoval's physically challenged students won't have the benefit of the latest technological supports if he doesn't have access to quality, ongoing professional development. Ms. Chen will have a difficult first year, and perhaps, will even consider leaving the teaching profession.

Finally, none of this vision will be possible if tomorrow's teachers do not receive the training they need today. The most critical element in technology use is the preparedness and skill level of those who employ it. Therefore, we must focus resources and technological training on teacher education institutions, which today are among the last to receive state of the art technology. Too often, educators are being equipped to teach 21st century students with 19th century tools.

Education technology offers vast new capacities to tap into every child's potential, but the planning and crafting for such endeavors is significant. Educators who use technology extensively are exhilarated by its potential, yet exhausted by its demands. We must commit the resources to ensure that technology becomes an effective tool to help all students excel.

Christa McAuliffe articulated the enthusiasm of all teachers when she explained: "We touch the future, we teach." We now all have the opportunity to "touch the future" by committing our nation's technological expertise, limitless imagination, and energy to empowering America's teachers and students.

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John I. Wilson, a long-time special education teacher and Association leader, became executive director of the National Education Association on November 1, 2000. NEA is the nation's largest teachers union, with more than 2.7 million members, a staff of 565 and an annual budget of over \$267 million. NEA also represents education support personnel, higher education faculty, school administrators, retired educators, and education students who plan to become teachers.

Wilson previously served the Association as executive director of the North Carolina Association of Educators (NCAE), which represents 72,000 active and retired school employees. During his five years at the helm of the NEA state affiliate, Wilson gained an outstanding reputation for successfully championing statewide education reforms.

Under Wilson's leadership, NCAE strengthened teacher training systems, professional development programs, teacher compensation, and teacher recruitment. His impressive track record includes the development of new support systems for teachers pursuing certification by the National Board for Professional Teaching Standards, resulting in more National Board-certified teachers and candidates from North Carolina than any other state. Wilson led NCAE's National Average 2000 Campaign, which over the past five years moved

North Carolina's average teacher salary rank from 43rd in the nation to 23^d. In addition, he helped establish the North Carolina Teacher Academy, which is now funded by the legislature, and provides teachers with high quality professional development.

Prior to his appointment as NCAE executive director, Wilson was the chief lobbyist for NCAE and was repeatedly rated by the North Carolina Center for Public Policy as one of the most influential lobbyists in Raleigh.

Before joining the NCAE staff, he spent 20 years in the Raleigh and Wake County Public School Systems as a middle school teacher of special needs students.

Wilson became an NEA member as a student at Western Carolina University, where he served as president of the Student North Carolina Association of Educators. He graduated in 1970 with a Bachelor of Science degree in education. He received a Master's degree in education from the University of North Carolina the following year.

Throughout his long teaching career, Wilson was an active Association member and leader. He served as president of the Raleigh Association of Classroom Teachers, the North Carolina Classroom Teachers Association, the Wake County Association of Classroom Teachers, and in 1981, he was elected as president of the North Carolina Association of Educators.

He also served on the NEA Board of Directors for five years and on the NEA Executive Committee from 1983-1989.

In 1992, Wilson accepted a staff position with NCAE and became its manager of government relations. In 1995, he was named to the position of NCAE executive director.

Born on October 25, 1947 in North Carolina, Wilson loves mystery novels and is a voracious reader. He "lives and breathes politics" and, a true North Carolinian, he is an avid Tarheel fan.

MOTIVATIONAL TECHNOLOGY

Will Wright

Chief Designer and Co-Founder

Maxis

“Education is not the filling of a pail, but the lighting of a fire.”

W. B. Yeats

Background

Rather than focus this vision on how to educate people (pushing information) I've decided to go a bit deeper and address what I see as a more fundamental problem, how to get them to really want to pull it. I think we're now in a position to apply technology to a more individualized approach that will light the spark inside others and make them want to learn.

When it comes to effective education, motivation is the key. Try to prevent a motivated individual from learning and you'll find it's just as hard as educating an unmotivated student. With the rapid growth of the Internet most Americans now have the rough equivalent of the Library of Congress sitting on their desktops at home. Imagine what might happen if they were really motivated to use it for education.

Computer advances are bringing a wide array of new technologies (intelligent digital agents, realistic simulations, real-time graphical databases) into the home. Yet most of these will only realize a small fraction of their educational potential unless people find the motivation to use them.

At the same time the consumption of various forms of entertainment media around the world continues to skyrocket with no end in sight. The ironic thing here is that the compulsion we have for entertainment (and play) is rooted in deeply evolved reward mechanisms in our brains that appear to be nature's form of “educational technology”. Our culture has divided entertainment and education into two widely

separated camps but this division does a disservice to both activities.

Entertainment and play have the magical ability to inspire us through compelling stories, challenges and activities. We are driven to consume entertainment because it feeds something in us; it exercises our imaginations. What we need to do now is learn to channel this inspiration; to redirect it; to transform it into a more persistent motivation to learn more.

Entertainment > Inspiration > Motivation > Education

Hobbies such as model making and R/C aircraft can kindle interests in history and engineering. Many kids who are fans of Japanese animation and manga later develop a strong motivation to learn about Japanese language and culture. Science fiction tends to spark an awareness of contemporary environmental and science issues. Pick any form of entertainment media—books, movies, games, the web—and you'll find that the connections to reality are deep and strong.

Of course some people are already inspired enough by Jurassic Park to go read a bit about genetics and paleontology, but very few. There is a large amount of friction involved in this process. What if we could remove most of that friction? What if movies (and other forms of entertainment) contained embedded educational footnotes that could be accessed at any time and were personalized to each individual based on their current interests?

The Vision – 20 years from now

Mary sits down to her media center (MC) for the evening. This integrated system manages most of her digital media—movies, television, games, music, net access and online shopping. It also has connections to her school; class schedules, assignments and homework.

She was watching an old movie last night “Mutiny on the Bounty” with Mel Gibson, an old actor that she remembers as one of her mother’s favorite actors. Several footnotes appeared at the bottom of the screen during the movie, which she deferred and decides to now look at. Most of them are related to the ship design and operation, topics that her MC knows that she has a strong interest in (based upon its observation of her interests over time).

The movie itself contains a “footnote” track with thousands of links associated with elements of the film (settings, actors, characters, technology, science, history, literature). In Mary’s case only about one of a thousand notes was triggered based on her personal interest profile. These notes can point to almost anything—books, articles, games, other movies, music. They’re kind of like hyperlinks in HTML except they can be embedded into any form of media and are specific to the personal profile of the user.

She decided to watch this particular movie because a new song from her favorite band contained a line mentioning the “the poor souls on the Bounty...” and she didn’t understand the reference having never heard the story. Fortunately there was a footnote on that line pointing to various books, movies and articles. She picked the movie because she recognized Mel Gibson’s name.

As she clicks through the footnotes she comes across a website showing the evolution of ship design through the centuries. She is immediately taken with the style and design of the Viking long ship. A footnote there brings her to a game where she gets to control a Viking colony. After playing the game for a while she decides to order a book, a fictional account of Viking culture that was noted during part of the game.

Because she has given her MC permission to compare notes with her buddy list, she was able to see that her friend Samuel ordered this book last year and gave it a high rating. She also notices that her history class will be covering this period in a few weeks and her MC suggests that this might make a good topic for her semester report.

Mary doesn’t really make a clear distinction between her education and entertainment. They tend to support each other as she smoothly jumps between the two. Since her unique interests are identified and supported so rapidly she finds that the scope of what interests and motivates her is expanding as well.

What’s needed (not much)

To make this work we need three things: a classification for defining subject material, a format for embedding and linking this “footnote track” to existing media and a method for measuring the interests of a user.

The classification scheme might work something like the old Dewey Decimal system but more flexible and expandable. By going through an intermediate description such as this we can avoid many of the problems associated with direct hyperlinks (broken links, outdated content, etc.) while at the same time removing direct control from the media creators.

The interests of the user can be specified relative to this classification scheme. Every movie you watch, song you hear, game you play and news article you read will give the system a better idea of what you find interesting. For most people a particular combination of interest elements will be the most meaningful measures (“18th century – sailing ships – models”). Limited forms of this are already in use today (Amazon recommendations, TIVO, direct marketing).

The footnote track can either be directly embedded in media (HTML) or time streamed.

Which notes actually get triggered and displayed to the viewer will be based on a matching score (user adjustable) that compares the subject of the note with the interest of the user. Some will want to set this threshold very high (few notes), others will not.

This really is just an expanded version of web linking applied across all media with an agreed upon subject classification. The only way to make something become this universal is to make it drastically simple.

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Will Wright, Maxis' Chief Designer, co-founded Maxis with Jeff Braun in 1987. Wright began working on what would become SimCity—The City Simulator in 1985. Using a complex technique, he found a way to bring realistic simulations to desktop PCs. Previously simulations of this sort were only available to the military, scientists and academicians. But now, using an easy to use graphic interface, the world of simulations opened up to consumers.

Wright has had a lifelong fascination with simulations. His interest in plastic models of ships and airplanes during his childhood in Georgia eventually led to his designing computer models of cities, ecosystems and ant colonies.

SimCity was released in 1989, and within a few months became a hit. The game has since won 24 domestic and international awards. With Fred Haslem, Wright co-designed SimEarth—The Living Planet in 1990, a simulation of a planet based on the Gaia theory of James Lovelock. In 1991, Wright and Justin McCormick designed SimAnt—The Electronic Ant Colony, a scientifically-accurate simulation of an ant colony. SimCity 2000, and SimCopter, a helicopter flight game, are also part of Wright's recent repertoire. The latest incarnation of SimCity, SimCity 3000 Unlimited, the definitive version of 1999's best-selling game SimCity 3000, has continued in the tradition. The long-awaited 4th generation, SimCity 4, is due out this fall.

Taking computer entertainment to its most personal level, Wright's ground-breaking game

The Sims, puts players in charge of the lives of a neighborhood of simulated people. Released in February of 2000, this wildly popular title has become a cultural phenomenon, sold almost 7 million copies worldwide, has received numerous "Game of The Years" accolades, and has become the best selling PC game of all time. To date, The Sims has inspired four expansion packs: Livin' Large, which allows players to put their simulated families from The Sims into new extreme situations and settings; House Party, which gives players the chance to host outrageous parties for their Sims; Hot Date, which gets The Sims off the couch, to an all-new downtown area and into the dating game; and, due out this spring, Vacation, which allows The Sims to get some rest and relaxation with their families and friends on a fun-filled vacation island.

Next up for Wright is the much anticipated The Sims Online™. Scheduled for release in the second half of 2002, The Sims Online will enable you to take your Sims to an online world where you get to be yourself or whoever you want to be. In this world you have your own piece of land to do with as you please. In this open-ended, online world, you choose your role, your attitude and your destiny.

Wright has become one of the most successful designers of interactive entertainment in the world. In 1999 he was included in Entertainment Weekly's "It List" of "the 100 most creative people in entertainment" as well as Time Digital's "Digital 50", a listing of "the most important people shaping technology today." This February he will join the likes of Shigeru Miyamoto of Nintendo, Sid Meier of Firaxis Games, Hironobu Sakaguchi of Square USA, and John Carmack of id Software when he is inducted into the Academy of Interactive Arts and Sciences' Hall of Fame.

However, his interests are not limited to computer games. Each year Wright, along with his daughter Cassidy, takes part in the annual Battlebot competition which is broadcast nationally on Comedy Central. His past robots, which do battle with robots designed by other contestants, have taken top honors. Interestingly, it was Wright's interest in robots that eventually led him into computer programming.

THE LAST TEACHER

Michael Zyda

*Director, The MOVES Institute (Modeling, Virtual Environments and Simulation)
Naval Postgraduate School*

and

Douglas H. Bennett

*Study Director
National Research Council's Aeronautics and Space Engineering Board*

Technology that enables a revolution is always accompanied by upheaval of some form or another. The experience of change is part of being human and is not necessarily bad. However, if not thought out carefully, there can be manifold unintended consequences that fall out from advances in technology, be it revolutionary or not. With funding and motivation, the following is possible in 15 to 20 years. But what is *possible* should be thought about very carefully.

The Last Teacher

Smooth and soft like silk brushing the nape of a neck, the first Cog's voice whispering into the ears of a child was born on the glowing coals of a minor labor dispute in Belmy Beach, Florida. The intelligent virtual computer companions, known as Cogs since they mimicked true cognition, was the technology that Education Systems Solutions, Inc. placed their one bet on. Simply known as ESS to the venture capital world, when it came time for system deployment, ESS chose the slowly decaying retirement beach strip of Belmy Beach for a very simple reason: the strip was old and the people were older. A few tourists wandered through town on occasion: those on vacation who ignored the mouse-eared sirens of Orlando and picked their leisure spot randomly off the state highway map. The occasional, but rare, bikini-clad teenager injected a fleeting youthful presence into the beach strip's main artery,

highway A1A running the length of the Orange State's east coast.

But the town and the year-round inhabitants were the main constituents of the beach strand mix. And, as a dog and owner grow to look like one another, the town and its people were twins of the same genetic disposition. Weathered lines in the elderly faces mapped the tired cracks in the concrete parking lots. The buildings sagged with age and teetered from sheer exhaustion towards the Atlantic Ocean that rolled ashore in small, weak, lapping wavelets. The ocean itself—to the far north the mighty Atlantic's strong shoulders, arms, torso sinews snapped tight by the chill cracking ice of the Arctic, powered ship-crushing jaws in the form of 100 foot high waves—here, on the long sloping, deep sand strand, seemed... bored. Listless. As if the ocean's knees got weaker the closer it approached the equator. The ocean cared little for the old people. The old people cared little for the tourists. And, no one cared for education.

Almost no one cared. Some cared but felt powerless, because they were. The working class motel maids, desk clerks, putt-putt golf jockeys—those with kids—cared about the education along the strip. The parents didn't want their children following in the family business. They wanted their children to move beyond their status, to get jobs at Kennedy Space Center, only twenty minutes north. Or, better yet, to move away from the Florida beach community altogether. But they didn't know what to do.

Some went to County Council meetings and spoke up with nervous voices or in broken English to say that they needed to pay the teachers more to

attract the smart ones. “The people who really know stuff who can teach my kids right.”

But the council, average age 73, consistently restricted funding. “The current education is just fine. The way we have it is just fine. We have plenty of kids graduating and heading to the best colleges in the country.”

Of course everyone knew they were referring to the one school near the NASA center where all the engineers’ kids attended. That was a given.

The real truth was spoken in hushed voices in closed cocktail gatherings at local hotel bars. These informal get-togethers occurred regularly after the open council meetings. It was where the real education policy was set. Cigarette and cigar smoke drifted over their heads. More smoke poured out of sun-spotted nostrils. “I’ve raised my kids in New Jersey and paid plenty of taxes up there to take care of those schools. Let the native Floridians pay for their own kids’ education. Damned if I’ll pay one more cent.”

But there were no natives left, not natives with money in any case. So, referendum after referendum to raise taxes for increased teacher salaries failed, and education languished.

Hurricane Carlos was three days away when the teachers went on strike. It was bad timing. Kaplan Lay, still too young to know any better, led the strike. A native of Florida, she was a powerhouse of energy with long brown hair that snapped like a whip when she turned her head. She inspired her students and actually had them believing that they could move beyond their world. She even interested - not outright inspired, but interested - the old and bored, those teachers who taught out of habit that kept an eye on the retirement horizon.

All classes stopped. The children roamed free. And, the locals grumbled.

Technically, Hurricane Carlos missed the town, but the winds on the edge of the storm were strong enough to cause moderate damage to the town’s infrastructure. The county had to re-allocate funds since the state government judged the damage to be too minor to warrant disaster status. Young teacher Lay refused to back off the strike. She was labeled anti-American, an instigator.

“She’s not thinking of the town’s common good and she’s not even a good teacher,” the letters to the editor stated bluntly. And those were the nicer letters. After two weeks the threats started coming in. Anonymous letters scrawled on bar room napkins and even one pasted together from cut out magazines of AARP and Good Housekeeping. Kaplan’s cat went missing. Things started turning nasty and the strike got national press.

Like the calm eye of a hurricane moving onto land, Sam Stevens emerged from his rented Chevy Malibu. He wore a smart tan suit with black mirror-polished shoes. He pushed his sunglasses, black and bulging, up onto the bridge of his nose. He exhaled heavily and looked around at the hurricane residue still littering the parking lot of the three-story hotel he would call home for the next six months. “Fitting time to arrive, just after a hurricane,” Stevens thought. As the vice president for market insertion at Education Systems Solutions, he was there to start a revolution in education. And like hurricanes, revolutions meant disruption.

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20 Years Later in Iowa

Vivian whispered quietly, but firmly in Spiral’s ear, “You shouldn’t have made him cry.”

“All I said was that he was being stupid. I mean he asked a dumb question.”

“Spiral, young gentlemen in the fourth grade such as yourself do not call other students stupid. And, you know Alex is sensitive to that type of thing.”

“He’s just a crybaby is all,” Spiral kicked at the dirt in the recess yard. He looked up and saw a group of his classmates looking at him and whispering. They knew his Cog, Vivian, was chastising him through his ear gels - the combination speaker and microphone that molded like soft chewing gum to the inner curve of each ear. It was only through these

small speakers that Spiral's constant school-time companion, Vivian, communicated with him. Actually, the small ear gels were the only physical form that Vivian ever took.

Spiral turned his back to the other children and stared at the fields of corn and soybean fields stretching off into the distance.

"That's enough, Spiral," Vivian said. "Your erratic behavior calls for you to see Last Teacher Lewis."

"Aw, do I have to, Vivian?" Spiral pleaded.

"Yes, I've already notified him you are coming. He's expecting you."

Just then the recess bell rang and the children herded themselves back into the school.

Spiral hated Last Teacher Lewis. The LTL they called him. The LTL insisted on having all his students look him right in the eye when they spoke to him. It made it hard to think of what to say when Spiral had to look him in the eye. Students never looked each other in the eye. They were usually listening to their Cogs anyway.

Spiral sulked down the hall towards the LTL's office at the front of the building.

A girl with blond pigtails sticking straight out from either side of her head ran past him.

"Oh, Spiral has to see the Last Teacher! You're going to get it now!"

"Shut up, braid girl!" Spiral snapped.

"Oh, great comeback, Spiral. I see you've been practicing." With that, the girl gave a skip and a giggle. She quickly adjusted her ear gel that was about to fall out and hopped into the immersive reference library before Spiral could shout something back. But he didn't really have anything to say anyway.

"Pay no attention, Spiral," Vivian whispered. "She's being very immature. I'll have her Cog reprimand her."

Spiral didn't answer. He hated when he got teased because he never could match insults very well. But he was even angrier because he had to miss the weekly Caribbean Encounter. Every week his class got to use the 3-D immersive reference library to link up to a research station in the Caribbean. The divers there took cameras down to coral reefs so that students felt as if they were standing by the coral with holographic fish swimming around the room. All the children would stand there so quiet looking at the display, not wanting to miss anything, that you could hear the Cogs whispering individually about different fish and coral types. One time an eight-foot long Tiger shark swam through the middle of the room. All the girls screamed. Spiral smiled at the memory. The Caribbean Encounter was his favorite weekly event.

Spiral remembered his anger and shouted out, "Now I have to miss it!" He kicked the nearest wall hard.

"Now, now, Spiral. Do we have to talk again about managing our anger?" Vivian said sternly.

"No," he replied sullenly. Ahead was the LTL's office door. He hated this. He hated this. If it weren't for the LTL he would just walk away and go home, or go fishing, or go... just do something other than staying there. And now he had to see the LTL again only because he yelled at another student. He'd try to be more careful next time. At least he'd wait until they left school and the Cogs weren't listening. Spiral looked forward to checking in his ear gels each day before leaving school so he could do what he wanted.

* * * * *

"You can't be serious! Excuse me, Mr. Stevens, but as I recall you're the man who is near to costing me and all the other teachers here in Belmy Beach our jobs. How dare you dance your way down here to Florida with the dog and pony show about replacing teachers with computers. Your so-called Cogs are supposed to rid the world of human teachers and now you're actually offering me a job at ESS? As if the hurricane didn't cause enough problems right when our strike was starting up. We've only been on strike a month and we have to deal with you!"

“Oh, please understand Miss Lay, I am very serious.”

“That’s Miz, thank you.”

“Okay, *Miz* Lay, I am very serious. The Cog technology is moving forward and the has-beens are going to be left behind. These changing times can be harsh, I know. But the real talent will roll with the punches and I think you have real talent.”

“At the last council meeting the term I heard used for the older teachers was ‘drift wood.’ ‘Has-beens’ as you call them sounds much nicer. But it’s all the same: ‘dead wood’ ‘dead beats’ ‘useless’ ‘leftovers from a bygone era.’”

“Those are your words, not mine.”

“I came here to meet with you because I thought you had some compromise in mind that you wanted to discuss. Don’t you think it’s odd of you to offer a job to the person leading the teachers’ strike?”

“Miz Lay, I am the front man for a corporation that has invested eighty million dollars in just two years to develop a technology that will create a revolution in education. We put monitoring systems in over a thousand classrooms across the United States and watched them for over a year. We were able to break down exactly how the best teachers teach kids and turn that into a personalized teaching device for students. That is where the Cogs came from. And, in the process, we created a one-to-one student teacher ratio.”

“Yes, I know. Those are the systems that monitored the teachers’ as well as the students’ vital signs for physical feedback. A total invasion of privacy that was advertised as a research project. We know all about your research that the taxpayers paid for.”

“It was a research project, Miz Lay. And, yes, the Department of Defense originally sponsored the work under a contract to help soldiers in the field. But, it was a very successful research project. What I’m trying to tell you is that there won’t be

any compromise. We have far too much at stake. The country has too much at stake. The strike here in Belmy Beach is nothing, barely a footnote in history compared to what is coming. If it didn’t happen here in Florida, it would happen in Iowa or New Jersey or California. You should count yourself lucky that you have this opportunity I’m offering you.”

“Well, Mr. Stevens, it looks like we’re finished here.”

“You’re young and motivated, which I appreciate. And, despite what the local editorials say, you are one talented woman. I’ve seen you operate in public and you have a very bright future with our company if you want. And at twice the salary you’re currently making, I suggest you think very carefully about my offer.”

“Well, the deal is not done yet, is it Mr. Stevens? We still have the council meeting next week.”

“Kaplan... Fine, Miz Lay. You and I know clearly where the vote of the council will be. I’m not telling you to stop trying to fight us. But, at some time you have to know you’re wasting your time. If you come to work for ESS you can make a real difference.”

“And exactly how would a third-grade teacher make a difference at this multi-mega-million-dollar corporation of yours?”

“There are plenty in the company who want Cog-only instruction, while a few others—a minority for sure—want a combination of human teacher and Cog instruction. You could help make that happen.”

“I’ll have to think about it, Mr. Stevens.”

“I’d expect nothing less. I’ll leave the day after the council meeting. My offer is good until I leave town.”

Last Teacher Lewis squinted at the computer screen on his desk. His wife told him he needed laser eye surgery to sharpen his vision, but to Lewis that meant his vision was fading and faded vision meant he was getting old and getting old was the end of things. Or, just “the end.” It didn’t matter that he was near retiring. He just didn’t want to be old.

He squinted at the name Spiral Western on the screen. The Cog notification system had a countdown for when he was arriving in the office. One minute ten seconds. Nine, eight, seven. The boy would be here for the third time this week. Spiral was a difficult child that the Cog didn't know how to cope with. "Your erratic behavior" is what the Cog would blame the trip to the LTL's office on. "Your erratic behavior" was just a code phrase meaning that the Cog's reasoning algorithm was not refined enough to advise or correct the child any further.

Lewis leaned forward in his chair and folded his hands on this desk waiting for Spiral. The countdown numbers were large enough for him to see clearly from a distance: Fifty-four seconds, fifty-three, fifty-two. Counting down for blast off, or seconds to get out of the way of an approaching car, or ... the number of teachers left in the Last Teacher Program. Forty-eight, forty-seven.

"Yeah, that's about right," Lewis thought. There were forty-seven real flesh and blood people in the Last Teacher Program left in the state of Iowa. And, they were dwindling fast. The Cogs had been perfected to a point where they could replace teachers for most of the children, all but the troubled ones like this Spiral.

"What an odd name," Lewis thought. "What are these parents thinking these days?"

But then the boy came from an odd home and that's where all the trouble was. No matter how good a Cog is at teaching, they had yet to figure out how to turn a Cog into a counselor. And with an alcoholic mother and a father who tried to earn a living from the few casinos scattered around the state, there was no way a Cog listening in for a few hours a day was going to correct the behavior problems.

Twenty-eight, twenty-seven, twenty-six.

The Vivian Cog that Spiral used was good, Lewis admitted to himself. But, it was not that good. They had tried Cog-only

education when the Cogs first came out all those years ago after that stike in Florida. Rumor in the shrinking last teacher circle was that students from an early all-Cog experiment in California were still in recovery.

But then the company, his employer, ESS, had changed their game plan. They kept minimal human-in-the-loop teaching alive while they perfected the Cog programs to account for children's personalities. The Last Teacher Program was all that was left. They were trying to glean the last bit of humanity from the few surviving teachers. Even now Lewis was being monitored while he waited for Spiral. And, when he talked to Spiral, his discussion would be recorded and broken down into logical parts for the future Cog personality updates to absorb.

Seventeen, sixteen, fifteen.

If only the teaching union had embraced the technology at that dispute in Florida. They could have made sure that the Cogs became a teacher aid, and not a teacher replacement. Lewis knew the story well. It had been written up a thousand times with two significant variations in all the history books. The ESS textbook version that the Cogs used told the students how a revolution in education had been created by an innovative company. The Last Teacher version, that the students never heard, was that teachers had been removed and replaced by machines. It was the first time that machines began to teach humans. Or, put another way, humans started learning from machines.

The one thing both versions of history agreed on was that the teachers refused to accept the new technology. They saw Cogs as a threat, not a potential aid to help their students. Things might have turned out differently. But it was far too late. Once the basic concept of Cog education was proven, the profit motive took deep root. Spending money on education was not in the public's interest when a low priced Cog could do the trick.

Eleven, ten, nine.

If only they had agreed to a middle ground. It was lonely being the only adult in a school full of children. If only. If only.

Three, two, one.

“Hello, Spiral. So, Vivian sent you in again. Now look me in the eye and tell me what happened.”

* * * * *

Sam Stevens gunned his rental car out of the fast food parking lot and pulled onto A1A. With a vanilla milkshake in hand and fries within easy reach headed north along the Florida coast. He would catch the toll road East and be in Orlando and on the airplane home by five o’clock.

Sam was happy. Genuinely happy. More blissful, exultant, ecstatic and even joyful than he remembered ever being. The county council had voted in favor of the motion to install Cogs as the main instructors for all students in first through eighth grades. It was a coup of the highest order. Sam sported an ear-to-ear grin, but the milkshake straw sticking out of his mouth made his smile crooked. Not only did they approve the motion, but they would also phase out all teachers over the next three years to transition to all-Cog instruction. ESS would finally have a real chance to prove the future of Cogs.

Sam took a left at the light heading away from Belmy Beach and towards Orlando. He watched his rearview mirror while his last view of the Atlantic was obscured by a faded hotel on the main strand.

“I’m about to become a millionaire,” he said out loud. “I, Sam Stevens, am about to become a millionaire.” He started laughing and honking the car horn at no one in particular.

The Belmy Beach School District was small. There were only three thousand students total in grades first through eighth. In this area, the profit would be modest. This meant three thousand Cogs at a thousand dollars per Cog per year. Total: three million dollars per year. On the national level, the numbers were huge and easy to calculate. Over fifty-three million students in the United States meant a potential market of

fifty-three billion annually. But the best part, ESS was the only company developing this technology and they were so far ahead it would take would-be competitors years to catch up.

No, Sam corrected himself. That’s not the best part.

Out of character for him, he yelled out the window to the cars speeding by in the opposite direction, “The best part is that Sam Steven’s—yours truly—owns a half percent of the company!”

He took another long draw on his milkshake and relished the fact that the revolution was happening and he had helped make it happen. It was too bad about that Kaplan Lay woman turning down his offer. But revolutions always have winners and losers. She had chosen her side.

* * * * *

Spiral noticed that his hands hurt. When he wondered why, he realized he was clenching them tightly into small fists. When he wondered why he was doing that, he realized that he was walking down the hall that passed Last Teacher Lewis’ office. He hated walking that way. He could feel the LTL’s eyes drilling into his back like some slimy worm crawling through the ground. He moved to the side of the hall opposite the LTL’s office.

“Don’t look in,” he muttered to himself. “Don’t look in.” Despite his best effort at self-control, he glanced inside the doorway as he passed. Spiral stopped suddenly and backed up taking a better look. The office was empty except for the LTL’s wooden desk. But otherwise the room was bare.

“Where’s the LTL?”

“Oh, didn’t you hear, Spiral?” his Cog Vivian answered, “The Last Teacher program was cancelled last week. Last Teacher Lewis was allowed to finally retire. After all those years of service he was rewarded with an early retirement.”

Spiral walked into the Last Teacher’s office.

“Spiral, even though the Last Teacher has left, you are not allowed to be in his office,” Vivian said firmly.

He ignored her and walked up to the desk. There was a balled up piece of paper on the floor next to it.

“Spiral, you are not allowed to be here. You must exit the room now or I’ll assign you a demerit.” Again, Spiral ignored the Cog.

He bent down and picked up the paper. Unfolding it, he saw that the paper was Education Systems Solutions company stationary. Next to the open book logo was the company slogan, “ESS is the Education Revolution.” The letter was addressed to “*Last Teacher Harold Lewis.*”

“Spiral,” the Cog demanded. “You have ignored me for too long. You have now received five demerits. Put the paper back where you found it and leave the Last Teacher’s office immediately.

“Or you’ll do what, Vivian?” Spiral replied calmly.

“I will issue you more demerits,” the Cog replied firmly. Spiral started reading the letter.

“Dear Last Teacher Lewis, Thank you for your years of dedicated service to ESS. As you know, the Last Teacher program was created to capture those elements intrinsic to human nature that were previously missing in the individual teacher Cogs.”

“Spiral, did you understand what I said, young man? If you do not respond, you will receive more demerits.”

“The Cog programs have been updated with the latest behavioral pattern modifications and we calculate that they can account for 98.76% of all behavioral cases encountered in the school system. As a result, the Last Teacher Program is being discontinued. Enclosed are details of your retirement package. If you have any questions, the toll-free number below will link you to our automated database of Frequently Asked Questions. Thank you again for contributing to the perfection of ESS’s Cog programs.”

“Spiral, you now have five more demerits for your behavior. If you persist, I will be forced to call your parents. And, I know you don’t want that.”

Spiral set the paper gently on the desktop. He looked up as if Vivian, his personal Cog were standing right in front of him.

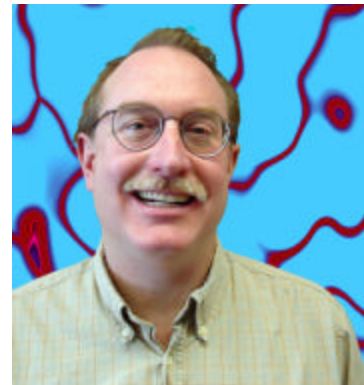
“Oh, is that all you’ll do, Vivian, call my parents?”

“That is indeed what I’ll do young man.”

Spiral smiled broadly and took off his Cog ear gels. He placed them next to the letter and walked out of the office and down the hall towards the exit.

He could hear Vivian calling loudly from the headset, “Spiral, your erratic behavior calls for…”

Spiral pushed open the heavy metal door and felt the warm Iowa sun streaming on his face. He walked down the sidewalk and smiled at the thick sounding clunk the door made, as it slammed shut behind him.



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