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ABSTRACT

This publication focuses on promising new and emerging technologies and what they might mean to the future of K-12 schools. Half of the volume contains articles devoted in some way to "Vision," and articles in the other half are under the heading of "Leadership." Contents in the "Vision" section include: "Customizable Content" (Walter Koetke); "Extending the Prospects of Evidence-Based Education" (John Willinsky); "Pervasive Computing: Enhancing Learning in the Classroom and Beyond" (Bill Mark); "The Next Generation Internet and the Schools" (Louis Fox and Ron Johnson); and "The Tyranny of the Quantifiable" (Jaron Lanier). This section also includes an interview with Jeanne Moreno, Vice President and Chief Information Officer of Citrix Systems, Inc. Articles in the "Leadership" section include: "Paper and Pixels...In Search of the Ultimate Textbook" (Tammy McGraw and John Ross); "Ask Smartypants! An Evidence-Based Education Project" (Krista Burdette; Tammy McGraw; and Christopher Corallo); "Combining Telephony and Interactive Television To Facilitate Effective Communication between Schools and Families" (Tammy McGraw; John Ross; Steven Greenspan; David Weimer; Andrea Basso; and Soleill Gregg); "Internet2: Putting New Technologies To Work in the Schools" (Louis Fox, Comp.); "Extending the Use of Collaborative Virtual Environments for Instruction to K-12 Schools" (Tom Morgan; Ron Kritz; Steve Howard; Fernando das Neves; and John Kelso). This section also includes an interview with Mary Baker, Manager of Emerging Technology, Broward County Public Schools, Florida, and Nancy Barba, Director, Program Development and Alignment, Broward County Public Schools, Florida. (AEF)

IN▶▶SIGHT

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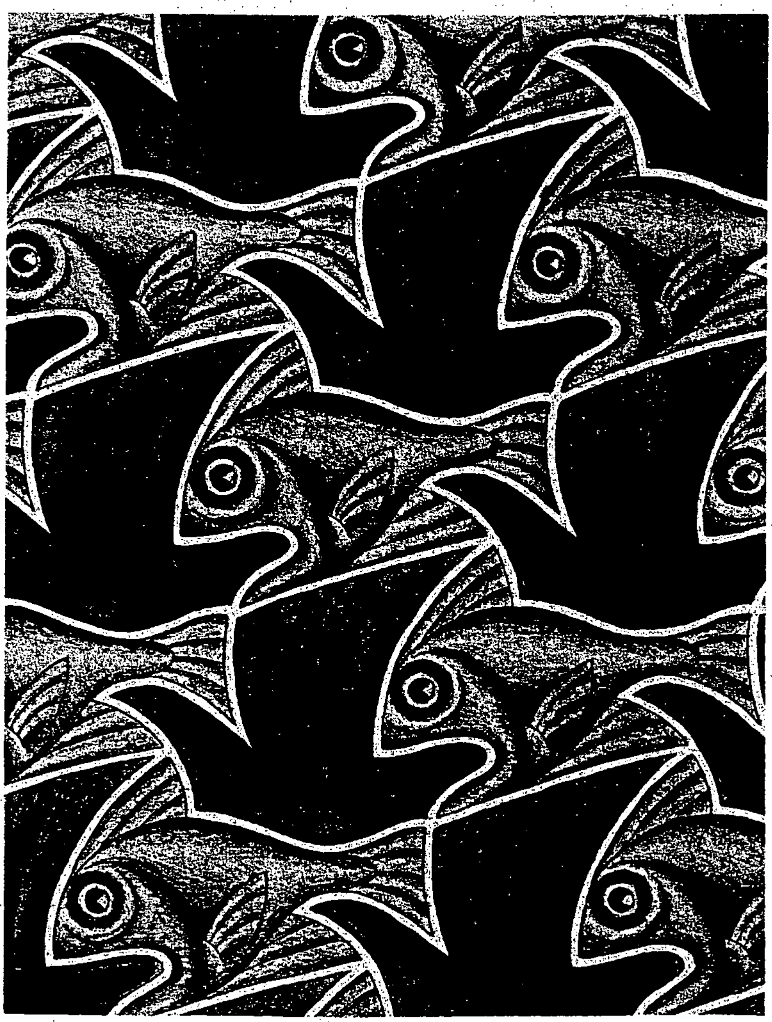

VISION

INAUGURAL ISSUE 2001

V I S I O N

CONTENTS

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V I S I O N

IAETE

OUR MISSION: TO SUPPORT THE PURPOSEFUL USE OF NEW AND EMERGING TECHNOLOGIES TO IMPROVE TEACHING, LEARNING, AND SCHOOL MANAGEMENT

IN ▸▸ SIGHT

I am pleased to share with you the inaugural issue of IN ▸▸ SIGHT, an annual publication focusing on promising new and emerging technologies and what they might mean to the future of K-12 schools. My team and I spent a great deal of time thinking about an appropriate title for a publication that would provide a forum for ideas about how technology might, in the not-too-distant future, impact our classrooms while providing a glimpse of what is currently possible. IN ▸▸ SIGHT, then, is intended to be both the presentation of thought-provoking articles by individuals who discern the true nature of some key technologies and the presentation of related work currently under way in schools and classrooms, work that demonstrates that these ideas are *in sight* of mainstream education.

We at AEL are proud to hold a national leadership designation in educational technology for the U.S. Department of Education's regional educational laboratories. IN ▸▸ SIGHT is an important vehicle for our leadership efforts, and we are committed to helping educators understand and plan for the purposeful use of new and emerging technologies in schools.

We believe that vision and leadership are inextricably linked, and we hope our publication conveys this belief. Perhaps no one understands this concept better than M.C. Escher, and we are grateful to Cordon Art B.V. – Baarn – Holland for permission to use Escher's *Fish and Boats* to express this idea so beautifully.

Tammy McGraw

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Pictured from bottom to top: Tammy McGraw, Editor in Chief; Krista Burdette, Managing Editor; Carla McClure, Senior Writer; Virginia Seale, Copy Editor; Sara Marchio, Copy Editor; and John Ross, Web Producer. Not pictured: Mardell Raney, Executive Editor, and Richard Hypes, Art Director.

VISION

"The future belongs to those who see possibilities before they seem obvious."

—John Scully

V I S I O N

CUSTOMIZABLE CONTENT

Walter Koetke, M.A.

Walter Koetke gives hope to educators who wonder how it is possible to provide individual instruction for all children. One key element necessary to meet the individual needs of children is the ability to customize content for a wide variety of users. Over the last several months, we have been exploring the idea of electronic textbooks. We invite you to look at the Leadership section to see how we have applied imperceptible digital watermarking technologies to a promising model for an interactive textbook.

I VISION

CUSTOMIZABLE CONTENT

Walter Koetke, M.A.

Math teachers excited about the presentation crowded the classroom. All were attending on their own time after a full day of teaching. The presenter began by showing how he used a Teletype time-sharing terminal as a particularly effective way to teach graphing to beginning algebra students. The Teletype could print only text characters, and it did so very slowly. The special overhead projector (which displayed the output on a screen as it was printed) created so much heat that teachers sitting near the projector were uncomfortable. But the teachers' enthusiasm grew. They understood what they saw, and they immediately started suggesting additional topics that might be better taught with this technology. They had no doubt that doing so would increase students' understanding of graphs and their applications.

The time of this presentation was the late 1960s. History shows that the exemplary teaching demonstrated that evening was never implemented in many classrooms. The cost of a time-sharing terminal was high. A single terminal in a class of 35 students limited use to demonstrations; students could not really use it on their own unless they spent time before or after school. Teachers had to create their own materials on their own time because none had been published. The slow speed of the Teletype required several minutes to print each graph. One could add several additional good reasons why this technology was never widely used in schools.

Ten years later, the same demonstration was given using a personal computer rather than a time-sharing system. Speed had improved and the cost

The point of this bit of history is not that schools resist change, but that the development of effective new technology is not enough to guarantee change. That technology must also be affordable, widely available, supported by teaching materials, and accompanied by appropriate teacher training.

had dropped. Monitors had replaced the Teletype, but they were still text-based. Most of the other reasons that math educators had not adopted a better way of teaching graphing continued to be valid.

In the late 1980s, after another 10 years had passed, the demonstration was given again. User interfaces on personal computers were graphic rather than text-based, processing speed was much faster, and costs were lower. Mathematical programs like *Derive* and *Mathematica* made it easy to create very effective teaching tools. In fact, such programs caused mathematicians to reexamine the priorities of what was important for students to learn in mathematics and when. Once again, however, math teachers did not rush to adopt what appeared to be so useful. Why? Cost remained an issue. A tool available only in school and not at home did not give students sufficient opportunity to explore and practice. Classroom sets of personal computers were rare, and teaching students in small groups did not fit the model of the mathematics classroom in a traditional school. Teachers were given no training or support if they wanted to be innovative. And the list goes on.

Finally, in the 1990s, more than 20 years after desirable change became possible, the relatively inexpensive graphing calculator became available. Student materials were written. Teachers attended in-service classes or learned on their own time. The calculator was portable; it could be used in school and at home. The innovation of the Teletype workshop presented in the 1960s could finally be replicated in public school classrooms. Today, students who study algebra without using a graphing calculator are at a significant disadvantage when compared to those who do.

The point of this bit of history is not that schools resist change but that the development of effective new technology is not enough to guarantee change. That technology must also be affordable, widely available, supported by teaching materials, and accompanied by appropriate teacher training. Perhaps most important, technology must have a major demonstrable impact on the education of the majority of students.

When people discuss educational change, there are two problems that just won't go away. First, the political and sometimes personal viewpoint that approaches education on a "We're right and you're wrong" basis. Two examples are the ongoing debate in early childhood education over the value of an academic curriculum versus a developmentally appropriate curriculum and the constant bickering between advocates of phonics and advocates of whole language about the most effective way to teach reading. Second, when one is teaching children, one size doesn't fit all and never will.

The need to nurture and teach our children is one such fundamental need. Many people believe technology can help in this endeavor, yet very few are working to create new technology that will nurture and teach. Instead, educators are expected to adopt and adapt technologies created for other purposes.

When looking ahead at technology's ability to customize content, one should not assume that what is possible and desirable will necessarily happen. World peace is possible, desirable, and certainly beneficial to the majority of people, but we are not likely to experience it in our lifetimes for even a single day. The capabilities of technology are growing exponentially, and there are good reasons to believe that growth will continue. However, history does not suggest that people and societies change exponentially—a handful of individuals, maybe, but only a very small fraction of the population. Our fundamental needs as humans remain as they have been for many hundreds of years. Technology will be widely and wisely used when it helps to meet one or more of those needs. The need to nurture and teach our children is one such fundamental need. Many people believe technology can help in this endeavor, yet very few are working to create new technologies that will nurture and teach. Instead, educators are expected to adopt and adapt technologies created for other purposes. Certainly parents have a sincere desire to nurture and teach their own children; but in our culture, that desire rarely broadens to include the children of others. I suggest that the technologies we will adopt most readily are those we see as important to us—at home, at school, or wherever the use of those technologies is appropriate.

The difference between education research and scientific research is worth noting when we discuss educational change. A basic principle of scientific research is control of all variables in an experiment. Replicability and consistency are critical. When a researcher goes home from work, he must be able to return in the morning knowing that none of the variables in his

experiment has changed. He can resume work precisely where he stopped the previous evening. How does this compare with education research? I suggest that we do not even know what all the significant variables are when two people interact. As for replicability and consistency, suppose a teacher and student had an effective, positive interchange during the last five minutes of the school day. Will the morning begin exactly as the day ended? The teacher may come to school with a headache. The student may have spilled his cereal and been admonished by his mother just before coming to school. There is no way consistency can be maintained.

Before looking ahead, look at what already can be done with existing technology. To what extent is customized content a real possibility when school starts next year?

Because education research is different from scientific research, it is open to much broader interpretation. If there are two conflicting ideologies in education, both are supported by a great deal of research. Pick a point of view, and you will be able to find research to support it. Because education research is so open to interpretation, the results of a specific research project often reflect the beliefs of those funding the project. Even when those results are reliable and valid, they are naturally the subjects of considerable skepticism.

An additional obstacle to education research is that, unlike research in science or medicine, failure is rarely tolerated. Failed scientific research is an expensive learning experience. Failed medical research is also an expensive learning experience, and it could even lead to the deaths of laboratory animals. Failed education research is less expensive, but it might mean that a class of students did not learn the subject. What then?

Before looking ahead, look at what already can be done with existing technology. To what extent is customized content a real possibility when school starts next year?

Suppose you are about to register your daughter in fourth grade at a new school. You have looked at the school's curriculum, and you are pleased that the objectives for each subject in each grade are expressed in terms you can understand. They tell you exactly what your daughter will be taught. There are some objectives in the history course that look like they are beyond her reach, but those in music look like things she learned at least two years ago as part of her dance lessons. The school registration process consists of a few forms for you to complete and an online, adaptive placement test for your daughter. The placement test determines exactly which objectives she already has mastered in each subject. The results are available as soon as she finishes the test. In this way, the school will be able to provide her with a truly individualized curriculum. She will start exactly where she belongs in each subject. Your concern about the history course was valid—the placement test shows she should begin history about 10 weeks into the third-grade history curriculum. Her knowledge of music is also as you thought. She will begin her music lessons at roughly the middle of the sixth-grade music curriculum. Her reading is excellent; that too will begin at the sixth-grade level. In fact, mathematics is the only subject that she will actually start at the beginning of fourth grade.

Impressed with the notion that she will have an individualized curriculum, you ask to see her classroom. What you find is not at all unusual. There is a whiteboard, several shelves of books, a closet full of art supplies, and brightly colored decorations to celebrate the opening of school. There are four personal computers notable only because they are in different parts of the room rather than lined up on a table. One section of the room has a traditional arrangement of student desks and another has tables and chairs for group work.

Upon meeting the teacher, you ask how she can really provide individualized instruction to 24 students. Just the daily record keeping of where each child is in each of six subjects seems overwhelming—and that does not count providing instruction. Six subjects for each of 24 students sounds as if it requires 144 lessons plans each day. In fact, it does! The teacher then explains that she does have some nonprofessional teaching help, as well as a great deal of support from the computer.

In addition to the teacher, there are three nonprofessional adults (usually volunteer parents) who help with the children. Although there is only one teacher in each of the school's classrooms, the principal has committed to a ratio of one adult for every six children in each classroom: thus the three helping adults for this fourth-grade class. The computer provides lesson plans and record-keeping assistance. There really are 144 unique lesson plans needed each day; a computer provides the plans, but the teacher and adult helpers provide most of the instruction. That instruction includes all of the traditional methods of teaching and learning, as well as occasional computer use by the students.

When school starts and you see the class in action, you really appreciate the benefits of truly individualized instruction. Your daughter likes to do mathematics first. It is her least favorite subject and she wants to get it over with. The lesson plan from the computer asks her to arrange some manipulatives to represent repeated addition and then to do a paper-based problem set with repeated addition problems. She is about to be introduced to multiplication, but that is still a lesson or two away. Today's lesson seems easy, but when she takes her problem set to the teacher, they spend a few minutes discussing the two problems for which she has the wrong answers. The teacher uses the computer to print a second set of problems and asks your daughter to complete it before going on. This time, all the answers are correct. Your daughter then takes a short online test to confirm that she has achieved the objectives of the lesson.

The online test is a critical part of the individualization of your daughter's instruction. The test not only evaluates her work on today's lesson, it also tests some of the most important objectives from earlier lessons. All results are accumulated in the computer. There are always several alternatives for the next lesson. If she does very well on the test, then her next math lesson is the next lesson in the curriculum sequence. If the test shows she has not yet mastered today's objectives, then the next lesson will be an alternate lesson on the same objectives. The system has several alternates for each objective or set of objectives so students do not have to repeat a lesson to revisit material. A third option is that the student shows mastery of today's objectives, but the accumulating review of earlier objectives shows that your daughter's skill at adding sets of three-digit numbers is not up to par. In this case, her next math lesson will be an alternative lesson that reinforces this earlier objective. The system will not let her move forward when there appears to be a gap in prior

What else can be done with technology that is already available? A great deal! I suggest that technology development could stop today, and we would continue to see innovative uses of what we already have for the next 30 years.

knowledge that should be filled. Cumulative tests are given when appropriate, and the results are used to further individualize future lessons.

Each lesson contains one or more suggestions for extending the lesson. These suggestions are primarily for students who find the subject or specific lesson especially interesting. Lessons might be extended by challenging problems in mathematics, a second experiment in science, a book to read that is related to the history lesson, and so forth.

By tracking your daughter's success with each lesson, the computer is able to determine which learning style seems most effective for her. For example, if the math lessons with mostly visual presentations are almost always successful, while the math lessons with mostly text presentations are much less successful, then the system will adjust so that she is usually given a lesson based on visual presentations first. In addition to a custom curriculum that provides exactly what she needs, the system presents that material in the way she is most likely to learn it.

With the exception of the automatic learning style selection, the system described is available already and is an excellent example of technology used to support education. The technology does not take sides; it does not require that a particular curriculum be taught, and it does not require that a student spend a great deal of time at a keyboard. For those educators who believe that calculators are detrimental and should be reserved for high school students, this system will work. For those who want first graders to have access to calculators, this system will work. For those school districts with administrators who feel their curriculum is best for their children, the system will work with their curriculum. The system does require well-defined objectives, lesson plans to support those objectives, a testing algorithm that verifies the student learning, and a lesson-sequencing algorithm that assures mastery of all objectives. None of the requirements presupposes a particular theory of learning. Traditionalists, constructivists, and all others can be accommodated. The system will help manage a student's education, and a teacher remains responsible for delivering that education.

Given the almost certain success of such a system, why is it not already in widespread use? The system described conflicts with several deep-rooted administrative practices in our public schools. In this system, the ratio of students to adults is smaller. Even though the additional adults need not be certified teachers and may even be volunteers, the need for them raises the cost of personnel or personnel management. When students are free to work at their own pace, the notion of grade level rapidly disappears. In fact, the notion of completing six grades in six years rapidly disappears. A significant number of students might need longer, and a significant number may proceed more quickly. Those who proceed rapidly will require additional skills on the part of their teachers. A typical sixth-grade teacher may not adequately serve a "sixth-grade" student doing mathematics at the ninth- or tenth-grade level, and such disparities may be more the rule than the exception. True individualization is possible, but using it will place new demands on our public schools. The public needs to balance a desire for better education with the cost and risk of changing traditional ways of managing and funding schools.

What else can be done with technology that is already available? A great deal! I suggest that technology development could stop today, and we would continue to see innovative uses of what we already have for the next 30 years. For example, students can use an inexpensive digital camera in all subjects at almost any grade. Their photos can document their work done in or out of school; be shared with other students, parents, and relatives as attachments to e-mail; illustrate a story they write; add interest to an oral presentation; report on a scavenger hunt in which they found items related to a specific lesson such as geometric shapes, land formations, or historical buildings; and so forth. The digital camera can help students learn sequencing, maintain their portfolios, and learn about visual composition. Students can create large projects, such as a 360-degree panoramic view or a wall mural of pictures related to the history they are studying. The cost and time delay for film processing prohibited many of these possibilities a few years ago, but now the one-time cost of an inexpensive camera is the largest expense.

The speed of Internet access continues to increase. Many homes and most schools are now served by digital cable, DSL lines, or T1 lines—the slowest of which is 50 times faster than a 56K modem. What can we do with a faster Internet besides doing things we already do, but faster?

Thanks to faster access, the ability to transmit motion video and sound over the Internet is improving rapidly. The speed is already acceptable for many applications if one is using a connection at least as fast as a cable modem. According to recent statistics, that includes most schools. Suppose we put an inexpensive Web cam in a classroom. Students would love it. They could see themselves on the Internet. So could their parents. Do you wonder what your child is doing in class? Turn on your computer and take a look—from the office, from home, or wherever—and you can see her in real time. If a student continually misbehaves, a teacher need only call home and ask Mom to watch the class for a while.

The Web cam also could serve other functions. It is far from ideal, but a student who was home sick for a few days could keep up with some aspects by watching that class via the Internet. Parents unable to attend "back-to-school" night could see and hear the presentations, and an out-of-town working parent or grandparents who live far away could attend an elementary school play. Many things are already possible, and the list will get much longer as multimedia technology and the speed of the Internet continue to improve.

Cell phones have enjoyed more sales than any other form of recent technology. Analysts attribute this to their ability to work anytime, almost anywhere, for anyone. They work for a salesman driving through Montana who must contact the home office in New York, and they work for the junior high girl at the mall who must call home to see if she can stay out 30 minutes later than promised. Once cell phone technology worked well and the price reached a point the public could afford, use exploded. The current state of computer communications resembles the state of the telephone just prior to cell phones. Remote communication with a laptop computer is possible, but a laptop is bulky, fragile, and often inconvenient. The salesman would have to stop to find a phone to connect his laptop, and the junior high girl is not likely to have carried her laptop to the mall. Current laptop technology does not quite fit the way people live. Simplifying computer connectivity to the level of using a cell phone is predictable technology.

There are many stories in the press regarding the "war" between wireless communication technology and broadband communication technology. Which technology will dominate? For the next several years, a combination of the two seems most probable. This prediction seems safe; Bill Gates, former CEO of Microsoft and now its Chief Software Architect, and Lou Gerstner, Chairman and CEO of IBM, have made the same prediction. Because large corporations heavily invested in one or the other do not change easily, both forms of communication will continue for awhile. However, I suggest that within 10 or more years, wireless technology will dominate. That prediction is not based on a deep technical analysis of which is most cost effective. Rather, it is based on the fact that people find wireless more convenient, and people's acceptance is what eventually makes an application of technology successful or just another neat idea. Remember videodiscs? Neat idea. Cell phones are wireless, and that is what makes them so convenient. People can use them when there are no wired phones. Similarly, wireless computing technology can be used where there are no wires: in underdeveloped countries, in old school buildings, and in your daughter's room.

There are already impressive applications of both communication technologies. Timex recently introduced a watch that receives e-mail messages from the Internet. The messages are limited to 100 characters on a 12-character, single-line, scrolling display, but that is enough for paging, phone numbers, stock quotes, and a host of other short messages. AT&T Laboratories in Cambridge, England, offers a free download that places the display screen of your Internet-enabled PC into the browser window of any other Internet-enabled PC. The software allows you to actually operate the PC that is on your desk at home or in the office from wherever there is an Internet connection. No more synchronizing between a portable computer and a desktop computer:

An e-book with significant memory could, in fact, contain several books—all of a student's textbooks along with a few books checked out from the library. Goodbye, heavy backpacks.

just operate the desktop from the portable. If this technology catches on, the capability—and hence the price—of a portable PC might drop considerably.

Which technology is likely to have the greatest impact on education over the next five years? I believe the answer is PDAs—personal digital assistants. These are typified today by graphing calculators such as the TI-83, by organizers such as the Palm Pilot IIIc, and by handheld computers such as Compaq's iPAQ. The capabilities of all three types of devices are beginning to converge. They can all access data remotely and connect to the Internet for large updates. They can connect to remote sensors to collect data directly from the physical world as well as from their keyboards. They can all download programs from the Internet and they are, or soon will be, able to communicate wirelessly. Relative to current computer technology, they are all notably inexpensive. And, most important, educational programs are being written for all of them.

I believe PDAs are the step that will really make computing technology accessible to all students, just as the graphing calculator in the earlier example allowed all students access to a better way of learning mathematics. In addition to an affordable price, PDAs restore the "personal" aspect of personal computers. When the term "personal computer" was introduced, it was because a user had a computer that was connected only to the wall—it was all his or hers. The PC was intended to replace a time-sharing terminal that required you to share a computer with several others. Today the name remains, but we have lost the "personal." Today's PC connected to the Internet is very similar to a terminal connected to a time-sharing system. It is far from personal. I suspect that if most home users really understood how much information was going from their computer to the computers of businesses on the Internet, they would unplug their Internet connection and never use it again. With PDAs, you are back to having a personal device: one that fits in your pocket or purse and one that connects to other devices only when and for as long as you choose to have it do so.

A little further out in time, the technology of electronic paper will begin to have a major impact. There has been talk of e-books for many years. They are available today but a market for them has not developed. In spite of some conveniences provided by the e-book, people do not want to read a book on a screen. There is something satisfying about holding a book in your hand, about turning a page when you have finished, about the way a page feels and looks and smells. All of this is lost when you use today's e-books. But electronic paper is a different story. Electronic paper is a display device much like a computer monitor or PDA screen. Electronic paper displays whatever the computer transmits to it. But electronic paper looks and feels like paper. It can be made into a book, with pages that look, feel, and turn like book pages. Electronic paper already exists in the lab, and efforts to commercialize it have just begun. The monitors that many thought would replace paper may themselves be replaced by a new kind of paper, and the long-anticipated e-book might become a reality.

Perhaps we should think of the e-book not as an ordinary book, but as a stack of ordinary books. An e-book contains a computer chip, a large memory, an index display on its spine, and many pages of electronic paper. An e-book with significant memory could, in fact, contain several books—all of a student's textbooks along with a few books checked out from the library. Goodbye, heavy backpacks. What do you see when you turn to the first page? Whatever book you choose from selections listed on the spine. When you finish with the selection, just choose another and the contents of the electronic pages all change. When the loan period for the books you checked out at the library expires, the book simply deletes the choices from the spine. There's nothing to return.

School libraries and other libraries that provide electronic books can be much smaller than today's conventional libraries. Libraries could, in fact, be available over the Internet. Copyrights can be enforced at least as well as they are today. If a library owns rights to two electronic copies of a book, then more than two users cannot simultaneously check out that book. Since the book is automatically deleted from the user's e-book on the expiration date, there is no need for library fines. The next user can then have immediate access to the book or may even have downloaded it earlier, knowing that it would not be

As long as you had to stop at the market, you could ask the refrigerator what other regularly used items are needed. The refrigerator can detect the transmitters noted earlier; every item you put in the refrigerator has one.

viewable until a certain date. Readers who like to browse through library stacks would be disappointed. There would no longer be any of those familiar stacks. Readers who most often just want to find a specific book and check out a copy would be delighted with the convenience of e-books using electronic paper.

Further out on the timeline are transmitters the size of a grain of rice that can be read by an appropriate computer "in the area." The familiar bar codes used in supermarkets and department stores are the forerunners of this new technology. Current bar codes identify a type of product—a Lexmark Model 7000 printer, a jar of Del Monte applesauce, and so forth. Transmitters uniquely identify each individual item—a Lexmark Model 7000 printer, serial #123456-789; a 12 oz. jar of Del Monte applesauce packed 4/5/2015 in carton #A12345. When a transmitter is near a computer equipped to detect it, the item containing the transmitter can be identified. The more you think about these transmitters, the more useful they might become. With a transmitter on every piece of electronic equipment, theft would be very difficult because each piece of stolen equipment would keep reporting where it was. If students had a transmitter built into their school ID cards, they could check out books in the library, get on a school bus, have their attendance reported for each class, and so forth, all by just being there. When they chose to skip school, their ID cards would report where they were. When a student walked up to a school computer, it would know who the student was and immediately load all that student's work from the network. No more login, logout, and set-up time. The more you think about these transmitters, the more you also begin to wonder about protecting your privacy as well. If my new belt and shoes can both be uniquely identified, then it would be very easy to track my whereabouts at all times.

What new technology will be available in two or three decades? I believe we will be in a world in which computers are no longer seen. They will still be with us, but they will be very small and pervasive. Most electronic devices—your furnace, refrigerator, coffeepot, car, cell phone—will be wirelessly connected to the Internet, or whatever the network is called by then. You might check your PDA before you leave work. If you indicate that bacon, eggs, and toast is all you want for dinner, the refrigerator and breadbox will check that they contain the needed ingredients. Your PDA will list the needed ingredients, flashing "jelly" in red to indicate you are out of jelly. As long as you had to stop at the market, you could ask the refrigerator what other regularly used items are needed. The refrigerator can detect the transmitters noted earlier; every item you put in the refrigerator has one. When you are on a trip, you can verify that the coffeepot is turned off and adjust your thermostat. You are not worried about robbery or fire because the entire house is connected to alert police and fire departments. Anything out of the ordinary will bring help immediately.

What will this mean to K-12 education? Schools will be decidedly safer, and far less student and teacher time will be consumed by administrative tasks that do not contribute to learning. An individually customized, closely monitored, and frequently evaluated education should finally be available for all students.

As technology offers educators new abilities to help deal with old problems, I suggest that some things will remain the same. The public school model may or may not change, but the need for a caring adult as an active participant in the education of a child will not change. Kids have many needs beyond the academic, and to be successful, an academic program must deal with many of those needs. Students learn from the behavior and values modeled by caring adults, and that learning cannot be separated from them. Technology will provide some extraordinary new tools to support education, but the need for a caring adult to work with each child will remain as the most important element.

There is one lesson from my early years of teaching that I have never forgotten. I had an eighth-grade class to whom I was teaching algebra. The topic for the next class was to be the derivation of the quadratic formula. I prepared very carefully. I developed what I considered the best possible presentation. When I gave the presentation, I really felt that all the students were paying attention and understanding. As I finished, a girl with long flowing hair who rarely contributed in class was frantically waving one hand for attention while holding her hair with the other. I was delighted. I thought even she had become involved in the presentation. When I called on her, she frantically asked, "What should I do? What should I do?" I asked, "About what?" She responded with sincere concern, "All my ends are split!" Although the question was unrelated to the content of the lesson, it reminds us that students bring many concerns to class. Teachers must attend to the needs and concerns of their students to ensure that learning can occur. Caring adults, not technology, are the keys to successful education. It would take a powerful technology indeed to deal with split ends and the quadratic formula in a single lesson—but people can do it, and they do so on a regular basis. That is what customized content is all about.

VISION

2

EXTENDING THE PROSPECTS OF EVIDENCE-BASED EDUCATION

John Willinsky, Ph.D.

John Willinsky makes a compelling case for evidence-based education, a framework to help schools benefit from education research. We have been exploring how this framework, on a much smaller scale, might help educators identify, evaluate, interpret, and apply the most relevant research related to new and emerging technologies. Presented in the Leadership section is an overview of Ask Smartypants!, *a Web-based tool devoted to our exploration of the evidence-based education model.*

2 VISION

EXTENDING THE PROSPECTS OF EVIDENCE-BASED EDUCATION

John Willinsky, Ph.D.

The reasoning is straightforward. What's good for medicine should be good for education. And what is good for medicine right now is the way physicians are drawing on evidence-based medicine (EBM) in choosing the most effective treatments for their patients. Checking with the best available evidence before making a critical decision is hardly a new idea in itself. What has changed in medicine over the last three decades is the concerted effort to make medical research that speaks directly to what works best in clinical practice readily accessible and comprehensible for physicians. The potential parallel with education almost leaps out. Why shouldn't teachers be similarly assisted with the relevant research for the educational choices they face in their efforts to improve the schools?

Evidence-based education would mean, for example, teachers selecting reading programs for the schools that lead to significantly higher test scores than other programs, based on a comparison of randomly assigned students to each program and to a control group. Evidence-based education would mean teachers opting for methods of teaching mathematics that consistently proved more effective than other techniques with the target population. It would not guarantee that test scores for students go up but would ensure that teachers were more likely to use widely proven effective educational methods. This should inspire, in turn, greater public confidence in the schools. It should also foster a new appreciation for educational research, which has for too long been a source of disappointment, if not mockery, within education reform circles: "What do you think are the two major findings on bilingual education?" ("Previous studies are flawed and more research is needed!")

The public's and profession's skeptical regard for educational research reflects a sense of intellectual waste and missed opportunity, especially when one considers the sheer amount of research produced, most of it at public expense. The federal government's Educational Research Information Center (ERIC), for example, now offers abstracts on more than a million education-related documents and journal articles.[1] There must be a better way to organize the research process so that it offers greater assistance to the principal reorganizing a school, the teacher starting a new school year, and the child struggling with third-grade science concepts.

When it comes to narrowing the gap between research and practice, evidence-based medicine is as good a candidate as we have. It is hardly surprising that an evidence-based approach to education has recently earned the endorsement of the National Research Council (NRC) in the United States and the Teacher Training Agency (TTA) in Great Britain, which is responsible for funding teacher education in that country.[2] The Campbell Collaboration, launched in 2000 and now based at the University of Pennsylvania, has taken initial steps toward supporting an evidence-based approach to social issues, including education (more on this later).[3]

This is a good time, then, to consider what it would take to support the large-scale introduction of evidence-based education into the schools, including schools of education where teachers learn their first lessons about their trade. Yet, introducing the ideas behind EBM into education calls for something more than simply plug-and-play, to borrow software jargon. Curing a patient is not the same as educating a child, but then research in the health sciences, in scale and funding, is not the same as research in education. Still, there is much for educators and educational researchers to learn from EBM, including its recognized limitations, in thinking about how we can improve the contribution that research can make to education.

EVIDENCE-BASED MEDICINE

David Sackett, a pioneer in his field and director of the Centre for Evidence-Based Medicine at Oxford's Radcliffe Hospital, has explained how EBM emerged from the frustration caused by research demonstrating that doctors were recommending no less than 180 techniques in treating a common urinary tract infection, as well as by studies that determined it was taking 13 years on average for research-proven treatments to find widespread use by physicians.[4] The answer to research's remoteness, Sackett felt, was to increase the physician's access to largely clinical-trial research that bore directly on his or her medical practice. However, the randomized clinical trial, representing the "gold standard" for EBM, turned out to amount to no more than 2 percent of the medical literature. Spurred in part by the success of EBM over the last 30 years, the number of such trials now exceeds a million, Sackett estimates. These studies are further bolstered in EBM publications by meta-analysis, cross-sectional studies of patient records, follow-up studies, as well as by some of the basic or pure research in areas such as genetics and immunology.[5]

The typical EBM publication presents physicians with carefully screened research, specifically dealing with patient care in "an easily digestible summary (average reading time is about 30 minutes) every 8 weeks."[6] EBM can be pointed in its advice—"One patient in 11 will be prevented from dying or needing long-term institutional care if treated in an organized Stroke Unit rather than a General Medicine Ward"—and in its specification of, for example, "the number of patients you need to treat to prevent one additional bad outcome (death, stroke, etc.)."[7] It can also compare treatment costs against such measures.[8]

There are now software tools that support EBM, such as CATmaker that helps physicians create Critically Appraised Topics (CATs) from online guides for articles on therapy, diagnosis, prognosis, and aetiology/harm.[9] EBM publications also invite physicians to add their own commentaries and experiences to the studies presented. If gold-standard evidence in support of EBM's effectiveness in improving medical practices has itself been notably absent up to this point, the gains from using "proven efficacious therapies" on patients are well-established.[10] More

recently, the EBM concept has been extended to best evidence medical education programs that prepare residents, for example, to teach medical students.[11]

However, evidence-based medicine is still in its formative period and has been subject to critical attention. It has been seen by some in the medical profession, for example, as shackling the very professionalism of doctors, especially as it can be used by insurance companies and Health Management Organizations to turn a physician into "a dupe in a political game of health economics" by dictating treatments on a strict cost-benefit basis.[12] A second relevant concern has been expressed over the very research questions asked and measures taken in gathering the evidence. The point is well made by medical educator Frederic Wolfe, who cites the eminent statistician John Tukey's maxim—"Far better an approximate answer to the right question, which is often vague, than an exact answer to the wrong question, which can always be made precise."[13] Wolfe's own educationally relevant examples of problem-based medical education get at the limits of the typical EBM question. He holds that a research question, such as "Is achievement higher under Problem-Based Learning than traditional [medical school] curricula (e.g., USMLE, local test scores)?" would be more fairly posed as "Does Problem-Based Learning lead to better problem solving and lifelong learning?"[14] Certainly the answer will be an approximation that will take years to attain, but it does a far better job of getting at the quality of medical care than a test score.

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It is not hard to imagine that evidence-based education could easily slip into this tendency of letting a single achievement score decide the fate of programs that are really about the long-term impact of educational values. The shortcomings of the clinical trial's reliance on singular and immediate measures were first challenged by AIDS activists in the 1980s when they exposed the shortcomings of encouraging people to seek a "definitive" answer through clinical trials rather than helping them to live with the uncertainty, as well as with the value choices that need to be made with medical treatments.[15]

This reliance on a single source of evidence, the randomized clinical trial, also has been challenged by health historians who rightly argue that their work is no less evidence-based, no less relevant to decision and policymaking.[16] History, as

Clearly, much can be learned from evidence-based medicine's achievements and critiques in moving from the assessment of medical treatments to analysis of teaching methods. Any application of this evidence-based approach to education, however, needs to work from the major differences that exist between the two research enterprises themselves.

historian Virginia Berridge argues, possesses an "ability to open up issues and to ask broader questions that no one else does." In her own work, she draws the parallel, for example, between the use and regulation of opium and tobacco a century apart. But then another lesson that history offers is how shortsighted it is to focus research exclusively on individual responses to treatments, losing sight of the social and economic factors that affect classes of people and are certainly the source of inequities in the general state of our health.[17]

The narrowing of measures and the careful comparison of treatment techniques may be necessary when facing a failing patient or, for that matter, a failing class of students. Yet that does not mean that we need overlook other, less instrumental, roles that research has long played in policy circles. Policy analyst Carol Weiss, for example, has come to the conclusion, after decades of evaluation work in education, that "governments don't often use research directly, but research helps people reconsider issues, it helps them think differently, it helps them reconceptualize what the problem is and how prevalent it is, it helps them discard some old assumptions, it punctures old myths. It takes time and reconceptualization before research actually leads to a change in policy."[18] The slow impact of this knowledge on people's thinking, which only gradually leads to changes in policy and practice, may have been disconcerting to David Sackett when it came to saving people's lives, but democracies tend to work politically in this way. And Weiss uses the vital link between activism and research in the women's movement as yet another demonstration of how knowledge afforded by systematic inquiry can motivate and inspire people in that educational sense, both as feminist researchers and as democratic citizens.

THE EDUCATIONAL APPLICATION

Clearly, much can be learned from evidence-based medicine's achievements and critiques in moving from the assessment of medical treatments to analysis of teaching methods. Any application of this evidence-based approach to education, however, needs to work from the major differences that exist between the two research enterprises themselves. For example, the Cochrane Collaboration, which is dedicated to developing EBM in the field of health, has assembled carefully indexed databases of some 250,000 clinical trials, reflecting the growing support for this research. By comparison, education has a dearth of such studies for various reasons. Experimental conditions are more difficult to maintain in schools than in clinics, difficult in part due to the shortage of research funding. With the budget of the U. S. National Institutes of Health now exceeding $20 billion annually, the funding for medical research far overshadows the support available to education, with the budget of the U. S. Office of Educational Research and Improvement currently at $700 million.[19]

The more telling issue lies in how the research is conducted. While most of NIH's research funding goes to basic laboratory research, when it comes to the study of medical practices, the clinical trial is recognized as the best way and is known as the gold standard. This is not the case in education. Apart from the difficulty in meeting the funding demands of such elaborate large-scale studies, many educational researchers and teachers feel that what is most interesting about teaching and learning goes on outside of what experimental approaches can capture utilizing test results. At issue in these different research approaches to the study of teaching are the very nature of learning and the play of values in education.

We tend to see health in a far simpler and straightforward manner (although news coverage of diet, exercise, and lifestyle choices ensures that health is no longer simply something one only thinks about when faced with illness). In response to our very different ways of seeing education (between, for example, skill acquisition and personal growth), educational researchers have developed and adapted a great variety of research methods for investigating teachers' practices, including action research, phenomenology, and critical ethnography, to name a few. Educational research has long drawn on the full gamut of the social sciences and humanities. It has adapted the methods of anthropology, economics, history, linguistics, literary criticism, philosophy, political science, psychology, and sociology, as well as taking up the newer incursions of feminist, racial, gender, and cultural studies. The very richness of analysis and understanding that is available, the very play of tensions and challenges across these methods, and the positions taken by researchers within them, make critical contributions to our understanding of education and the evidence that bears on that understanding. To think of

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constricting the focus as a way of redeeming the value of educational research would be terribly shortsighted.

Rather than encouraging people to think that educational research is about determining "best practices" in some absolute sense of, say, psychomotor efficiency, people need to see what is best in relation to fulfilling agreed-upon educational values, including the value of education as a topic of ongoing public deliberation.

Education is as much about values as outcomes, and how the child comes to value learning is itself a critical outcome. It is as much a matter of children coming to care for reading as it is about how they manage to decode a specific text at the end of the third grade. For all of this stress on school accountability, there can be no assurances that children's literacy test scores reflect on whether those children have learned to see reading and writing as a way of engaging with the world, whether they will write a letter to one who matters, follow an election campaign, figure out their employment rights, or even enjoy a good book. The philosopher would say that the skills we test are necessary but not sufficient. The inspired teacher might say that education is as much about catching the wonder of teaching as learning the day's lesson.

The broad range of research that is being conducted in education allows for a quality of experience with language and literature, numbers and science. It can keep the basic skills from being mistaken as the sole measure or, worse yet, the very end of education. The challenge that we face with evidence-based education is how best to organize the very range of this knowledge in a helpful way to provide coherent access to this wide range of evidence, argument, and values. This range extends well beyond what is found in the medical literature, though it is but a fraction of the size of it judging by the holdings of the National Library of Medicine, with 18 million items, compared to that of the National Library of Education, with 1 million items.[20]

Now don't get me wrong. If there is any lesson to be drawn from EBM, it is that educational research should increase the number of randomized trials it conducts, as this is undeniably a valuable and underrepresented research technique. Equally so, current efforts to create reliable directories of experimental educational studies need to be supported as a way of improving their coordination and ensuring equitable coverage of student populations. But I differ on setting such educational research as the gold standard. Rather, we need to hold to this broader conception of relevant evidence when it comes to helping educators and others make decisions that affect the schools. It would be a disservice to the very goals of education to turn policies and programs as well as the life of the classroom over to the strict dictates of a statistically significant difference achieved in experimental trials.

In thinking about how children should be educated, people need to be able to move beyond test scores to get a feel for life in the classroom; they need to see how, for example, science students make ethical decisions, just as they need to know whether women have an equal opportunity to be scientists. This is why, in thinking about evidence-based education, it is important to think about creating better, more coherent access to the whole range of educational inquiry. The large and diverse body of evidence that educational research has produced already could do far more to support public and professional deliberations over the educational values that matter and the nature of schooling. It could do much to inform and stimulate people's thinking about education, possibly increasing their involvement in the research process, as well as drawing researchers into greater engagement in this public discourse.

For EBM, the issue of providing physicians with access to the research has meant winnowing out virtually all medical research except the abbreviated and compiled results of randomized clinical trials. While this offers great possibilities for providing physicians with wireless access to EBM Informatics in the examining room during 15-minute patient consultations, I am not sure this is the road we should take with education. What is at stake is well represented in Lois Weiner's study of what educational research in the 1990s can offer for the preparation of urban teachers.[21] Her article surveys a wide range of relevant studies, which allows her to identify not only particularly helpful studies in improving achievement, but also critical informative theoretical work on the educational climate that can provide participants with insights into the larger relevant historical ideas and roles. Her approach enables her to reveal contradictions between political and research agendas that have not otherwise become part of the public discourse around accountability. She concludes that we need to understand how research, in this broader sense, can be made to matter more in school reform and teacher preparation.

It is tempting to say that education has no bottom line. It is a social process, involving adults and children, communities and parents, states and nations. Education is as much a public discussion over what it means to learn to live together as it is a technique for ensuring that interest rates are comprehensible. Having research determine how we teach our children does not become a democracy, or at least does not become it nearly as much as research that seeks to expand how we talk, think about, and act on the education of the young. We do not want teachers working in ignorance of the research. We only need to think about research in a more—dare I say—educational light.

Decisions within education are concerned, at times, with raising the proportion of test scores that are at grade level or better, but they are also made with much more than that in mind. And in thinking about system-wide educational reforms, consulting a wide range of evidence makes no less sense. Let us create this capacity for professionals and public to step back in time, examine changing student demographics, review the political economy of school support, move in close, explore student work, or listen to how teachers are responding to testing pressures. This is the case, then, for increasing the prospects of an evidence-based education as a far broader, more educational, and democratically engaged development.

This begs the question of whether teachers, if not the public, will have any interest in their newfound ability to consult research. The evidence on teachers' interest in research is decidedly slight but not without promise. For example, Everton, Galton, and Pell found that among their sample of 302 teachers in the United Kingdom, 96 percent "had seriously considered educational research findings since first qualifying as teachers." Most of the teachers' exposure (67 percent having consulted journal articles) happens through in-service programs, while 73 percent were able to name an influential study or finding. The educators claimed that the research did affect their thinking, with half of them believing it led to improvements in their teaching behavior, and effectiveness. Not surprisingly, the educators may well have valued research that focused on the classroom, especially as it touched on teacher-pupil interaction and evaluation, but they also expressed an interest in research that "helped them to design their own project; taught them to interpret data; and enabled them to prepare research summaries."[22]

This balance between practical concerns and more scholarly pursuits strikes an encouraging note of increasing professionalism for teachers through greater ease of access to the knowledge afforded by research, especially as it can be more fully integrated with the other sorts of knowledge generated in educational settings. The Everton, Galton, and Pell study also points to how increased access needs to work both ways, so that the primary issues for teachers—such as mixed ability teaching and pupil disengagement—could become a greater part of the research agenda. It suggests that evidence-based practice could well be met by practice-based research.[23]

AN EVIDENCE-BASED SYSTEM FOR EDUCATION

Among the most promising of recent initiatives toward evidence-based education is the Campbell Collaboration introduced earlier. The Campbell Collaboration seeks to "develop continuously updated, multi-national systematic reviews of studies on the effects of demonstration programs in the social and behavioral sectors, including education."[24] Not surprisingly, it is dedicated to preparing for "practitioners, policymakers, educators and their students, and members of the public" reviews of randomized field trials, but it plans to attend to other sorts of research as well. The Collaboration also has established a Social, Psychological, Educational, and Criminological Trials Register after the clinical trials databases used in EBM.[25] This will assist researchers in pulling together the results of various studies through meta-analysis techniques, as well as help to spread new standards of assessment and evaluation, while affording public access to research results. It will also enable gaps in the field trial literature to be identified, as well as allow for the general state of field trial research to be evaluated.

There is also the Evidence for Policy and Practice Information Co-ordinating Centre, which is at the Institute of Education, University of London.[26] Given its goal of "evidence informed policy and practice," it provides teachers, parents, and policymakers with systematic reviews of existing research, while attempting to foster a research process that is "open to scrutiny, criticism, and development; a research process that values and takes steps to encourage participation, at all stages, by anyone with an interest in education." The Centre, in defining its review methodology, is clearly not as fixed on the clinical trial standard as the Campbell Collaboration. Still, it requires of its volunteer review groups, made up of researchers and research users, an elaborate process of surveying and mapping the research in a given field with detailed analyses of key studies.

Both the Campbell Collaboration and the Evidence for Policy and Practice Information Co-ordinating Centre clearly represent a valuable service to education and research. Their review processes will increase the public and professional presence of educational research. Both operate, however, on assumptions about the state of educational research that should be challenged in light of new information technologies. They assume that considerable effort is needed to (a) locate relevant studies, (b) identify and sort out different types of studies, and (c) summarize and synthesize the results of the critical studies into a form that makes sense for practitioners and policymakers. This means inserting a considerable layer of labor and mediation between research and practice.

Given that efforts to establish a basis for evidence-based education are just getting under way, it seems fair to raise the simple but powerful question of whether we need to build an elaborate mediating apparatus between research and practice. Doesn't it make more sense to work instead with improving the accessibility and intelligibility of the research directly, so that it can better serve those it would help? After all, researchers are currently experimenting with a wide range of new online scholarly publishing systems that include e-journals, digital libraries, open access, and automated indexing systems, all holding the promise of improving the ways in which this knowledge can be managed.[27] These systems could end up doing little more than simply speeding up the publication and delivery of research to researchers' desktops, or they also could be designed to facilitate educators' and the public's access to relevant evidence without having to build in a whole new layer of mediation between research and practice. It is already happening in medical research, to stay with our principal parallel. The federally sponsored MedlinePlus Web site has demonstrated how public access to basic and clinical trial medical research can be integrated into an information system that serves patients and doctors.[28]

So, while I lend my support to the Campbell Collaboration and related initiatives, we need to do something more daring as well. I want to advance an ambitious and encompassing model for evidence-based education. This model would take advantage of new information technologies, as well as the spirit of open-access publishing that is emerging in the science on the Web. It would work with what now seems the gradual, but inevitable, transfer of scholarly publishing to electronic media, whether organized by a research library or professional association. Creating an effective public and professional portal into educational research will take considerable experimentation and testing to create an effective system and would necessarily require the cooperation of major educational research associations, such as the American Educational Research Association, federal government bodies such as the Office of Educational Research and Improvement, and teachers' and administrators' associations.

I've come to believe, after working on new models for scholarly publishing over the last few years, that we can build systems that could well serve an evidence-based approach to education for educators, policymakers, and the public. It would require minimal mediation between research and public, as well as minimal additional labor, while incorporating far wider access to research. Although my own work with the Public Knowledge Project is still at the stage of testing prototypes with users, the critical components for such a system now seem apparent.[29] A research publishing system that would support evidence-based education for educators, policymakers, and the public should offer (a) a coherent, public gateway to as much of the educational research as possible; (b) a sophisticated indexing system that enables the research to be linked not only to related studies, but to critiques, overviews, and data sets; (c) a means of moving back and forth from the research to related materials on classroom practices and programs, government policies, and legislation in different jurisdictions, media reports, and organizations; and (d) supportive educational resources, such as summaries, commentaries, glossaries, reviews, FAQs, and instructional modules;

which would as soon serve faculty and students as much as educators and the public. We are clearly seeking ways of integrating research with related orders of information. In this way, the sense and application of that research can be more readily grasped, just as the ideas it raises can be more fully pursued and explored, whether by student or faculty, interested professional, or the public (See Figure 1).

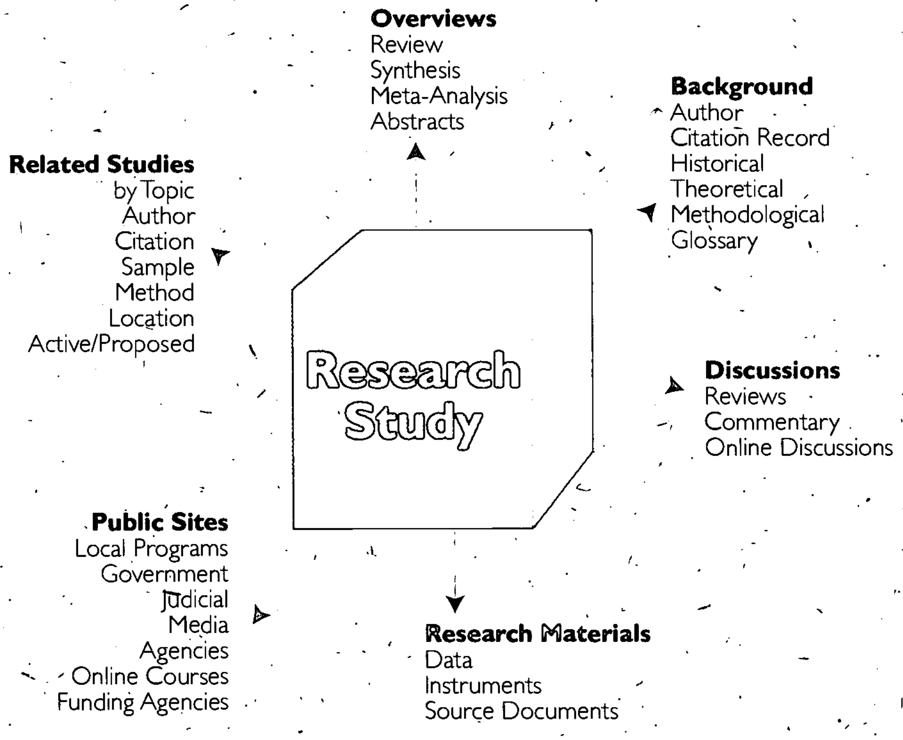

Figure 1. Navigational Metaphor for Public Knowledge Portal. Ideally, indexing systems should enable users to move outward from the research to related resources, as well as to move from the resources to related studies. Adapted from Willinsky (2000).

This approach would lead to an online educational research portal that enables the user to access relevant research on a given topic, while being able to narrow the search to the population study (age, poverty level, race, region, etc.), and to the research methodology (ethnographic, experimental, historical). It would allow the user to dig into the data, to review the students' work, or to listen to lessons. It would alert a user as to whether media reports or relevant legislation were available on a topic. Or, beginning with the media reports and at any given point, a user could check related studies, a cited study, or debates over such research in the literature.

Such a site could form a common public space for educators and researchers. Imagine teachers not only adding comments to studies based on their experience but posting examples from their own or their students' work (with permission) that bear on a given program. Teachers would be able to increase their own levels of accountability and professionalism by situating their own teaching practices within the context of published studies. They would be able to request participation for their classes in random trials, just as they might invite researchers to work with them on questions of common concern. In this sense, evidence-based education would be about collaboratively creating and sharing more of what is to be learned by systematic inquiry. It would be far less about submitting to the evidence handed down from on high.

As ambitious as such an approach to scholarly publishing seems, it could be a far less expensive approach to evidence-based education than the EBM model.

This design would keep the site far more intellectually and educationally alive than evidence-based databases. There would be commentaries and critiques, backgrounds and overviews, all within the user's horizon of awareness. Such a global system for educational research could also be used to initiate and coordinate new studies, to create continuing and cumulative educational measures across a wide variety of communities. It could engender a far more dynamic research model, afforded by shared data and collaborative virtual workspaces, than exists today in the educational research community.

As ambitious as such an approach to scholarly publishing seems, it could be a far less expensive approach to evidence-based education than the EBM model. It would take advantage of new scholarly publishing systems, just as it would not depend, after all, on a team of trained researchers adding another layer of mediation and meta-analysis onto existing research resources. Rather, it would seek to use new methods of organizing knowledge to take greater advantage of the full range of educational research that already exists and would certainly continue to be produced. This refusal to limit the sources of evidence to clinical trials will mean that the system does not necessarily curtail users' exposure to ideas, as opposed to results. It would have a place for radical critiques, underrepresented voices, and new conceptions of what, for example, constitutes critical issues like equality in education.

There is no question that responsible professional educators must consult a variety of sources before making critical decisions. This by no means discounts the experience and wisdom gained by teachers in the schools. That wisdom needs to be tested and augmented, however, by the work of others who are devoted to learning more about education through systematic inquiry. The democratic spirit of this inquiry also means attending to the exception and dissenting opinion. The research no less than the education itself needs to be seen as part of a public process that makes teaching and learning, whether of teachers and students or researchers and scholars, part of democracy's deliberative spirit.

Rather than regarding evidence-based education as a way of rationalizing behavior and governing the practices of a teaching profession that is struggling with the effects of social disparities that are well outside its making, we need to take hold of the possibilities of increasing the public qualities of knowledge generally, as both an educational and democratic act. Let us, by all means, increase and improve access to all of the available evidence, but do it in a way that can expand the opportunities for learning and exchange all around.

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V I S I O N

3

PERVASIVE COMPUTING: ENHANCING LEARNING IN THE CLASSROOM AND BEYOND

Bill Mark, Ph.D.

Bill Mark's look at pervasive computing will no doubt leave readers excited about the not-so-distant future when powerful new systems will allow us all to interact with our environment much as our beloved George Jetson did in the 1960s cartoon. While we, too, look forward to increasingly sophisticated computational devices, we have focused our attention on two currently pervasive technologies: the television and telephone. Together these devices form the basis of a promising new communication service known as PhoneChannel, presented in the Leadership section.

3 VISION

PERVASIVE COMPUTING: ENHANCING LEARNING IN THE CLASSROOM AND BEYOND

Bill Mark, Ph.D.

ABSTRACT

Life is becoming more computational. Overtly computational things (laptops, handheld PDAs, and so on) are widespread in all developed countries. But the greatest growth—and the greatest potential—is in covertly computational things: music players, automobiles, TVs, cell phones, cameras, whiteboards, and practically anything else. As covertly computational devices become part of our daily lives, and as they become more interconnected, they form a new ***pervasive computing*** infrastructure. Access to conventional computing in our society has been uneven. Notably, schools in the United States have remained computationally poor compared to many businesses. But in the pervasive computing world, access may become more even. For example, personal electronic devices like music players and cell phones are increasingly prevalent among young people. As these devices become more computational, they will constitute a serious computational infrastructure wherever young people gather. Schools may find themselves in the wave of pervasive computing, as students bring (or wear) computation into the classroom and continue to learn with it outside of the classroom. But this will be only the beginning of a larger revolution in which computation becomes a seamless part of education, enhancing learning by providing learners and teachers with new ways to interact and share knowledge. This article focuses on pervasive computing for learning, exploring the growing potential as

pervasive computing advances in three waves: interconnected devices, smart spaces, and augmented collaboration.

THE PROMISE OF PERVASIVE COMPUTING

We can already put computation almost anywhere. Embedded computation controls braking and acceleration in our cars, defines the capability of medical instruments, and runs virtually all machinery. Handheld devices (especially cell phones and pagers) are commonplace; computational wristwatches and other wearables are becoming practical; computational furniture and rooms are demonstrable. Relentless progress in semiconductor technology, low-power design, and wireless technology will make embedded, connected computation less and less obtrusive.

Our relationship to pervasive computing will be different from our relationship to conventional computing. Right now people think in terms of performing explicit tasks on the computer: creating documents, sending e-mail, and so on. With pervasive computing, this comfortable explicitness disappears. People will do whatever they normally do: move around, use objects, see, and talk. The computation in the environment may be able to facilitate these actions, and people may come to expect certain services, but they will usually not be doing things on the computer.

We see the beginnings of this form of interaction with some existing embedded computers. For example, an automatic braking system engages when the driver performs the normal action of pushing the brake pedal. The "automatic" is significant; the computation is implicit. Braking simply works better (most of the time), and people do not care how. Currently such invisibly computational interaction is extremely limited. We allow it only when our intent is unambiguous and when the computer can clearly do the job better than we can. In order to take advantage of pervasive computing, we must greatly expand this form of interaction. Implicit computation will be available everywhere; we need to figure out how to leverage it. When we do figure it out, it will have a profound impact on most aspects of society, including education.

Children are constantly learning. In classrooms, learning is usually with respect to some formal expectations. Teachers find ways to address the highly individual capabilities and learning gaps of their students with respect to those expectations. Outside of the classroom, learning is usually more informal. Pervasive computing offers the ability to integrate these learning venues, bringing the curriculum outside of the classroom, bringing informal learning into the classroom, and delivering the insights of teachers and learners to other teachers and learners in real time, during the learning experience.

A recent report points out that learning is most effective when four fundamental characteristics are present:

- **Active Engagement** – a combination of experience, interpretation, and structured interaction with peers and teachers

- **Participation in Groups** – the opportunity not only to imitate others, but also to discuss the task and make thinking visible

- **Frequent Interaction** – frequent opportunities to apply ideas and receive immediate feedback on success or failure

- **Connection to Real World Context** – application of underlying concepts to real problems[1]

There are many opportunities to introduce these characteristics into the learning environment, some dependent on technology, others not. But pervasive computing offers a unique way to enhance the learning experience by expanding the learning environment, both physically and socially. In particular, pervasive computing offers students and teachers new forms of interaction with the physical world and with each other. Consider the following vision of classroom-and-home education (see Figure 1).

Students enter the classroom with personal notepads or other computational devices. These devices are automatically networked into the classroom's innate computational facilities, which might include electronic whiteboards and other displays, the school's knowledge store, and the Internet at large. Students at home due to illness or other reasons, outside on field trips, and so on, are similarly linked in. All of the computational devices unite in forming an environment that is an active participant in the educational process.

The teacher begins a discussion of the day's material. The students respond, take notes, and point to images on paper, notepads, or the whiteboard. Much of the learning experience is embodied in the spoken interaction, and the environment captures that interaction in order to leverage it for enhanced learning. This is not a matter of recording and playback. The environment creates an organized informational digest or *context* from the discussion. Based on its understanding of that context, it participates in the learning process, making proactive suggestions of relevant information and guiding students using pedagogical approaches chosen from previous experiences in this and other classrooms. The teacher initiates most of the classroom interactions, sometimes delegating continuing interaction to the environment, fluidly rejoining from time to time.

For example, a particular student interaction pattern might cue the environment to interact with a student or group of students according to a pedagogical scenario that worked in similar situations. Under guidance from the teacher, the environment may link in other students with similar learning gaps and students who have mastered the material to join in the interaction. The teacher may give the environment the responsibility for guiding the students through the material and giving them feedback, on its own or in conjunction with the teacher and other students. At the same time, other students may be looking ahead or reviewing learning interactions from their class or others. Students may work individually or in groups, depending on the material and the work styles of the students and teacher. Much of the interaction with the environment is both spoken and visual, carried on through the students' notepads, the whiteboard, and other display devices.

During and after school, the students interact with their personal electronic devices outside of the classroom. Most of this interaction is for entertainment, but the devices are used for homework as well. Some of this interaction uses the device itself, e.g., students learning about measurement could capture video of and time their progress through a hallway. Other interaction is with the pervasive computation embedded in the environment, e.g., querying structures to determine their age and constituent materials. The pervasive environment is also a proactive part of the interaction, initiating interaction with students as they pass near relevant objects. These interactions could be planted by teachers, but could also be opportunistic, as computation in the environment notices the electronic devices of passing students and interacts with them based on stored information about the day's classroom experience.

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Figure 1: Classroom-and-home educational environment

It is hard to escape the proliferation of personal electronic devices. Cell phones are ubiquitous, even (in some countries, especially) among children. Pagers are prevalent among professionals and some children.

The students go home with their devices, turning the dinner table (for at least part of the time) into an extended mediated classroom. The devices can interact with other devices in the home, or simply use their own audiovisual capabilities. The dinner table discussion of "what we learned today" is enhanced by the context of the student's interactions during the day, perhaps annotated by the teacher during class. Parents' and siblings' comments are integrated into the lesson plan and brought back to school to be shared with others.

NEAR TERM (NEXT 5 YEARS) – CONNECTED DEVICES

It is hard to escape the proliferation of personal electronic devices. Cell phones are ubiquitous, even (in some countries, especially) among children. Pagers are prevalent among professionals and some children. Both cell phones and pagers are rapidly gaining in their capability to handle electronic mail. Personal Digital Assistants or PDAs are also a rapidly growing category, most often used for address book and calendar functions at this point, but with other applications, including educational software, becoming increasingly available. Cell phones, pagers, and PDAs are converging into a single device that will be used for communication and personal notepad functions.

These converged devices will represent an evolutionary step between computers and the "smart objects" that will come later (see next section). Computers are general-purpose devices that can perform a wide variety of functions. Smart objects are physical objects that have been given computational capability, but whose function is derived from and constrained by the original object. For example, the brake pedal in many cars has been transformed into a computerized braking system. The brake does what it always has (stops the car); it just does it better. It does not perform any other computational function.

The converged PDA/cell phone/pager will still be thought of as explicitly computational but not as a computer. For example, a PDA is modeled on a pocket notepad, a form factor that has been around for hundreds, or if you count clay tablets, thousands of years. In short, people are quite familiar with using a stylus-like implement to record small amounts of information on such objects. In their computerized form, these notepads provide some extended functions (e.g., automated search; soon some speech recognition, e.g., "Get me Mary's assistant."). The PDA is not a general purpose computer—it provides only a narrow range of functions. But it is still computational: people use it for what they view as explicitly computational tasks (like automated search). The point here is that these devices will be far more prevalent, and more prevalent across broader communities, than conventional computers.

Devices have more impact when they are interconnected. Personal electronic devices will become much more powerful when they can be formed into flexible interacting groups, for example, the group of all of the personal electronic devices that are in a particular classroom or the group of students working on a particular science experiment. Of course, cell phones and pagers are connected now, but they are not connected in a way that allows flexibility or promotes group interaction. Cell phones are connected through a centralized switching network, which works well for paired connections, but not for flexible groups. Pagers are connected only through broadcast networks. Most PDAs are not connected at all.

But all of this is changing. Wireless connectivity is a major driving force for PDAs and other personal electronic devices. Emerging technology and standards will make classroom scale peer-to-peer networking feasible. A key advance is *ad hoc* networking, in which networks can be formed and changed based on the devices that are within range and are enabled to participate.[2] For example, an *ad hoc* classroom network can be formed among the personal electronic devices of students as each one enters. The teacher's console, whiteboard, and other classroom display devices would be standing members of the network. But even in the absence of these devices (which will be slower to penetrate into classrooms), a valuable network can be readily formed from the students' and teacher's personal devices (which are proliferating).

This network can implement part of the visionary scenario in the previous section, enhancing learning along the dimensions called out by Roschelle, *et al*. The personal device network enhances learning by **actively engaging** students in information relevant to their lessons (e.g., introducing complementary information from outside of the classroom and leading students through the solution methods of their classmates or other students). The device network also encourages **participation in groups**, making it easy for students to interact electronically based on shared problem-solving approaches. **Frequent interaction** is available through electronic interaction with the teacher, other students, the software on the device, or a combination of all of these. Feedback can be tailored to individual students based on the history of their work in a given area, as stored on their personal devices. Finally, **connection to real world context** is available whenever students use their devices in other situations. For example, e-mail to a friend could automatically bring up a geography lesson on a student's device; an electronic purchase could lead to an interaction about arithmetic or budgeting.

Connected devices represent a significant new potential for enhancing education, but they are only the beginning of the pervasive computing revolution. They are, after all, still explicit devices whose use must be learned and practiced. In the next phase, computers will get out of the way. Instead of being seen as explicit devices, they will become part of the environment.

MEDIUM TERM (NEXT 5 - 10 YEARS) - SMART SPACES

As computational capability becomes smaller and requires less power, it becomes possible to incorporate it into almost any physical object. Computation starts to be more about spaces than devices. The idea of computation being used to create "smart spaces" can be seen as early as the 1960s work of Doug Engelbart at SRI, which explored human-computer systems that could augment human capability.[3] The Media Room developed by the MIT Architecture Machine Group in the mid-1970s explored the concept of users interacting with room-sized computational environments.[4] The result was a new human-computer interface based on the combination of speech and gesture input and text/graphics output.

A decade later, Mark Weiser and his colleagues at Xerox PARC were investigating a different paradigm in which spaces consist of invisibly computational objects, objects that embody computational extensions of their originals (smart Post-it notes, badges, pads, etc.).[5] People interact with these smart devices as they move through their day. Unlike the Media Room, explicit interaction with the computer is meant to be minimal to nonexistent. In the "ubiquitous computing" world envisioned by Weiser, people interact with computational entities pretty much the way they interact with physical entities, not the way they interact with computers.

As the technology of pervasive computing has improved, research in this area has flourished, producing significant interactive environments based on these earlier concepts. The MIT Media Lab's Things That Think project shares much of the heritage of ubiquitous computing.[6] The Smart Rooms of A. Sandy Pentland and colleagues have a similar point of departure but additionally create complex 3-D information environments that leverage human spatial reasoning capability.[7] Smart Rooms and Pentland and Liu's Smart Car also focus on inferring human intentions through their actions in order to provide enhanced interaction.[8] Classroom 2000 brings the smart-space concept into the classroom, with automatic indexing of whiteboard and video imagery to lecture notes.[9]

As smart spaces evolve, people will not have to work through (or possess) devices in order to participate in computationally enhanced experiences. They will do what they normally do, with the computation invisibly making things better, faster, safer, and so on. The vision scenario previously described illustrates this kind of interaction: As students move around, the computational world proactively helps them learn, alerting them to aspects of the environment that are relevant to recent lessons. **Active engagement** and **connection to real world context** are fostered in students' daily lives through the proactive involvement of the smart spaces they inhabit.

Enticing as the smart space world is, it has a major shortcoming: It ignores the interpersonal interactions of people in the space, e.g., "in general, the room ignores spoken utterances from the lapel microphones not specifically directed to it."[10] This is an important simplifying assumption that makes widespread implementation feasible within the next 10 years, but it also defines the smartness of the space in terms of human-computer interaction: the capability of the space to understand what people are trying to tell it. In fact, people will interact with each other much more than they interact with the environment, no matter how smart the environment is.

LONG TERM (BEYOND THE NEXT 10 YEARS) – AUGMENTED COLLABORATION

Most of people's learning and knowing is conveyed through spoken interaction with other people. Pervasive computing environments must understand natural speech and dialogue in order to bring this huge part of human activity into the learning experience. This requires far more than recording speech for later playback. People do not learn much by listening to transcripts—even if they are well-indexed and enhanced with multimedia content. Such interactions lack the fundamental learning-enhancing characteristic of **active engagement.** In order to enhance the combination of experience, interpretation, and structured interaction with peers and teachers that active engagement entails, the pervasive computing environment must understand and augment the largely spoken collaboration of its participants.

Speech is "in." The last several years have seen the mainstreaming of speech recognition technology, for both telephone interaction and dictation applications.[11] This speech technology represents a stunning but limited achievement based on years of research. Much of it is restricted to (single) human-to-computer interaction. Understanding multi-person casual (or "natural") speech remains a research endeavor. There are many differences between human-computer and human-human interaction: When people talk to each other in all but the most formal settings, they have conversations. They use casual speech, with all of its ellipses, disfluencies ("uhh," "umm," etc.), and topic changes. People slightly overlap each other's speech, especially if there are more than three people in the space. Gesture recognition becomes important because gesture is an integral part of natural speech. The environment must also identify and track speakers so that it will know who is saying what to whom, identify references to objects and images in the room, and spot and follow topics through the shifts and turns of an ongoing conversation.

In order to augment collaboration, the environment must go beyond recognizing the speech to integrating what is said into a shared context for its participants. Context is the representation of the information that is relevant to the people and devices within the space. This context must be a *composition* of relevant information: Mere collection of information is of much lower value. In the learning environment, collaboration is a multi-person (teacher-student[s], student-student[s]) effort to create a shared context that represents correct understanding of a set of concepts. To the extent the computational environment understands the collaborative interaction, it can help learners develop correct understanding. As illustrated in the visionary scenario in Figure 1, it can expose them to pedagogy that has worked in similar situations, connect them with other students who already have a correct understanding, find relevant information outside of the environment, and even point out conflicts with other parts of the context.

EVOLUTION OF THE TECHNOLOGY

Pervasive computing *will* affect education, perhaps in the ways and over the times sketched above, perhaps in different ways over different times. In any case, the evolution of the underlying technology will be a key driver in what actually occurs. Technology evolves. It is subject to the forces of selection in society: economics, demographics, and behavioral norms and changes. The course of this evolution, like any evolution, is notoriously hard to predict. The outline in the previous sections is just one possibility, contingent on a large number of factors.[1]

Among these are some fundamental factors that will play a key role in the technology evolution. One fundamental factor is the exponential rate of progress in electronics and computation. "Moore's Law"[12] is a characterization of the speed of the advance of silicon electronics; there are similar characterizations of the speed of advance in network technology and connectivity. The technology of the connected device world (Near-Term section) is in hand now (that is why it can occur within five years).

Equally fundamental are the human behavioral characteristics that will shape the evolution. The fundamental human habit of creating associations with physical spaces ensures that pervasive computing will not homogenize the world, e.g., we will always have learning spaces. Human beings have a profound need to interact with each other, especially using speech. Even in the near-term world of connected devices, people use the devices primarily for communication with other people.

Computation can be used to portray worlds that are outside our conventional conceptual system but that are understood by users in terms of a self-consistent synthesis of known concepts.

When computation becomes part of the environment, people will continue to communicate with each other, and they will expect the environment to understand them in order to assist or augment what they are trying to accomplish. Technology will have to evolve in at least two dimensions to survive in this world.

First, the technology must evolve in ways that help people think about and interact with computational environments. If people use computation in an environment without being aware of an interface, what are they aware of? How do they think about the environment? People will need new metaphors to aid them in "the coherent structuring of experience."[13] The easiest approach is to **inherit** an existing metaphor. This is the smart object approach: People think of the computationally enhanced object very much the way they thought of the pre-computation original (e.g., the brake pedal in an automatic braking system).

Another approach is to **project** a metaphor based on some aspects of physical reality. People know that they are interacting in a computational (or "virtual") world; the metaphor helps them to learn and understand the workings of that virtual world. The *desktop interface* (i.e., a computer screen with certain icons governed by certain rules of behavior) would never be confused with a physical desktop. Nonetheless, people can use the physical desktop as a metaphor for thinking about how to transfer activities (arranging documents, filing, etc.) from their physical world to the virtual desktop world.

Finally, we can **create** a metaphor. Computation can be used to portray worlds that are outside our conventional conceptual system but that are understood by users in terms of a self-consistent synthesis of known concepts. For example, video games and simulations like SimCity create coherent world views that are comprehensible to people, even though they are new to our experience.

Pervasive computing environments are real physical spaces, but real physical spaces do not *do* anything when people interact in them. People do not talk to physical spaces and expect them to respond. How does the space show its reaction to an interaction or notify users that it has performed a task? How does the space know that someone is talking to it? Science fiction authors have imagined a future in which people interact explicitly with an anthropomorphic computer that controls a space (like the infamous HAL 9000 of *2001 A Space Odyssey*[14] or the ship-wide computational environment addressed as "Computer" in *Star Trek I*[15]). The pervasive computing environments of science fiction have super-human interaction skills. People in the space assume that all of their interactions with each other are understood and that all of their interactions with the computer are properly interpreted and dealt with.

The foreseeable future of pervasive computing environments will be much different. People's metaphors must evolve with the growing capabilities of the space and with their increasing experience with this form of interaction. The automobile was once very much like the then-familiar carriage—only without the horse. The "horseless carriage" metaphor was an important evolutionary steppingstone. In the future, the horseless carriage metaphor could further evolve into a "driverless car" metaphor. Pervasive computing metaphors could similarly evolve as an extension of smart object metaphors: from a smart shopping list that manages itself on a PDA, to a smart refrigerator that manages the larder, to a smart kitchen that manages the family's meals. The smart shopping list starts out as a straightforward inherited metaphor from the real shopping list. The smart refrigerator is a conceptually easy next step. From there, the "mom-less" kitchen seems comprehensible.

Talking to rooms or nodding to refrigerators will seem entirely natural. The metaphors of the past will seem quaint: Whoever thinks of a car as a horseless carriage?

From a future historical viewpoint, people will be seen as having ceded more and more responsibility to pervasive interaction environments. But from the point of view of the people interacting in future pervasive interaction environments, things simply work that way. Talking to rooms or nodding to refrigerators will seem entirely natural. The metaphors of the past will seem quaint: Whoever thinks of a car as a horseless carriage?

The challenge is to continually improve the technology while maintaining appropriate metaphors to guide people along the way. Augmented collaboration will be very limited for many years to come. The metaphors need to help people create and maintain the appropriate notion of the partial competence of the space.

The second dimension of technology evolution involves understanding real human interpersonal speech. As mentioned in the previous section, this is a research problem (which is why augmented collaboration is at least 10 years off). The fundamental problem, as artificial intelligence researchers have long known, is that it requires a great deal of detailed knowledge to *really* understand what people are saying. We commonly observe

A reasonable near-term goal (one that still requires significant research) is a pervasive computing environment that uses information extraction techniques to map spoken interaction into an externally provided context like a lesson plan.

that it is extremely difficult to understand what people are saying unless we have some knowledge of what they are talking about.

Decades of work have gone into understanding the structure of language, and there has been substantial progress.[16] Nonetheless, the challenges that remain are daunting. This is not to say that we cannot progress until we achieve the entire solution. One evolutionary approach is to set the goal at only partial understanding of the information. For example, *information extraction* aims to understand key elements, not necessarily all, of verbal information, much like skimming a body of text.[17] A reasonable near-term goal (one that still requires significant research) is a pervasive computing environment that uses information extraction techniques to map spoken interaction into an externally provided context like a lesson plan. The space will not understand everything that is being said, but it will greatly enhance the interaction of the people in the space.

Another evolutionary approach is *topic tracking*. Following the threads of a conversation is essential to understanding multi-person speech.[18] Conversations move among different topics, even within a focused task. Conclusions about a topic may follow after several intervening topics have been discussed. One or more speakers may or may not "get their say" on a particular topic, which is often an important fact for mediation and decision making. Enumerating all of the topics may be important for later information extraction ("What did we talk about yesterday?"), and so on. Topic tracking does not require full understanding of the conversation, only recognition of key phrases and some understanding of the rules of human dialogue (e.g., how a subject is introduced and reintroduced). A good topic tracking system can recognize the fundamental structure of the conversation, even if not every word is understood.

Finally, there is *response generation*. The computational environment must be able to hold up its end of the conversation. A natural assumption is that the environment should join in the conversation verbally, but that approach has two problems. The first is that synthesizing natural speech is extremely difficult. Anyone who has dealt with synthesized speech is aware that current technology produces stilted, hard-to-understand speech. The second problem is that a spoken response is not always best. For example, in the first scenario in this article, a group of students is working on a problem in a classroom that contains other students. The best way to convey a response to that group is not necessarily to generate speech: Depending on the content to be conveyed, graphics or text might be a better option. To present the gestalt of a complex situation, speech is rarely best. ("A picture is worth a thousand words.")

Fortunately, unlike human beings, computational systems are readily able to choose among and instantly produce responses in a variety of media. As is often the case, this capacity for variation is an evolutionary advantage. Even in the earliest phases of development, the environment will be able to produce *some* kind of useful response. As technology improvements enable new capabilities, the environment will be able to increase its repertoire, eventually including fully natural speech synthesis.

We can expect the evolution of augmented collaboration to start with topic-based information extraction and move along a path toward an ever more complete understanding of human interaction. Responses generated by the environment will evolve from the largely visual to a fluid combination of spoken and visual information, based on the content to be conveyed, the characteristics of the environment, and the needs of the intended recipients.

CONCLUSIONS

Pervasive computing will enhance education by seamlessly expanding the learning environment beyond the classroom and by offering new ways to actively engage learners with the environment, their teachers, and each other. The focus of this article has been on the synchronous impact of this new world, i.e., the impact on learners during the time they are involved in the learning interactions. It is worth noting that this is only part of the potential impact, and it may not even be the most important part.

An interesting and far-reaching aspect of pervasive computing is the potential to capture and organize the information that is relevant to people as they go through their lives—including their education. As discussed in the Long Term section, pervasive computing environments will begin to develop contexts that embody the information that is created and used by their participants. These contexts will be compositions of the subject matter that was discussed, the external materials that were referenced, and eventually the spoken interaction of the people in the environment.

In educational settings, these contexts will embody what people have learned as children and then later as adults. A context will become a personal resource that grows with and belongs to an individual. A person will refer to a context to refresh his or her memory, to selectively share his or her knowledge in group activities, and perhaps even to use as a portfolio when looking for a job. More exciting, contexts—to the extent individuals are willing to share them—become a resource for communities and society as a whole. The entire experience of children learning to read in a community could become a resource of the schools, available to proactively coach new learners and train new teachers. The day-to-day interactions of teachers could become a resource for the teaching community and for curriculum developers.

Pervasive computing will be a revolutionary change in the way computation intersects society. It is up to all of us to make sure that the change is for the better.

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VISION

4

THE NEXT GENERATION INTERNET AND THE SCHOOLS

Louis Fox, M.A. and Ron Johnson, M.S., M.A.

Louis Fox and Ron Johnson present an interesting and nontechnical overview of Internet2 from the early days of ARPANET to the newly launched Internet2 K20 initiative. Mr. Fox expands this discussion in the Leadership section and provides insight into some of the more innovative applications currently under way.

4 VISION

THE NEXT GENERATION INTERNET AND THE SCHOOLS

Louis Fox, M.A. and Ron Johnson, M.S., M.A.

CONTEXT

The revolution in computers and telecommunications networks and the accelerated rate of this growth, along with the global explosion in knowledge and ready access to powerful communications tools, are creating unprecedented changes in business, commerce, government, science, health care, and education. New jobs, new industries, an explosion in entrepreneurship, new modes of community building, increased learning opportunities, ease of access to timely information and global markets, and the ability of an extended community to interact closely across space and time: all are dividends of this revolution in network and information technology and the remarkable underlying Internet culture of change. Yet the fruits of this Information Age are out of reach for many in our nation. This gap, the "digital divide," threatens to continue to cut off some populations from new opportunities. Access to new forms of education, good jobs, medical and health information, communication, and the chance to participate in the affairs of the broader society may be denied to them. For some citizens, technology brings the promise of inclusion, opportunity, wealth, and better health; for others, greater isolation and continuing poverty. Many look to our K-12 schools to bridge this gap.

America's schools are the doors to participation in the Information Age for all children; however, schools have been slow to embrace these new technologies with the related culture of change and opportunities they represent. This article

The current Internet, sometimes referred to by its technology community as a "thirty-year overnight success," has its roots in the 1960s as special interest projects of a small band of university-based computer scientists and researchers.

will explore some of the opportunities and challenges presented by the Next Generation Internet, in particular the effort known as Internet2, and by the clash of school and Internet cultures. It also will look at the need to realign school technology adoption and deployment models to take advantage of new (and existing) Internet technologies.

A note of caution: Predicting the future historically has been work best left to prophets and oracles, or to their modern day counterparts, economists. That said, our schools must endeavor to prepare students for a future they (and we) can, at best, only dimly imagine. Thus, in this article we will limit ourselves to observations that stem from actual instantiations of promising technologies, some in experimental or "alpha" stages. And so our view, where we stray from what is known, is toward a possible, seemingly probable, future and necessarily "through a glass darkly."

FROM THE INTERNET TO INTERNET2

The current Internet, sometimes referred to by its technology community as a "thirty-year overnight success," has its roots in the 1960s as special interest projects of a small band of university-based computer scientists and researchers. In 1969, the U.S. Department of Defense's Advanced Research Projects Agency (ARPA) established ARPANET, the forerunner of the Internet. The ARPANET network, along with a research and development process, connected computer scientists and computers at the University of California at Los Angeles, the University of California at Santa Barbara, Stanford Research Institute, and the University of Utah. Within a few years, many other educational and research institutions connected to the network and became engaged in "Internet-related" research and development.

During the 1970s, developers created the architectures and protocols used to enable largely independent computers to talk to one another via an open and, compared to the proprietary alternatives, highly-scalable and extensible network. In 1970 ARPANET hosts started using Network Control Protocol (NCP), the first host-to-host protocol. By the mid-1980s, Transmission Control Protocol/Internet Protocol (TCP/IP) had become the dominant protocol in the research and education worlds. It is now the lingua franca of nearly all computers and personal digital assistants (PDAs) in the world.

In its infancy the Internet was quite a forbidding place for the uninitiated. Those who used the Internet (mainly computer experts, engineers, and scientists) had to understand and work in esoteric computer programming dialects. Users had to keep in their heads a revolutionary new set of architectural assumptions about an unprecedented level of connectedness and interdependency among hardware, software, information, and users.

The rapid growth of the Internet (and the Internet tools and capabilities we have and use today) was in great measure not so much a result of the root technologies themselves as it was and is a result of what is often called "Internet culture." For example, in sharp contrast to other approaches, the developing Internet standards (here the word "standards" has a much different meaning than that of a rigid agreed-upon dictate) and protocols, along with other basic documentation and related tools, were shared with any and all, freely and openly, along with a standing invitation to participate in further development of standards, protocols, and tools. More important, the Internet standards, protocols, and tools were (and remain) a dynamic product of a broad and open community process where the ultimate tests are not formal agreements and specifications or votes. Instead, the true tests are *rough consensus*, both in the development process and as evidenced by real-world adoption, and *working code* (i.e., proven workability and interoperability in the Internet and among the overall Internet technology mix). The power of this open process that sustains such standards and protocols, coupled with the explosion in participation that the open Internet standards approach provides, enabled rapid evolution of core Internet technologies and the quick emergence of network-oriented applications. Newsgroups, listservs, shared access to files, and, foremost, electronic mail all emerged as viable and popular applications.

Progress was remarkable. The ARPANET grew to encompass more research institutions. The unique open Internet standards and the de facto development paradigm of "rough consensus and working code" enabled broad participation in the development of the Internet.

By the mid-1980s, over 1,000 hosts were connected to the Internet. But running a quasi-production network to link all manner of research and education institutions was outside the scope of the Defense Department. In 1986, the National Science Foundation funded a new network focused at first on providing widespread access to five U.S. supercomputer centers. This new network, called NSFNET, also was based on TCP/IP technologies. It became a cornerstone of the global Internet that evolved from ARPANET. The four research sites of the original ARPANET evolved into hundreds and then thousands of higher education and corporate research NSFNET sites. This enabled the participation of thousands and then tens of thousands of developers and implementers who collectively accelerated the expansion of the toolkit and content of the Internet. By 1990, over 100,000 computers around the world were connected to the Internet. (Its original matrix, the ARPANET, was decommissioned that same year.)

With the emergence of user-oriented and "friendlier" e-mail tools like Pine and Eudora, which were based on Internet standards and developed in accord with the Internet principles at universities, along with powerful and nonproprietary message handling protocols (like POP and IMAP), and better, more human-friendly, easy-to-use connectivity tools like NCSA Telnet (which allowed users to connect PCs and Macintoshes), and user-oriented interfaces for listservs and newsgroups, the Internet rapidly opened up and engaged a much broader community of users and contributors.

Perhaps the most significant Internet event of the 1990s was the creation of the technologies of the World Wide Web (WWW). In a key development, Tim Berners-Lee and scientists affiliated with CERN (Geneva), the European Centre for High Energy Physics, established the protocol based on hypertext that makes it possible to connect the content on the Web with hyperlinks. Then, in 1993, developers at NCSA at the University of Illinois released a Web browser called Mosaic, allowing computer users to view files on the World Wide Web more easily, files that include graphical elements as well as text. With the stage set by pervasive e-mail messaging capabilities and the broadly extended connectivity provided by the NSFNET, the addition of the World Wide Web caused the Internet to become

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broadly useful and to engage a critical mass of users. These developments set the stage for the mass popularization and commercialization of the Internet.

By the end of 1994, the Internet had truly arrived. The NSF and NSFNET community actively sought vehicles for "privatizing" the Internet and more actively bringing it to the world outside of research institutions and development communities. As a result, there was an explosion of private companies contending to provide Internet access to individuals and institutions. Similarly, a growing number of institutions in the educational sector (K-12 schools, colleges, universities, libraries, and museums) began to be connected and to contribute to this globally linked communications network and warehouse of information. The "privatization" of the Internet reached its recent apogee by the late 1990s as innumerable companies rushed to establish an online presence, products, and services. The recent global stock market downturn has led to a "shakeout" of Internet businesses where only the strongest companies have survived.

Most business and technology leaders agree that this recent economic phenomenon is just a consolidation phase; the Internet will continue to play a significant economic and social role in the twenty-first century, perhaps like railroads, or the steam engine, or the technologies of mass production did earlier. Today, in fact, nearly half of all U.S. households have Internet access. The number is even higher in Canada and in Scandinavia. And the rest of the world is catching up even as the Internet expands from computers to PDAs, to next generation cell phones, and to home and business appliances. In the end, this remarkable phenomenon is at least as much a product of the organizational and social innovations of the Internet culture as it is of the power of the core Internet technologies themselves.

Meanwhile, today's Internet—the commodity or commercial Internet—has recognized a number of limitations. At the same time numerous opportunities and new possibilities have emerged. Some challenges, like the inability to provide workable "quality of service" or end-to-end performance guarantees needed for applications such as voice telephone calls (which have strict and demanding constraints dictated by the necessary requirements of the human ear), were outside the scope of the Internet's original design goals. Challenges, such as dealing with tomorrow's gargantuan amounts of traffic, numbers of users and sites, and requirements for Internet addresses, are the consequences of unanticipated success. Other new but challenging opportunities, like the delivery on demand of real-time, movie-quality, high definition television (HDTV) or even films over the Internet, are the product of extraordinary progress in a wide array of technology industries that are now convergent with the Internet's evolutionary path.

Since the mid-1990s, the Internet and Internet technologies creators have been planning to update and extend these technologies to address those limitations and challenges. There are a number of typically overlapping and cooperating groups, including the Internet Engineering Task Force (IETF) and the University Corporation for Advanced Internet Development (UCAID), who have been working with the Internet research community to move beyond the current commodity Internet technologies to create the "Next Generation Internet" or "NGI" capabilities. The major U.S. test-bed and focus of development and deployment for the next generation of Internet technologies and fabric is Internet2.

Internet2 is a consortium, led by more than 180 universities, many of which, along with industry and government partners, are the institutions and individuals who created the original Internet. The purpose of Internet2 is to develop and deploy advanced network applications and technologies, thereby accelerating the creation of tomorrow's Internet capabilities. It is important to note that this partnership—and the ensuing development cycle from research and development, to partnerships, to privatizations and, ultimately, to technology transfer and commercialization—is being deliberately and significantly accelerated in Internet2.

The primary goals of Internet2 are to (a) create a leading-edge network capability for the national research community, (b) enable revolutionary Internet applications, and (c) ensure the rapid transfer of new network services and applications to the broader Internet community. With the latter goal in mind, Internet2 has launched and will lead an Internet2 K20 Initiative to extend advanced networks, applications, and services to the rest of the education community. Unlike the first generation Internet, which took nearly three decades to reach the mainstream education community and public, the goal of this initiative is to bring innovators from across all education sectors to the table.

The Internet2 K20 Initiative will engage K-12 schools, colleges and universities, libraries, and museums (and their government and corporate partners) in the development of partnerships and collaborations across a wide range of areas that leverage Internet2 technologies and networks. The Initiative will focus on programmatic and content efforts that are likely to facilitate teaching, learning, and access to educational opportunities for the broad education community and its constituencies. Potential areas to be pursued include advanced content repositories; advanced applications; middleware collaborations; advanced network services; broadband; and related research, evaluation, and information sharing. The following is a description of examples of these efforts and the technologies that will support them.

THE INTERNET2 K20 INITIATIVE: BACKGROUND

As many in the higher education technology community are aware, there is a staggering array of often opposing or diverging perspectives, interests, beliefs, and aspirations within K-12 and higher education that relate to the potential uses and misuses of technology in education. In the views of some, technology is a catalyst for the reform—even the transformation—of education. For others, technology is an essential tool for improving access to education. At the other end of the spectrum, there is the view that technology is a distraction or even an evil force. We also are aware of the involvement of an amazing number and kind of often powerful and sometimes feuding organizations, societies, academies, associations, agencies, movements, special interest groups, unions, publishers, corporate entities, foundations, and other organizations. Local, state, and national levels in education, educational change, and in many forms of "ed-tech": none are exempt.

Meanwhile, in education and elsewhere, over-promising, unrealistic expectations, magical thinking, unintended consequences, scope creep, diverging goals, too many cooks, excessive complexity, rigid bureaucratic approaches, or lack of focus are fatal flaws that often undermine technology initiatives. The majority of leaders in the technology research, development, and deployment community

recognize that often technology hasn't lived up to its promises. Even so, they continue to believe in the power of networks and technology to sometimes transform. They are impressed by the many instances where technology has significantly enabled, enhanced, and extended areas such as health care, government, commerce, science, and education.

In the education environment, however, there often seem to be special cultural, organizational, and economic impediments to bringing technology into K-12 schools and classrooms. The deployment of the Internet's remarkable "relationship" and "publication" technologies to enrich and extend the degree and quality of communication and participation among students, teachers, and parents poses unique challenges. Many U.S. schools are not yet even on the road to significant implementation of previous generation Internet technologies. Proven tools with proven benefits such as pervasive e-mail and listservs remain unimplemented or even unplanned in many districts.

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A decision was reached by the Internet2 community to extend access to Abilene, the Internet2 national network backbone, to the broad educational community and thereby engage innovators from all sectors of education in the development and deployment of advanced network services and applications. This consensus evolved through conversations among various Internet2-related councils and groups and discussions among Internet2 members. This decision, however, was neither rooted in broadly shared goals for, or exuberant optimism about, reforming or transforming K-12 education (or even higher education!), nor was it based on widely shared desires to join forces with groups with such aspirations.

Instead, this invitation was shaped by Internet2's goals, which are intrinsically technology related, and which would be best served by enabling Internet2 member institutions and "connectors" to bring the many innovators and innovative schools who do exist in K-12 (and in K-20) to the table. These are innovators who share interests in and commitments to advanced networking, content, services, and applications. Many in the Internet2 community believe that an important lesson was learned from previous networking and technology experiences (e.g., World Wide Web). That lesson is that big payoffs come from getting tomorrow's technologies (and often preferred, open standard-based versions) into the hands of as many innovators and sectors as quickly and as "connectedly" as possible. This time, with the Internet2 K20 Initiative, it seems possible to bring in the broader education community much sooner. Innovators across the educational spectrum could be invited to engage in initiatives involving Internet2 technologies, without over-promising, overextending, or losing focus of its advanced technology missions.

The approach developed to connect the broader education community to Internet2 is through a process called "Sponsored Education Group Participants" (SEGPs). The new SEGP program is intended to allow expanded access to Abilene for state and regional education networks through sponsorship by Internet2 university members. State and regional networks may include nonprofit and for-profit K-20 educational institutions, museums, libraries, art galleries, or hospitals. These are entities that would require routine collaboration on instructional, clinical and/or research projects, services, and content with Internet2 members or with other sponsored participants. The program began in early 2001; and, as of September, there were already fourteen state K-12/K-20 networks participating and passing traffic on Internet2. An additional twelve states have expressed interest and it appears that by the end of the 2001-02 academic year, there may be as many as twenty-five states participating as SEGPs. If so, that will bring an extraordinary number of K-12/K-20, museum, and library innovators to the table and enable a sweeping range of diverse initiatives. The eventual result would be very broad participation across a large number of schools and districts.

The fundamental Internet2 K20 issue remains how to achieve Internet2's goals of rapid technology creation, diffusion, transfer, and evolution. These goals are the defining criteria for determining Internet2's relationships and roles in Internet2 K20 initiatives and partnerships. School technology leaders and Internet2 innovators agree that a well-conceived and realistic approach to K-20 can be a win for both the Internet2 and the K-20 communities.

INTERNET2 K20 INITIATIVE: THE PLAN

Broadly stated, the Initiative has six goals: (1) to bring innovators in K-12, community colleges, universities, libraries, and museums into appropriate regional, national, and international advanced networking efforts, creating new "workgroups" where warranted; (2) to develop mechanisms for enabling quick, pervasive technology diffusion and transfer; (3) to create mechanisms for timely communication across educational sectors and regions; (4) to leverage and propagate Internet culture ("rough consensus and working code" involving a diverse range of parallel independent efforts) along with education, private sector, and government partnerships; (5) to get interested and capable SEGPs connected and properly engaged in existing workgroups and projects; and (6) where there is interest and realistic opportunity, include appropriate experiments in learning and education and help enable experiments involving innovative deployments of advanced technologies in education at SEGP sites.

Among the many activities of the Initiative, relevant state and national special interest groups are being formed in areas described below:

- content: actively seek out local resources and support (e.g., in music [ethnomusicology and music education], documentary film, animation arts, local history, photo archives, course materials, etc.)
- learning courseware, curriculum repository, and access projects
- video: H.323 and future interactive video and multimedia technologies, digital video, low- to high-end video multicast, and the convergence of on demand video and broadcast
- scientific apparatus and other broad application areas which could be shared across educational communities
- middleware, enhanced portal, and "relationship-ware" deployment and partnerships
- advanced I2 server technologies, caching, and co-location
- IPv6 deployment to remove some key "legacy Internet" limitations

Internet2 will encourage a strong research and evaluation component in all projects and initiatives, especially those where there are learning, clinical, organizational, or social claims or consequences.

SEGP representatives and colleagues from their key constituencies (colleges, K-12 schools, libraries, museums, etc.) who are interested in participating in the work of the Initiative began meeting in late summer 2001. Initial meetings will be used as a springboard for sharing ideas and shaping projects and for the development of an outline of the first-year agenda for the Initiative, with refinements coming from Initiative participants during the academic year. Simultaneously and throughout the year, as more state and regional networks choose to participate, the Internet2 project directors will meet in each state or region with interested stakeholders to determine how to engage innovators from all education sectors in the work of the Initiative.

The Internet2 community is working within the following framework and goals for this Initiative:

- An Internet2 working group, called the Internet2 K20 Initiative, will be the mechanism to facilitate coordination efforts of qualified parties who are interested in exploring educational uses of I2 technologies across and throughout K-20. Coordination efforts will include a variety of approaches. Included will be conference calls; engaging outstanding K-20 innovators in ongoing Internet2 efforts; and the establishment of communication framework, which might include video and telephone conferences, regional workshops and meetings, as well as the creation of special interest groups, at the state, regional, and national levels.
- The primary means for engendering K-20 participation in advanced networking, services, content, and applications efforts can be via participation in existing Internet2 workgroups and initiatives. This approach will be the initial focus of the Initiative.
- Where new and attractive Internet2 content, application, or service-related ideas emerge from the Internet2 K20 Initiative that involve new workgroups or projects, they will be added and supported as Internet2 efforts, as will ideas and initiatives that arise from Internet2's education or research members and partners.

- Where there are Internet2 mission-related advanced technology content, services, and/or applications initiatives under way in K-20 or other related communities, Internet2 will pursue efforts to coordinate our respective efforts as appropriate, using the Initiative to do so. For example, there may be interest in engaging K-20 innovators in Internet2's arts and humanities initiatives.
- Internet2 has no expertise in significant educational reform or transformation, nor in the uses of technology outside of the research university community. Consequently, it will not attempt to play the program leadership role in conducting such efforts. Internet2 will, however, eagerly participate in and lead technology components of such efforts where participation supports significant Internet2 technology and technology diffusion and transfer goals. Internet2 goals for the K20 Initiative are (a) to enable innovators in education and in technology to have access to and employ our next generation technologies in their efforts and (b) to ensure that innovators in education, museum, and library communities employ Internet2 technologies as their development platform whenever appropriate.
- Internet2 will encourage a strong research and evaluation component in all projects and initiatives, especially those where there are learning, clinical, organizational, or social claims or consequences.
- The K20 Initiative can assist the SEGPs and other education community collaborators to establish efficacious and appropriate mechanisms to capture and communicate the knowledge generated by and from initiatives, innovators, and experiments. The K20 Initiative will work to disseminate such knowledge in the research, education, and technology communities.
- K20 Initiative partners will investigate the creation of purpose-built, Internet2-sponsored K-20 conferences and workshops to help facilitate understanding of Internet2 opportunities and to stimulate and sustain coordination and collaboration among K-20 communities and other interested parties.

Digital video is expected to play a major role in applications that will change how we teach, learn, collaborate, and conduct research in higher education.

The advanced networking environment of Internet2 has enabled the creation of revolutionary Internet applications. However, these applications often require network characteristics not generally available on today's commodity Internet, such as high bandwidth levels, multicast, latency (delay) control, and jitter (variability in delay) control. Eventually these new technologies and capabilities will be deployed throughout the global Internet. In the meantime, innovators from all sectors of education will have an opportunity to deploy, experiment with, and develop new applications or take existing applications to new levels of capability. Here are a few examples of current applications being developed and tested on Internet2.

DIGITAL VIDEO

The Internet2 Digital Video Initiative (I2DV) is a national, higher education video network service developed to provide capabilities and to support scalable and easy-to-use applications to deliver live or stored streaming and interactive high-quality digital video. The term "video" includes traditional video and also simulations, animations, virtual reality movies, images with audio sound tracks, remote control of microscopes and other instrumentation, and other types of digital media objects. Digital video is expected to play a major role in applications that will change how we teach, learn, collaborate, and conduct research in higher education.

Currently, many (not all) of the applications of digital video on Internet2 are prototypes, experimental projects, and conceptual designs rather than supported production services. One interesting and real-world project and collaboration is the ResearchChannel, which, among other innovations in digital convergence, provides a pioneering combination of a real-world broadcast television channel (as seen on the Dish consumer DBS network and various CATV systems nationally) with TV-quality on-demand video (www.researchchannel.com).

Beyond developing the technologies needed to deliver live or stored streaming digital video, the Internet2 Digital Video Initiative is working on ways to gather, store, and establish a means to license and distribute content for courses, informal lectures, documentaries, and videoconferences among Internet2 member institutions. This Initiative greatly enhances and expands capabilities for producing and distributing highly specialized digital video content.

Currently, there is little security associated with videoconferencing. Much work needs to be done before there will be appropriate authentication, authorization, and privacy services for videoconferencing.

ADVANCED VIDEOCONFERENCING (H.323 AND BEYOND)

H.323 is an International Telecommunications Union (ITU) standard for interoperability in audio and videoconferencing over Internet Protocols (IP) as well as Internet phone and voice-over-IP. Other standards exist as well, namely the IETF Simple Initiation Protocol (SIP). These are umbrella standards that specify mandatory and optional requirements in several areas to enable a complete "call" or communication sequence.

The goal of videoconferencing on Internet2 is to create an environment where one can truly interact with others without the barriers of distance. Videoconferencing can be delivered efficiently to one viewer or to multiple viewers simultaneously if it is being transmitted over a multicast-enabled network. Videoconferencing can be used on a single desktop or in a room-based environment and can be scheduled or left open 24 hours a day for drop-in use. Participants can be visualized in different ways, including showing the current speaker on the screen or having all participants' persistent presence appear in a box on the screen. The I2DV Videoconferencing Subcommittee of Internet2 is planning to develop an information exchange that would allow participating organizations to gather and make available information via the Web about videoconferencing work, experiences, and available resources at the various sites.

Currently, there is little security associated with videoconferencing. Much work needs to be done before there will be appropriate authentication, authorization, and privacy services for videoconferencing. Further, videoconferencing is very sensitive to packet loss. Quality of Service (QoS) "fast lane" treatment on the network is essential (more about QoS follows). Implementing QoS across autonomously managed networks is still in the development stages.

In a tele-immersive environment, computers recognize and track the presence and movements of individuals and objects and then permit them to be projected onto realistic, three-dimensional screens.

There are important social issues associated with videoconferencing as well. Eye-to-eye contact is difficult due to the separation of the monitor and the camera, which can lead to the disconcerting feeling that occurs when someone you are talking to looks over your shoulder the entire time. Work is being done to embed cameras into the monitors to help align participants' eyes. The future of videoconferencing may be in the development of tele-immersion, a technology that combines videoconferencing with virtual reality, transcending the intrinsic limitations of the camera.

REMOTE INSTRUMENTATION

Many scientific instruments can be connected to Internet2 and operated remotely.

The University of North Carolina at Chapel Hill has developed the NanoManipulator. This application allows long-distance remote control of a scanning-probe microscope. The viewer observes objects at nanometer scale as three-dimensional images. A haptic, or force-feedback device, allows the viewer to "touch" what he or she sees. www.cs.unc.edu/Research/nano/

Tele-vator is a computerized excavation backhoe that can be remotely operated over Internet2 high-performance networks. Because of its size and potential criticality of operation (e.g., in hazardous rescue situations), Tele-vator requires a high-level of sophisticated two-way feedback, including adequate depth of vision provided via high-definition stereovision. www.internet2.edu/resources/infosheetvideo.pdf

The University of Illinois at Urbana-Champaign's Bugscope project is an educational outreach program aimed at K-12 classrooms. The project provides a resource to classrooms so that students can operate a remote scanning electron microscope to image "bugs" at high magnification. The microscope is remotely controlled in real time from a classroom computer over Internet2 using a Web browser. http://bugscope.beckman.uiuc.edu/

VIRTUAL REALITY

Virtual reality (VR) is the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth and that may also provide an interactive experience visually in full real-time motion with sound and, possibly, with tactile and other forms of feedback. Basic elements and ideas of VR were in place in the 1980s, but it took the advancement in affordable computing power in the 1990s to bring VR closer to reality.

The simplest form of virtual reality is a 3-D image that can be explored interactively at a personal computer, usually by manipulating keys or the mouse so that the content of the image moves in some direction or zooms in or out.

Current Internet2 research on virtual reality is centered on tele-immersion.

TELE-IMMERSION

Tele-immersion is a new telecommunications medium that combines aspects of virtual reality and videoconferencing. It enables people to interact in real time as though they were in the same room, even though they may be separated by time and space. This new resource provides an opportunity for the full integration of VR into the everyday work environment and goes beyond the limitations of videoconferencing. Rather than merely observing people and their immediate environment from one vantage point (a camera is locked into portraying a scene from its own position), tele-immersion environments convey multiple images as moving sculptures that appear in the virtual space between users without favoring a single point of view. Users can manipulate objects as though they were working models.

In a tele-immersive environment, computers recognize and track the presence and movements of individuals and objects and then permit them to be projected onto realistic, three-dimensional screens. Seen through a pair of polarizing glasses, the screen dissolves into windows, revealing, for instance, other offices with other people who are looking back at the user.

In tele-immersion, physical and virtual environments appear united for both input and display. This new paradigm for human-computer interaction is the ultimate synthesis of networking and media technologies and, therefore, represents the greatest technical challenge for Internet2. If a computer network can support tele-immersion, it can probably support any other application. Tele-immersion can be thought of as the next logical step in the development of virtual reality. Jaron Lanier, often described as the father of virtual reality, is the chief scientist of the Internet2 National Tele-immersion Initiative.

HIGH-FIDELITY AUDIO AND BROADCASTING

The ability to transmit streaming real-time high-fidelity audio and video over the advanced Internet2 network allows technologies usually associated with the sciences to add exciting new dimensions to the arts and humanities. Internet2 networks provide the kind of real-time, high-quality audio and video that, for the first time, enable distance coaching at the highest levels of musical performance, as well as offer the possibility of remote orchestral job auditions and performances with remote collaborators. This type of interactive, high-fidelity audio is not possible over the commercial Internet due to bandwidth and other quality-of-service limitations which have been overcome with Internet2. Here are a couple of examples of how Internet2 is using its advanced networking abilities to further high-fidelity audio and video broadcasting.

- Established in 1987 under the artistic direction of Michael Tilson Thomas, the New World Symphony trains the most gifted graduates of distinguished music programs for leadership positions in orchestras and ensembles around the world. The New World Symphony, the first orchestra to become an Internet2 member, will use high-performance networks to offer its 85 young musicians ongoing access to great teaching artists at major music schools and conservatories across the country.
- KEXP, a Seattle-based noncommercial radio station, in partnership with the University of Washington and the ResearchChannel Consortium, transmits around-the-clock uncompressed audio stream of its programming over the Internet. Internet2 listeners receive the highest quality audio experience at a

rate of 1.4 Mbps. Streaming uncompressed audio over Internet2 high-performance networks not only represents the "gold standard" in delivering the richest and the purest musical content but also demonstrates how Internet2 networks can distribute the work of artists in the highest quality possible. This allows an audience to experience and appreciate music the way it is meant to be experienced live.

ENABLING TECHNOLOGIES

The following are examples of some of the underlying technologies being developed to make the previous exciting applications possible.

MIDDLEWARE

The term "middleware" is used to cover a broad array of tools, information, and what programmers call "hooks" that help applications use advanced network resources and services. Technology wags also refer to middleware as that which doesn't want to be addressed either by those who provide the infrastructure or those who write the applications. In reality, middleware can be thought of as glue layers that provide reliable, standardized support services like authenticating users and authorizing them (or not) to use specific applications or have access to certain resources. Indeed one common application of middleware is to provide the common services and information necessary to allow applications to restrict or enable access ("log on") to certain resources.

Relatively straightforward—though still exceedingly complex to design for any shared environment—middleware such as authentication (are people or programs who they say they are?), authorization (what is he, she, or it allowed to do?), and the directory services needed to keep track of users, resources, and any rules that may apply to them, comprise essential elements of any shared network computing infrastructure. Other services, such as cooperative scheduling of networked resources, enabling secure multicast or interactive video or object brokering (matching requests with providers for relatively high level services, such as databases, format, or protocol conversion) are major middleware preconditions

Attaining this level of cooperation is as important an aim of Internet2 as is the development of the tools themselves. It is an endeavor that parallels the development and evolution of the Internet and earlier Internet technologies.

for many applications and services sought by the research and education communities. These include a number of innovative applications.

Broad adoption across education of certain standardized middleware fabric is a key requirement for addressing the needs of the education community for capabilities like user-friendly, but broadly shared and highly cost-effective access to libraries, music, and other intellectual property; for use of widely and safely shared interactive services; and for workable and properly protected wide-scale student records access and transmission. To attain these possibilities, Internet2 middleware must be, as a practical matter, interoperable between applications, among campuses and other educational institutions, and the wider Internet. This effort will not be successful if individual groups or institutions build their own internal versions of middleware and then try to patch the pieces together. Instead, we need tools, policy frameworks, and standards that are reasonably common (again, as in "rough consensus and working code") across institutions. Attaining this level of cooperation is as important an aim of Internet2 as is the development of the tools themselves. It is an endeavor that parallels the development and evolution of the Internet and earlier Internet technologies.

IPv6

Over the next few years, conventional computers will be joined on the Internet by a myriad of new devices, including palmtop personal digital assistants (PDAs), hybrid mobile phone technology with data processing capabilities, smart set-top boxes with integrated Web browsers, and embedded network components in equipment ranging from office copy machines to kitchen appliances.

Internet Protocol version 6 (also referred to as IP next generation or IPng) is needed because the Web will run out of addresses by 2005. The current technology, known as Internet Protocol version 4 (IPv4), supports just 4 billion addresses, not nearly enough to cope with the explosion of new devices that will connect to the Internet and need addresses.

With the long haul in mind, IPv6 has been outfitted with an enormous 128-bit address space (IPv4 currently supports 32-bit addresses) that should provide globally unique addresses for every conceivable variety of network devices for the foreseeable future (i.e., decades).

But IPv6 is a big package, and addressing is only the most visible component of the work. IPv6 also attempts to deal with critical business requirements for more scalable network architectures, improved security and data integrity, auto configuration, mobile computing, data multicasting, and more efficient network route aggregation at the global backbone level.

In May 2001, Cisco Systems announced it will support IPv6, and Microsoft could have IPv6 support ready by next year. Despite the benefits of IPv6, many organizations may continue to use IPv4. Network Address Translation (NAT), which requires only a single IPv4 address for an entire network, has prolonged IPv4's lifetime indefinitely. However, new classes of devices will only be able to use IPv6. Since IPv6 and IPv4 can exist simultaneously on the commercial Internet, this will not really create a networking problem. Many of the answers to questions about the transition from IPv4 to IPv6 will depend upon how Microsoft integrates the new protocol into its software applications.

IP MULTICAST

IP multicast is an important part of Internet2 as it enables one copy of digital information, usually high bandwidth real-time audio and video streams, to be received by multiple computers at the same time (somewhat as radio and TV programs are broadcast over airwaves). Prior to implementing multicast, all traffic on IP networks was unicast: one user requesting files from one source at another Internet address. For instance, in a videoconference, copies of the same data are unicast to the number of receivers present. With IP multicast, one copy of the same data, sent to a group address, goes to one router, which then sends it to multiple receivers. IP multicast results in significant bandwidth savings across a network.

In 1994, the Internet Engineering Task Force (IETF) set up what is called the Mbone or the Multicast Internet. Since most IP servers on the Internet are not configured to support the multicasting part of the IP protocol, the Mbone was set up to form a network within the Internet that could transmit IP multicasts. One of the strategic goals of Internet2 is to support native multicast, instead of relying on the Mbone overlay of multicast tunnels. The Abilene backbone routers have native multicast enabled.

QUALITY OF SERVICE (QoS)

One of the primary goals of Internet2 is to support the research and education missions of universities through the development of new advanced networked applications. The commercial Internet cannot provide the necessary end-to-end performance assurances needed to run these applications over a network.

Quality of Service (QoS) refers to the capability of a network to provide better service to selected network traffic. The type of QoS deployed on Internet2 is known as "differentiated service." This means that certain advanced application data packets will get preferential treatment over other types of traffic.

The current routers operating on the Internet treat all packets as equals. If there is network congestion, the router drops packets indiscriminately. The Internet2 QoS-enabled routers are configured to give advanced application packet traffic priority; however, there are still no absolute guarantees that packets will not be dropped during congested periods. While the high-capacity Internet2 links are rarely congested, it is still important to deploy and to test QoS capabilities, since even high-capacity links can suffer instantaneous congestion, and, therefore, the occasional packet loss.

QoS across autonomously managed networks is still very much in the development stages. This is an issue for maintaining high performance across not only a single wide-area backbone but also multiple backbones and enterprise networks. Of course, campus and other networks need to be upgraded to contemporary network standards in order to participate in these QoS development and testing efforts.

VOICE OVER IP

Voice Over IP is a general term for the technologies that use the Internet Protocols' packet-switched connections to exchange voice, fax, and other forms of information that have traditionally been carried over the dedicated circuit-switched connections of the Public Switched Telephone Network (PSTN). Rather than voice traveling in the traditional circuit-committed protocols, it is converted into discrete packets of digital information and sent over the Internet using IP.

The challenge of Voice Over IP (VOIP) is to deliver voice, fax, or video packets to a user in a dependable flow with minimum delay. Much of IP telephony focuses on this challenge. Internet2 is the ideal networking environment for VOIP because it gives precedence to VOIP packets over other applications when or if there is congestion on the network.

END-TO-END PERFORMANCE

Internet2 member universities have gained access to high-performance backbone networks. Now, under certain conditions within particular regional and local network environments, faculty, researchers, and students can experience the full benefit of this infrastructure in the development and use of advanced applications.

However, too often many developers and campus network users experience a gap between the potential of the national high-performance networking infrastructure and their own experience when they use the network to accomplish their work.

The goal of the Internet2 End-to-End Performance Initiative is to create a predictable and well-supported environment in which Internet2 campus network users have routinely successful experiences in their development and use of advanced Internet applications. This is accomplished by focusing resources and efforts on improving performance problem detection and resolution throughout campus, regional, and national networking infrastructures.

ALIGNING SCHOOL AND INTERNET CULTURES: TOWARD INDEPENDENCE AND INTEROPERABILITY

The authors strongly believe that the organization, architecture, and culture of technology and its role in a school matter fundamentally. They can have a decisive effect upon the ability of a system or school to leverage technology for

Internet technologies and cultures also rely heavily on decidedly Darwinian approaches to evolve the technology and its implementations. Instantiations of a technology typically are seen as serving a calculated evolutionary purpose as vehicles for finding and figuring out what does and doesn't work, and for achieving necessary adaptation by the technology to, at least, survive in a critical mass number and/or a variety of environments.

change and for support of its core missions; and they often define, circumscribe, enable, or impede. In general, they can shape the approaches to all probable uses of technology in any part of that institution. Technology infrastructure and architecture (which frequently dictate or reflect the technology "culture" of an institution) condition the possibilities, nature, and likely success of a district's or school's technology initiatives. If the core institutional technology architecture and culture are not well-oriented to a mission, function, or application—like teaching and learning, or open and free communications, or an academically-oriented (rather than administrative) e-publishing infrastructure—then pursuit of that mission, function, or application area will be more difficult than if the technology infrastructure were aligned with this area.

Unfortunately, in many systems and schools, administrative systems and administrative telecommunications remain the sole technology focus and drivers. Building the technology organization and architecture on administrative systems tends to create an environment that is centrally controlled, procedure and process driven, and best suited to running a bureaucracy in high-control and accountability modes. Alas, such relatively inflexible centralized examples of technology management and architecture, combined with an administrative focus, make it harder to stimulate, discover, develop, and evolve applications, technology, and content that enhance learning, teaching, and communicating. Centralized, administrative-oriented systems, structures, and philosophies are not particularly attuned to or supportive of the needs and priorities of learning and teaching. They are structured to manage traditional projects and resources effectively, not to encourage broad experimentation with (and use of) new technology, independent action, unstructured collaboration, distributed participation, broadly interactive communications, or collaborative communities.

The main point is that such centralized processes are not well disposed to nurture the powerful technology innovation and adoption forces of the Internet technology and culture. In fact, they are often in direct opposition.

The evolution of Internet technology itself and many of the great success stories in bringing Internet and other technologies to bear in efforts to change and enhance teaching, learning, research, business, and health care are the products of a much different model with a different set of tools and philosophies. Internet approaches are based on stimulating and enabling diversity of innovators and implementers to work in parallel with only loose—and, in many cases, no formal—coordination. Open, evolving, community-owned Internet standards are the ultimate tests of interoperability, and critical mass adoption is often the main mechanism of coordination. It seems that in K-12 we will need to achieve similar levels of effective participation, creativity, energy, and diffusion to tackle the challenges we face.

Internet technologies and cultures also rely heavily on decidedly Darwinian approaches to evolve the technology and its implementations. Instantiations of a technology typically are seen as serving a calculated evolutionary purpose as vehicles for finding and figuring out what does and doesn't work and for achieving necessary adaptation by the technology to, at least, survive in a critical mass number and/or a variety of environments. In Internet industries and contexts, the often-used process is to drive evolving technologies, applications, and content to as many desktops and servers in as many local environments as possible. This is done best with mechanisms requiring minimal local human intervention.

Indeed, frequently what works best in the continuous evolutionary crucible of the Internet is configuring the technologies themselves to fit into or auto-adapt to many contexts. E-mail, browsers, listservs, network deployments, and Web-servers are all examples of this. These are all cases where important progress comes by evolving the technology so it works in the maximum number of contexts with the least need for broad organizational processes and structures. To be sure, there are often standard models or a set of "best practices" for implementing and managing the technology, but these are primarily guiding and facilitating rather than driving forces. But even where it is people, not technology vectors, who spread a new idea, adaptation, use, or form of technology, it is an evolutionary—rather than a central planning and coordinating—model that drives and informs technology progress and new and improved uses of technology. Capturing this kind of dynamism and evolutionary progress seems crucial to generating sustained progress in the uses of technology in K-12.

Another difference already mentioned between an "Internet model" and the traditional technology deployment model (still prevalent in much of K-12) is that the former looks for opportunities and mechanisms to make the technology itself and/or its users the vehicle of its own expansion and extension, often with stimulus from technology enthusiasts in a given locality. This approach has often proved to be a better vehicle for achieving scale and pervasive numbers of instantiations than the top-down, centrally controlled, organizational mechanisms favored by many K-12 and government sites. An example of the Internet approach is the way that Web infrastructure components are built so they are self-installing, self-extending, and self-modifying—that is, if you want to add streaming media to your Web browser, the Internet does that automatically via downloads, plug-ins, and cookie information. This is far more efficient than, say, a specific institutional initiative or project to modify or update the code on every computer in an organization.

In many cases, the Internet approach is a better model and modality for technology and content deployment than is a structure based on local entities mounting governing and guiding interventions and traditional projects. In this regard, it may be that the relative paucity of successful and pervasive implementations of simple things like enterprise-wide e-mail (for all K-12 teachers, students, and parents) or universal e-publishing capacity for all students (common elsewhere in education) is more the result of resisting—or at least not embracing—the normal and broadly successful implementation of these new technologies than it is the product of school resource constraints. In the world of Internet technologies, "top down," high central control approaches rarely achieve and sustain widespread deployment and evolving efficacious technology at network, component, applications, or content layers.

This leads to another characteristic of Internet technology, industry, and culture: perhaps radical, seemingly authoritarian, but sometimes liberating and democratic. Internet innovators seek, and the marketplace rewards, technology that is highly scalable, extensible, broadly usable and, ultimately, desirable to end-users. To a degree, localities, marketplaces, or sites serve as test environments where Darwinian evolution and adaptation of those technologies take place. Indeed, at times local governance and decision making are things that the successful technology needs to be able to overcome. This is often accomplished by the technology being automatically adaptive so it self-modifies to fit into a critical mass of environments. That is, the technology either evolves via update mechanisms built into the applications themselves or at the hand of end-users rather than central planners. For core protocols, the Internet industry takes the more heavy-handed approach of working in a "take it or leave it, but you need it" mode. However, this enables local deviation from top-down approaches with respect to those applications built on top of the Internet's basic network communications capabilities (or "Common Bearer Service"). Still, to the degree local variations work in the evolution and diffusion processes, this is again an instance of the Internet approach of rough consensus of a viable, critical-mass number of successful instantiations in different environments, and working code, which means not only that the code works but that it will also fit into, interoperate, and evolve with other instances of the same specification or with related technologies in diverse environments.

The rise, accelerating evolution, and astonishing pervasiveness of the Internet are remarkable phenomena. Some have characterized the approaches which have achieved this success as "post-organizational": a model of change predicated upon minimizing organizational, governance, and process entanglements while maximizing the power and relative independence of those employing the technologies.

The bottom line for us is that (a) to be more successful in deploying and evolving technology in better support to key missions, we need to transition to organizational structures, philosophies, technical architectures, and cultures that are aligned with our key educational missions and (b) to reap the rewards of technology, we need to orient our resources and structures to work with and to leverage—rather than work against and refract—the natural forces of Internet technologies.

More bluntly, we believe that in order to have an abiding effect on learning and teaching technologies and initiatives, many states, districts, and schools will need to make a frontal assault on their core information technology architectures and cultures. They must shift them so that their primary directives and approaches are to implement technologies that support communicating, teaching, learning, and distributed participation and that take advantage of the intrinsic, relatively informal, and easy-to-use characteristics of most Internet technologies. The pathway to this change really isn't to create additional segregated learning, teaching, communicating technology groups or initiatives. Such work-around approaches generally fail and usually drive up costs. (There are many examples of this failed approach in higher education, government, libraries, health care, and business, as well as K-12). Instead, in the end, a successful organization and architecture for (and of) technology is typically one that is aligned with the learning and teaching missions of schools. It must be oriented to an open, inclusive, communications-intensive Internet culture that enables and encourages independent and creative, though loosely interconnected, action—action with explicit goals of interoperability on the part of students, teachers, technologists, and schools themselves. School technology cultures that are based on principles of independent action and interoperability will be able to take advantage of the learning, teaching, and communicating capacities of today's Internet and, equally important, will be part of and contributors to the Next Generation Internet.

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The views in the final section of this article should not be construed as the official views of Internet2, the University of Washington, or any other organization; rather, they represent, solely, the opinions of the authors.

V I S I O N

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THE TYRANNY OF THE QUANTIFIABLE

Jaron Lanier

Jaron Lanier, a pioneer of virtual reality, discusses the complexities inherent in our quest to understand the benefits of technology in education. He contends that despite the excitement surrounding digital learning tools, there is little agreement about how to best use them. In the Leadership section Ron Kriz and his team from the University Visualization and Animation Group at Virginia Tech have joined Tom Morgan and the Virginia Governor's Schools to explore how virtual environments can be used effectively to enhance learning in K-12 education.

THE TYRANNY OF THE QUANTIFIABLE *Jaron Lanier*

THE RAINSTORM VERSUS THE OIL FIELD

Our era is characterized most fundamentally by its changing technologies. Whenever and wherever we might hope to influence events by changes in policy or pedagogy, new gadgets are likely to come along that will recast our efforts in hard-to-predict ways.

For instance, the introduction of e-mail, chat, and short messages system (i.e., SMS, chat over wireless devices) has driven an upsurge in the recreational use of written language among young people whose parents, weaned on television, movies, and the telephone, regarded the task of writing as more of an obligation, dictated by work or school.

In academia, both the sciences and the humanities have been reformulated by encounters with computers and in some similar ways. Computers have enabled software tools to make some problems (ones that were at one time treated as being irreducible, and therefore best handled by wizened intuitive individuals) into quantifiable and comprehensible processes. For example, there is now considerably less guesswork in drilling for oil. Computer analyses of oil fields have actually resulted in an increase in the available supply when only an ever-worsening decline had been predicted. It also has become clear, however, that not all complexities are equally complex. For instance, we have improved our predictions of the odds of a new oil well's success more quickly than we have improved our ability to predict the weather. By current standards, weather is considered a "chaotic" phenomenon; we have studied it and other such phenomena well enough to believe that some complexities will remain beyond us forever or at least for the foreseeable future.

We will get better at predicting the weather, to be sure, but we will probably never be as accurate as we would like. There are multiple reasons for this. One immediate

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problem is that computers are still rather low-resolution, slow devices when measured against the standards of weather. Another problem is that we can't measure the state of the atmosphere at any given time as well as we might like.

For each such immediate limitation in our abilities, there is a more dramatic version in the form of an ultimate question about the nature of computers: Can we build simulations that summarize the events of the universe well enough so that one subset of the universe (arranged to be a computer) could even theoretically simulate a larger subset to predict something like weather?

A second example of an ultimate question is whether it would ever be even theoretically possible to gather enough real-world data quickly enough to satisfy the demands of the weather simulation of our dreams. If we can't give the computer sufficiently good starting data, it cannot give us the results we hope for.

The weather is one of a number of natural systems that most theorists regard as sufficiently complex as to always remain beyond the reach of comprehensive and practical reduction. We might be able to understand the dynamics of weather. We might be able to predict how much the atmosphere will warm in the next century if we continue our current energy policies. We might be able to predict whether it will rain tomorrow in Poughkeepsie. But we may never be able to predict if it will rain there next month.

This is the nature of the sciences of complexity. We are able to achieve useful theoretical reductions at some levels of description and not at others.

TRAINS PASSING IN THE NIGHT

Unfortunately, the humanities have recently been provoked by metaphors from computer science without being tempered by the harshness of empirical successes and failures. Because our knowledge of the intelligent and social aspects of the human brain is so far beyond current science, we don't even know enough to get a clear negative result to an experiment about something as complex as education. If we understood the brain better, it would be easier to define what aspects we didn't understand. As it is, we can't even be articulate about our areas of ignorance, so it is almost inevitable that we pretend to know more than we do.

The central question in the "cybernetically-excited" humanities should be, "Is the human mind more like an oil field or more like the weather?" Political and academic forces seem to be increasingly inclined to see the human mind, particularly the young, developing mind, as being more like an oil field: malleable, optimizable, predictable. And profitable. This bias is seen in the increased emphasis on testing, the decline in funding for experiential learning that requires equipment (such as microscopes or clarinets), and the many stultifying primary school textbooks now in use.

There are two good reasons to think that human minds are more like weather than oil fields: One is based on evidence. As with the weather, there are narrow frames of description in which human behavior is fairly predictable and even predictably modifiable. Although these are better known to advertisers and political consultants than to educators, they nonetheless do exist. It remains true, however, that human behavior is the least predictable phenomenon we know. Many academic beliefs in human predictability were allowed to stand for years only to fall after an initial empirical test.

One story is of the Stanford researchers hired by Microsoft to design simulated "personalities" for computer software. The theorists believed that consumers would be helplessly and beneficially responsive to software that attempted to verbally dominate or be dominated by the user. This idea resulted in productivity software oddly called "Bob" that was "dressed up" as if it were a suburban S&M parlor. Needless to say, the result bombed in the marketplace, but what is remarkable is that it was tried at all.

The other reason to believe that human minds are more like weather than oil fields is a moral one. As we gain scientific insights into the workings of the human mind, it is important that we not slip into a belief that minds are merely elaborate machines. The founding documents of modern democracy rightly evoke arguments for the divine rights of free human beings, because ultimately the rights and status of a human being cannot be argued scientifically. We must rely on faith in some core of free will in a person or our notion of society collapses. This faith is neither true nor false from a scientific point of view, because it is a premise that cannot ultimately be expressed nor tested scientifically. It is a small crime against our culture when the language of education and the humanities encourage excessive quantitative assessments of individuals. Such small crimes did not begin with computers, but computers have provided a language that is stealthier and easier to accept in many quarters.

Like two trains passing in the night, the sciences and humanities have reacted to computational complexity in almost opposite ways. The hard sciences have started to parse

For instance, testing has been with us for a long time, but now testing is applied to schools, teachers, school districts, and any other unit of description—all done with language borrowed from engineering.

the world by how easily various parts of it can be usefully reduced. Some aspects of the world are understood to be more like oil fields and some more like rainstorms.

IF ONLY STUDENTS WERE COMPUTERS!

The humanities, alas, have moved in the opposite direction. Education has come to be increasingly characterized by "results oriented" approaches. What might seem to be a borrowing of terminology and technique from the business world is actually a second-hand borrowing from engineers and scientists. (I will refer mostly to the situation in the United States, with which I am most familiar.)

This has not resulted in the introduction of radical new education tools nearly as much as one might hope. Instead, it has more often resulted in new justifications for old ideas, precisely because these are more describable and more easily integrated into fantasies of predictability. For instance, testing has been with us for a long time, but now testing is applied to schools, teachers, school districts, and any other unit of description—all done with language borrowed from engineering. While there have been many examples of humans being treated as machines in educational, correctional, and medical circumstances since The Enlightenment, what is new is the "cybernetic" systems approach.

Because people are so complicated that we don't even know how complicated we are, we tend to treat ourselves with linear approximation. The core problem is probably political and economic. Societies don't like to devote a lot of resources to things that are not understood.

So, in countries where education is well funded, it tends to be rigidly construed. Examples are Germany and Japan: both have excellent universal education and teachers who enjoy status and live well—but this comes at the expense of an overly linear education model. I personally would not have survived in the schools of either country. In the United States, on the other hand, support for education is low: Teachers are poorly paid and have little status. But the system is a little more open. Many successful adults remember having one or two "magic teachers" who brought devotion above and beyond the curriculum to their work.

(It should be noted that as I write this, the Bush administration is trying to make American education more rigid, linear, and bounded like the Japanese or German systems. If my theory is correct, America will start spending more money on education if these reforms take hold, even though that is certainly not the intent at this time.)

The world as a whole probably benefits from the diversity of educational styles. There's some truth to the cliché that the United States has produced a disproportionate number of creative and innovative people even in quantitative pursuits like engineering.

Because the linear mind-set will accept approaches that create the illusion that a problem is understood, it is easy to get people interested in putting computers in classrooms. Even Newt Gingrich, a conservative American politician of the 1990s who was famously cautious about public spending, was excited about the idea of putting computers in front of children.

Because the linear mindset will accept approaches that create the illusion that a problem is understood, it is easy to get people interested in putting computers in classrooms.

What usually happens when this is tried is that policymakers face a rude surprise. If kids are allowed to use computers creatively, the result is even less linear and harder to track, and therefore justify, than what was there before. If the computers are used linearly, then they turn out to be more expensive than the old way of doing linear things. This is because the whole lifecycle of a computer includes maintenance that a book doesn't need, and a book lasts longer. This has resulted in a sort of confused situation in which there's still a lot of excitement about digital tools in schools, but no widely agreed-upon idea about how to use them.

SMELLIER THAN CHEESE

Since the benefits of computers in education are so complex that we rely on fake measurements, it shouldn't come as a complete surprise that the costs of computers in schools are often underestimated. The sad truth is that computers go bad as fast as cheese. The uses that children are most interested in—and that can be the most effective in most educational applications—happen to be just the things for which the most up-to-date computer is needed: 3-D graphics, sound, color, display, etc. So schools are in the position of making capital investments that become antiquated faster than any other item. School computers have a reputation on a par with school food.

The usual way that technologies are bundled for use in classrooms is as follows. Software is written for some particular machines by a vendor. The specified machines and software are bought and installed at great expense by a school, often with special one-time

funding support. After a couple of years the machines are quite obsolete by prevailing standards, and many of them cease to function correctly. It quickly becomes hard to find personnel to maintain the machines, as qualified candidates are motivated to learn about newer machines and to seek better pay elsewhere. Existing machines fall into disuse and then the whole cycle begins again.

Sadly, the length of time that it takes to develop software is sometimes longer than the period in which it is genuinely useful (although it may remain in use for a longer period of time). What is most frustrating is that the true and full costs of a generation of educational software are almost always grossly underestimated. It is also probably true that educational software usually has a briefer period of relevancy than anticipated.

This is a confounding paradox. Recently there have been campaigns to have businesses donate obsolete computers to schools in exchange for tax write-offs. This is worse than useless because it is inordinately expensive to find a way to make use of assorted and slightly but not quite compatible, old machines that are inherently dull.

Young people want—and indeed need—the very latest computers. The more recent a computer, the less it is merely a text processor and the more it is a potential simulator. In this way, computer power directly maps into educational paradigms. This observation should rightly be seen as problematic by advocates of underserved populations. There is no question that underprivileged kids depend on schools for many items that are not available in the home, often including food. It is unreasonable to expect these students to have access to computers at home.

Instead of trying to finance an endless dispiriting money pit, there is an alternative that should be tried. It would not be easy, but it's worthy of consideration.

Every year and a half or so, a new digital medium design coupled with a cultural-use pattern emerges suddenly among teenagers and young adults. This takes on giant proportions, sometimes dwarfing all other media usage. It then starts to slowly fade. Some recent examples, in reverse order of their appearance on the scene, include SMS, Napster, Doom/Quake, chat, e-mail, and personal Web pages. These are the collaborative examples, but they are joined by equally impressive, though more proprietary, experiences such as PlayStation 2 games.

In short, young people's ravenous appetite for interactive games and media-related products remains persistent and will probably continue to fuel the development of affordable consumer electronics and media.

Traveling in poor areas in the United States, and even in much of the urban Third World, I am struck by the widespread availability of consumer electronics. Video games, satellite TV, and other gadgets find their way to many places that lack sufficient potable water.

We should be leveraging the gadgets that kids are choosing for themselves, all over the world. Educational materials should have been flowing over Napster before it was shut down, for instance, and subjects should be taught through prevalent devices such as the PlayStation. We should have an early response team that charts digital trends, and we should act quickly to harness new trends as they appear. There are two profound challenges to this idea. One is that some businesses might not agree to have their products used for education. It might take some years but I believe the case must be made that consumer electronics and popular distributed software provide the ONLY means to reach the exploding populations of underserved young people, especially those in the developing world, quickly enough to provide them with educational options. Therefore, there are profound moral and strategic arguments for this approach that speak to almost all people and companies concerned with the future. The second challenge is creating educational situations and content well enough and rapidly enough on quick changing new forms of digital media. Here, I think the answer has been provided by ThinkQuest, a program in which students around the world and from many cultures collaborated to create very high-quality educational content for their peers, motivated by a scholarship contest. Kids, especially the leading-edge kids of the very populations we are the least successful at serving, provide the only adequate labor supply to create their own educational materials. Yes, there are businesses and individuals who would dislike the idea of kids being authors, but the need is so great that I hope they can be convinced that there is room for all approaches.

Although this thumbnail sketch is not an adequate response to the problem, I still maintain that leveraging the technologies of popular culture is likely to be both better and cheaper in the long run than periodically filling schools with out-of-date computers. And while it might seem easier to view new learning technologies as if they are yet another unpredictable summer storm, in doing so, we overlook signs that might enable us to use technology effectively in schools. In short, young people's ravenous appetite for interactive games and media-related products remains persistent and will probably continue to fuel the development of affordable consumer electronics and media. We should view this as an opportunity to ensure that these technologies and media are effective learning tools.

LOUIS FOX

Louis Fox is Vice Provost for Educational Partnerships and Learning Technologies at the University of Washington. Mr. Fox is currently leading a national Internet2 K20 Initiative. The I2 K20 Initiative brings together Internet2 members (180 research institutions) with primary and secondary schools, colleges and universities, libraries, and museums to get new technologies—advanced networking tools, content, and applications—into the hands of innovators, across all educational sectors in the United States, as quickly and as "connectedly" as possible, and to connect these innovators to similar communities around the globe.

RON JOHNSON

Ron Johnson is Vice President for Computing and Communications, Vice Provost at the University of Washington and a faculty member in the Information School. He and his colleagues have long been involved in the development and evolution of the original and now the Next Generation Internet, and are principal creators of key Internet and digital convergence technologies and applications, including Pine e-mail, IMAP, High Definition TV over Internet Protocols, CD radio over Internet Protocols, and outreach projects like DO-IT (Disabilities, Opportunities - Internetworking Technology).

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Walter Koetke is currently a Vice President at K12, Inc. Prior to his work at K12, he directed the design and implementation of The Learning Odyssey, an online curriculum for grades 1 through 8. Mr. Koetke previously was Director of Technology for Scholastic, Inc., and an award-winning mathematics teacher in the Lexington, Massachusetts, public school system. He holds a B.S. from MIT and an M.A. in education from Harvard University.

JARON LANIER

Jaron Lanier is a computer scientist, composer, visual artist, and author. Currently, Mr. Lanier serves as the Chief Scientist of the National Tele-immersion Initiative, a coalition of research universities studying advanced applications for Internet2. He is also the Chief Scientist of Eyematic Interfaces, a computer vision company. Mr. Lanier coined the term "virtual reality."

BILL MARK

Bill Mark is Vice President of the Information and Computing Sciences Division of SRI International, one of the largest independent research institutions in the world. The Information and Computing Sciences Division creates new technology in biocomputation, information security, system design, speech and natural language, vision and perception, and reasoning systems. Dr. Mark holds a Ph.D. in computer science from MIT. His personal research interests include pervasive dialogue and system design.

JOHN WILLINSKY

John Willinsky is Pacific Press Professor of Literacy and Technology at the University of British Columbia. Dr. Willinsky leads the Public Knowledge Project, an effort intended to make social science research more accessible, intelligible, and useful. He is author of several books, including *Technologies of Knowing: A Proposal for the Human Sciences.*

FACE TO FACE:
AN INTERVIEW WITH JEANNE MORENO

Jeanne Moreno is Vice President and Chief Information Officer, Citrix Systems, Inc.

Mary Baker and Nancy Barba, district administrators for Broward County Public Schools, Broward County, Florida, were asked these same questions during their interview. Their responses appear in the Leadership section.

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FACE TO FACE: VISION

AN INTERVIEW WITH JEANNE MORENO

Jeanne Moreno is Vice President and Chief Information Officer, Citrix Systems, Inc.

▶▶: *The trend toward wireless communication seems to be advancing, although not as quickly as some would like. In your opinion, what barriers impede widespread use of wireless technologies?*

JM: There are two categories of wireless technology. Each has its own implications for education. There is a wireless Local Area Network (LAN) that allows users to be connected to the network as they move throughout a campus. Users could be in a hall during a speech or a lecture; they could be in an individual lab; they could even be in the cafeteria eating lunch. The wireless LAN requires antennas or stations scattered throughout the campus. Anyone with a certain card (laptop or device) could connect to the LAN. That's probably the most likely solution for a campus or an educational facility. I haven't been in a school, at least in South Florida, that doesn't have K-12 connected to a LAN.

The wireless technology that much of the world refers to is that which is delivered by a type of voice or telephone technology by dialing in to a number. Companies such as AT&T and Sprint support this technology. There are other companies as well. Basically, through a connection to an intranet and after authentication through security software, students could tap into the Internet or e-mail or whatever they may need. This wireless technology is not as advanced and probably not yet appropriate for education.

▶▶: *Tell me more about how you see wireless LANs used in K-12 education.*

JM: I would say students could be connected with wires through the third grade. But in South Florida, we see fourth graders using laptops to complete homework and to communicate. (This is especially true in the private school system.) As laptops become more prevalent, wireless technology becomes more important. It is very, very difficult to go into older school buildings and hardwire communications into an open classroom where desks are not secured to walls or ceilings. So, I think wireless technology will be very useful as laptops and handhelds increasingly find their way into schools.

▶▶: *The long-predicted demise of traditional textbooks has not occurred. Why do you think this is so, and do you think it will still be the case 10 years from now?*

JM: I think most of us use the Internet for daily activities. Some use it to find simple information like telephone numbers, maps, or stock prices. Others use it for more complex tasks like research. Students already use it to research. Would they use it for textbooks? I think that's a natural extension. In the private sector, businesses already ship products with electronic media—installation guides, service manuals, etc. Electronic media for textbooks will materialize.

▶▶: *The recent court case involving Napster has raised the public's awareness of intellectual property rights and safeguards for materials in electronic form. What is the impact of intellectual property issues on innovation in technology product development?*

JM: I think the model for music is different from the model for the rest of the world. Most of us have to make our living by selling our products, and I think music just jumped ahead of the game. We at Citrix deliver our product over the Internet. We have found ways to ensure that our products are licensed and that we are paid appropriately for the product. I think the technology exists to safeguard materials. Companies have to make sure products are deployed that way. I'm not sure why Napster thought they could distribute somebody else's material without a license. The more difficult component has been the licensing mechanism that allows them to be used in an authorized, licensed, or purchased environment. Music didn't have that. Songs became electronic media without it. I think the companies who develop the electronic textbooks have to make sure they include a license key in the product.

▶▶: *When people first started talking about the digital divide, they referred primarily to the disparity in Internet access between the wealthy and the poor. But people are now talking about other divides among technology users, such as gender and geography. How does industry address this issue?*

JM: I don't believe there is a gender issue. I think within schools and industries, Internet access is Internet access. I don't think access is gender specific in any way or form. I can't imagine where it would be. Geographically, there are always places in the world that are ahead or behind others. Europe is more easily adapted to a wireless environment, because the land mass area is rather compressed. In the United States, there is a great deal of land between major cities. Wireless that can be activated anywhere in the United States will probably take a great deal more time to deploy, so there will be differences in technology. I think anyone who needs one could find an available PC today. Even from a socioeconomic standpoint, there are PCs in public libraries and other public sources.

▶▶: *The gender issue I'm referring to is the perception that some software programs are written primarily with a male in mind or with a female in mind. For example, competitive games appear to be designed to have greater appeal to males.*

JM: That's also true in board games. There are board games that appeal to one gender or the other. I'm not sure that the electronic world would be any different.

▶▶: *Well, do you see technology as dividing people in any way at all?*

JM: I think there is ease of access in the United States. Community centers are deploying PCs to give children the opportunity to do their homework or to give adults the opportunity to research on the Internet. I think it is the Internet that has exposed the world to electronics, and the Internet is readily available for those who need or want access to it. I don't think there is a divide here so much as a choice to use or not use.

▶▶: *You have touched on the last question. There seems to be a widespread assumption that every child should have access to a computing device and be able to operate it. In your view, how important is widespread access and usage among school-age children? How realistic is it?*

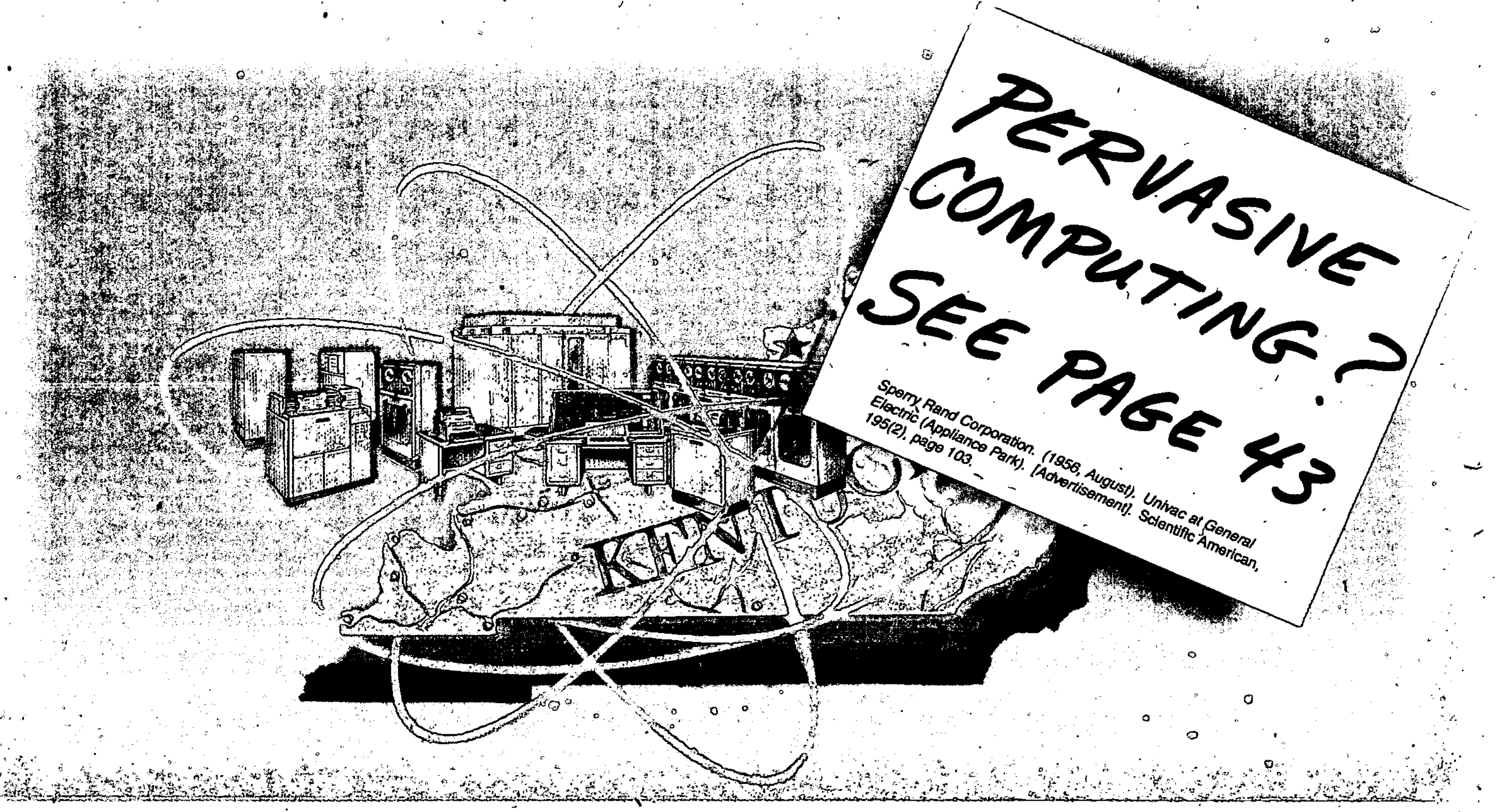
JM: I absolutely believe that every child should have access at an early age. My children are aged seven and nine, and they've been on computers and the Internet since they were two or three. They were using math games, reading games, and the Internet in preschool. I can't imagine where they would be if they had no access to computers today. I don't know how competitive they could be with the rest of the world. So, I say every child should have the ability. I'm not sure we can put it in their hands. They may have to reach out to find it.

One access and usage problem that schools face is equipment. The effectiveness of technology is heavily dependent on the software installed on the computer itself. So often, schools must use older computers, making it nearly impossible to run the applications and programs they want or need directly from the PCs. The programs are sometimes so large that they either don't fit or don't run properly. At Citrix, we strive to help school systems by allowing any device to attach itself to a set of programs or applications using a server farm. Our technology allows them to use the thinnest device, the oldest device, or the biggest device and still have access to needed programs. Any device (desktops, laptops, handhelds, etc.) is "served" the application from the server farm, meaning the program is not actually stored on the PC.

▶▶: *Thank you, Jeanne, for your time and your insight. Is there anything else you would like to add?*

JM: I think we fear change more than we fear technology. We fear grabbing on to it and maturing with it. It seems easier to let technology pass us by and then complain about it.

Also, the concerns of the educational community are different from those in the business world. We no longer talk about things like ethics, plagiarism, and divides. It may be surprising, but those topics aren't on the forefront anymore. We addressed them a long time ago. In the business sector, we either change or get left behind.



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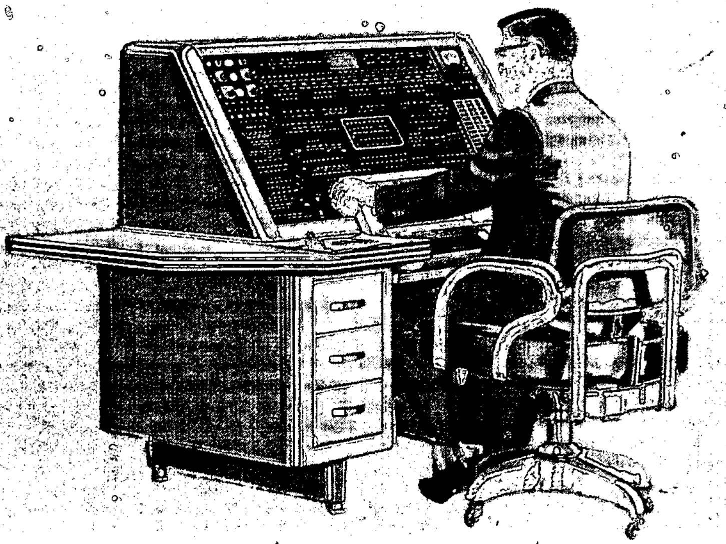

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VISION

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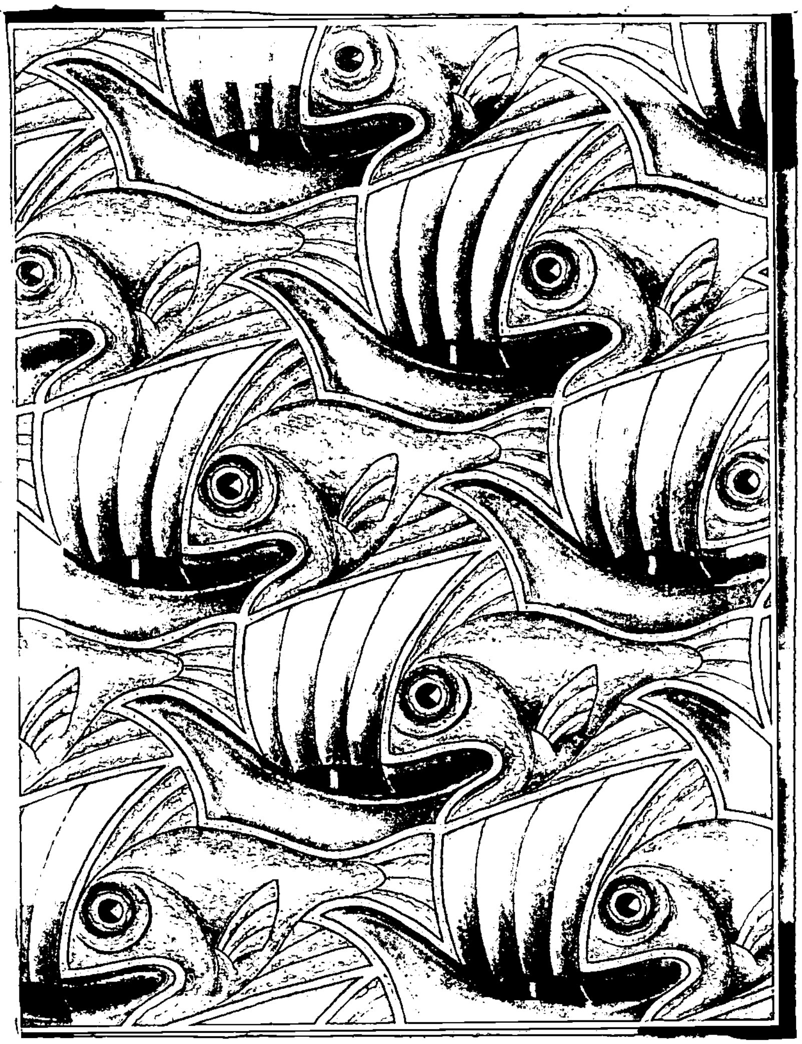
IN ▸▸ SIGHT

A PUBLICATION OF THE INSTITUTE FOR THE ADVANCEMENT OF EMERGING TECHNOLOGIES IN EDUCATION

IAETE



LEADERSHIP

INAUGURAL ISSUE 2001

LEADERSHIP

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IAETE

OUR MISSION: TO SUPPORT THE PURPOSEFUL USE OF NEW AND EMERGING TECHNOLOGIES TO IMPROVE TEACHING, LEARNING, AND SCHOOL MANAGEMENT

IN ▸▸ SIGHT

I am pleased to share with you the inaugural issue of IN ▸▸ SIGHT, an annual publication focusing on promising new and emerging technologies and what they might mean to the future of K-12 schools. My team and I spent a great deal of time thinking about an appropriate title for a publication that would provide a forum for ideas about how technology might, in the not-too-distant future, impact our classrooms while providing a glimpse of what is currently possible. IN ▸▸ SIGHT, then, is intended to be both the presentation of thought-provoking articles by individuals who discern the true nature of some key technologies and the presentation of related work currently under way in schools and classrooms, work that demonstrates that these ideas are *in sight* of mainstream education.

We at AEL are proud to hold a national leadership designation in educational technology for the U.S. Department of Education's regional educational laboratories. IN ▸▸ SIGHT is an important vehicle for our leadership efforts, and we are committed to helping educators understand and plan for the purposeful use of new and emerging technologies in schools.

We believe that vision and leadership are inextricably linked, and we hope our publication conveys this belief. Perhaps no one understands this concept better than M.C. Escher, and we are grateful to Cordon Art B.V. – Baarn – Holland for permission to use Escher's *Fish and Boats* to express this idea so beautifully.

Tammy McGraw

Dr. Tammy M. McGraw
Chief Executive Officer
IAETE at AEL
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Pictured from bottom to top: Tammy McGraw, Editor in Chief; Krista Burdette, Managing Editor; Carla McClure, Senior Writer; Virginia Seale, Copy Editor; Sara Marchio, Copy Editor; and John Ross, Web Producer. Not pictured: Mardell Raney, Executive Editor, and Richard Hypes, Art Director.

LEADERSHIP

"Leadership is the capacity to translate vision into reality."

—Warren Bennis

L E A D E R S H I P

PAPER AND PIXELS...IN SEARCH OF THE ULTIMATE TEXTBOOK

Tammy McGraw, Ed.D. and John Ross, Ph.D.

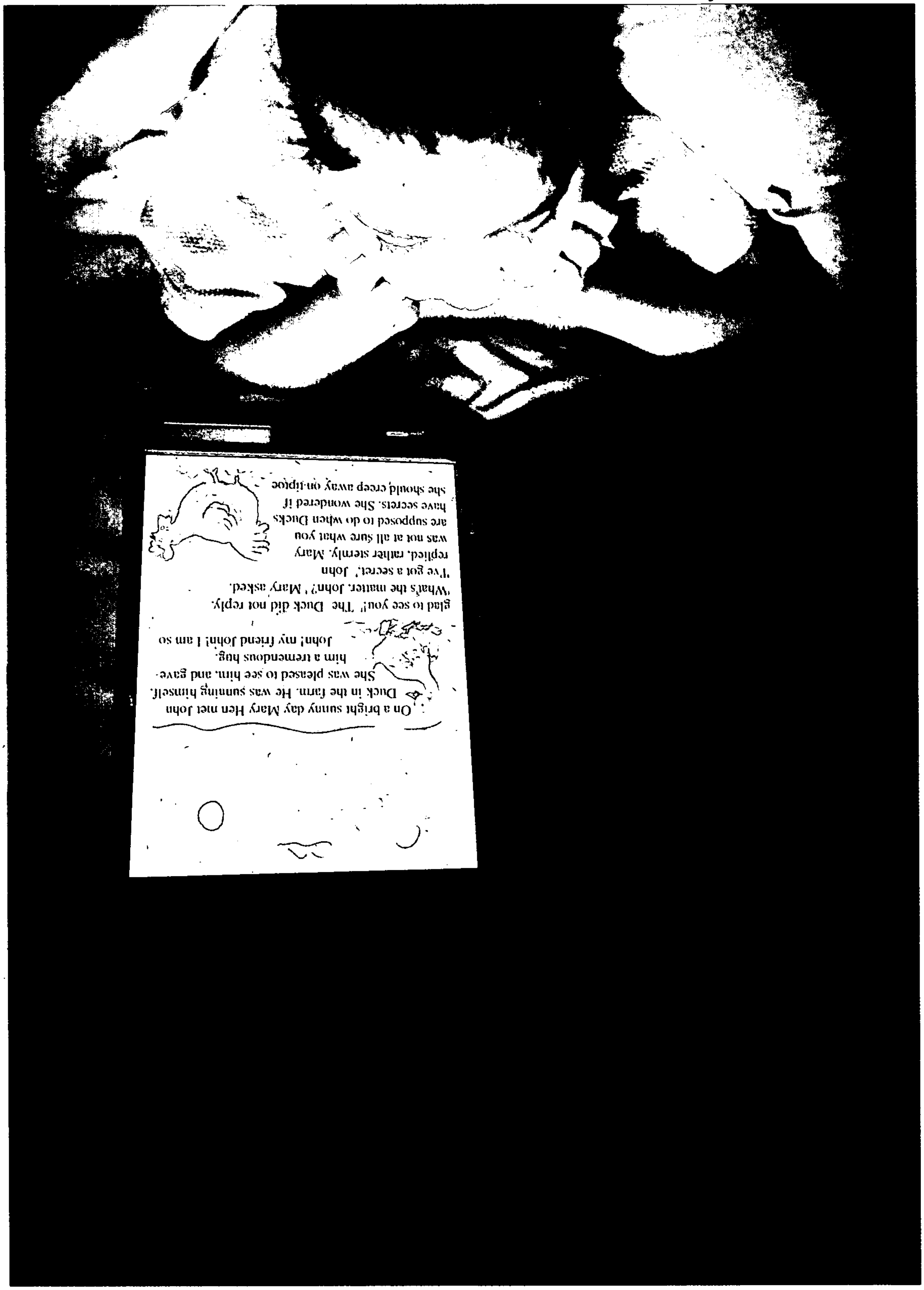
Tammy McGraw and John Ross explore many of the issues surrounding electronic textbooks and offer one approach to developing and delivering electronic instructional media. In the Vision section, Walter Koetke provides additional insight into how instructional media can be customized to meet the individual needs of learners.

PAPER AND PIXELS...IN SEARCH OF THE ULTIMATE TEXTBOOK

Tammy McGraw, Ed.D. and John Ross, Ph.D.

Few resources are more prevalent in schools than textbooks; yet, in many cases, textbooks inadequately address the needs of students and teachers. Outdated information is common due to the nature of textbook adoption cycles, and the information is often ill-suited to curricula and assessments. Printed textbooks containing inaccuracies often remain in use for six to eight years and literally pages of corrections are being posted to publishers' Web sites. John Hubisz, commenting on a recent study of 12 physical science textbooks most commonly used in middle schools across the country, states, "What I found was horrifying: None of the books—not a single one—was deemed adequate by nine primary reviewers and a host of other experts who offered comments. Each contained hundreds of factual errors, as well as experiments that couldn't possibly work, and diagrams and drawings that represented impossible situations. One can laugh at the silly mistakes, such as the equator going through Texas. Far more serious are the routine garblings of basic science: misstating Newton's laws; claiming that no solid substance can contain a plasma; and on and on."[1]

Textbook development is driven by market demand, and it can be argued that states with large student populations have the greatest impact on textbook development. Some states, such as Texas and Maine, are experimenting with replacing textbooks with laptop computers; however, this does not eliminate the


On a bright sunny day Mary Hen met John Duck in the farm. He was sunning himself.
She was pleased to see him, and gave him a tremendous hug.
John! my friend John! I am so glad to see you!' The Duck did not reply.
'What's the matter, John?' Mary asked.
'I've got a secret,' John replied, rather sternly. Mary was not at all sure what you are supposed to do when Ducks have secrets. She wondered if she should creep away on tiptoe

need for quality instructional media.[2] Equipping every teacher and child with a laptop computer to access the World Wide Web still falls short. With its vast resources, the Web can be burdensome to teachers already strapped for time, making it difficult for them to search for the most appropriate information and media for their students.

Laptop computers are not the only solutions being proposed to alleviate these problems. Another possible replacement for traditional textbooks is the e-book—a single-purpose device that displays reading materials in ways similar to traditional books. Several e-book devices are available including the Franklin eBookMan, goReader, and Gemstar eBook. They range in cost from $125 to $600. Steve Ditlea suggests that the proprietary file format inherent in many e-book devices makes them a less-attractive option.[3] Furthermore, the titles available for many e-books are not particularly well-suited for K-12 classrooms.

Not all suggested replacements for traditional textbooks are based on an electronic device to view digital content. Others suggest that the solution to outdated textbooks is to make them customizable at the district or even the classroom level.

Not all suggested replacements for traditional textbooks are based on an electronic device to view digital content. Others suggest that the solution to outdated textbooks is to make them customizable at the district or even the classroom level.

Classwell Learning Group, for example, is partnering with Kinko's to offer schools custom-made resources geared to meet the needs of individual students. Using online tools and content supplied by Classwell, teachers can select and organize materials into custom workbooks for students. The workbooks are printed and assembled by Kinko's and delivered to the school.[4]

Gilbert Sewall, director of the American Textbook Council, offers another aspect of customizable publishing to consider. He warns that local pressures could affect sensitive issues such as evolution or the depiction of Columbus. Parents could request a particular treatment of these topics within the scope of customization, creating difficult circumstances for schools and districts.[5] The content of the curriculum then becomes much more fluid and subject to tremendous variation across schools, raising many questions with regard to scope and sequence as students transfer from schools to other schools—even within the same district.

Clearly the idea of meeting the individual needs of all learners is appealing. Customizable publishing, at least on the surface, seems to make it possible to do this. It is important, however, not to diminish the role of the teacher in selecting and organizing the content prior to publishing. Teachers have long supplemented textbooks with ancillary materials because they recognize that a one-size-fits-all approach is not effective. The content selection and organization of materials take time, and this still becomes the primary responsibility of the teacher.

Policy is slowly beginning to reflect changes in instructional materials. Over the last few years, 21 out of 22 adoption states have expanded the definition of instructional materials to include technology-based products. However, few legislators have followed the lead of states such as Texas, which has revised laws to allow the purchase of laptops, software, or Web-based resources in lieu of traditional textbooks.[6] The adoption process has traditionally examined materials that would not change over time. That is, the printed book would be adopted for use in schools for a predetermined number of years, and those charged with the adoption process would not worry that the selected textbooks would appear significantly different in a matter of days, weeks, or months. One of the most attractive aspects of electronic books—the ability to be updated quickly—now becomes a significant problem in the adoption process.

Historically, the adoption process has been an attempt to ensure that children receive appropriate and accurate information in schools. Students were not called upon to make a determination about the usefulness or accuracy of their textbooks, although many would undoubtedly offer their comments. Today that has changed. Teachers must help students learn how to locate and assess information from the Web, thus empowering students, to a great extent, to determine the appropriateness or accuracy of information. Teaching students to locate appropriate information is not as easy as it might seem. Currently there are more than 2 billion pages on the Internet, with approximately 7.3 million new pages being added daily.[7] Even the best search engines retrieve information that, without the skills to assess accuracy, could mislead students. Students will no doubt encounter many opposing viewpoints on the Web and must be able to interact critically with that information.

Policy issues are not the only area of concern. New funding models must be considered. For example, subscription-based services, rather than one-time purchases, are becoming more common as are licensing agreements that allow companies to use content from major content providers in delivering electronic textbooks. As is the case with the traditional textbooks they would replace, electronic textbooks must be accessible to every student. If the Web is part of this solution, then access at home becomes another issue.

The underlying economic model has more in common with a pay-per-view theatrical performance or sporting event, than with print publishing.

Many intellectual property issues associated with electronic publishing are unresolved at this time. Authors and publishers of printed books have clashed over the rights to the electronic format of printed books. Recent lawsuits suggest publishers' growing concern over this issue.[8] Textbook publishers, well aware of Napster's assault on the music industry, are also cautious about the release of their content in digital form.[9] Digital rights management companies are poised to assist publishers in protecting their content. Rovia, for example, securely stores digital books on the Web.[10] Other companies are protecting digital content in a variety of ways including setting the content to self-destruct after a specified period of time.[11] Public domain titles, such as those written by authors who have been deceased for more than 70 years or documents supported by federal tax dollars, are more readily available given that intellectual property disputes are not a factor.[12]

Other legal issues abound. For example, users of printed books can loan them to a friend or resell them. This is not necessarily the case with electronic books. The Seybold report, according to Stephanie Ardito, suggests that: "Sharing titles is difficult, and resale is impossible. The underlying economic model has more in common with a pay-per-view theatrical performance or sporting event than with print publishing. While good for publishers, the model will create plenty of problems for readers and librarians."[13] Michael Looney and Mark Sheehan suggest, however, that digital rights management (DRM) software and electronic commerce have been the catalysts for the recent surge in e-book interest.[14]

It would seem that one major benefit of electronic textbooks is the savings that should result for schools. After all, traditional text printing and storage costs alone are significant to school districts. Even customizable books should result in

From a school or classroom management perspective, there is a major reason to refrain from replacing print media: the printed book is reliable even when technology fails.

savings. For example, McGraw-Hill Primis Custom Publishing's tool, Primis Online, enables users to view the materials in color online, yet they can be customized in black and white.[15] It appears, however, that the economic benefit will not be immediately apparent. Andrew Odlyzko[16] points out that publishers claim that switching to an electronic format can save at most 30 percent of the costs (those related to printing and mailing) though he suggests that electronic versions of established print journals are no less expensive than the print version of the same journal. He also suggests that publishers do not generally speak of savings, but of additional costs they bear in producing electronic publications. The issue of cost comparison is so complex that it is difficult to predict when or how these savings will be realized.

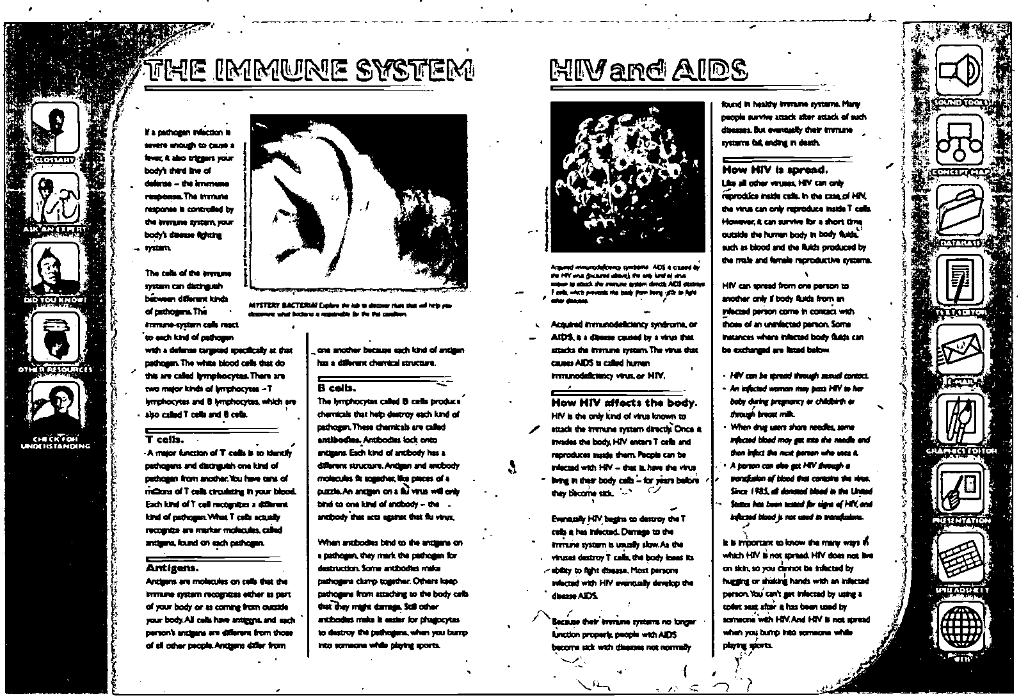
From a school or classroom management perspective, there is a major reason to refrain from replacing print media: The printed book is reliable even when technology fails. Bandwidth requirements, equipment maintenance and support, and network stability already weigh heavily on schools. Greater reliance on electronic media must be considered in this context.

In the midst of the growing electronic textbook industry, imperceptible digital watermarking—a technology most often associated with copyright protection—offers a viable alternative to the solutions presented in this article.[17] At the present, e-books do not appear to be replacing print media but rather supplementing it, indicating that print-based textbooks are likely to remain dominant in classrooms for some time.[18] The continued use of textbooks is not necessarily undesirable. McKnight, Dillon, and Richardson state, "We have had nearly 500 years' experience of using printed textbooks, and they not only support a wide range of applications, but users also have such a strong mental model of their generic structure and organization that they can successfully adopt an equally wide range of usage strategies."[19] They further suggest that while hypertext can support activities that would be difficult, if not impossible, to accomplish with printed text, we must be sure that these capabilities are used in pursuit of valid learning tasks. "It is not sufficient that we can browse a million pages on our desktop, or link 100 articles together for rapid retrieval at the click of a mouse button: such capabilities are only important in terms of their utility to human learners. Yet there are few signs that most learning scenarios require such support, and little knowledge on how we might best provide it in terms of usability, even if it were required."

There is much to be learned about how to best use the technologies available to us to support teaching and learning. Shneiderman contends that exploring vast holdings of information has become increasingly difficult as the quantity and diversity of the information has grown.[20] He suggests that while the computer is an effective tool for searching this information, it is far from ideal. He points out that novice users are often impeded by cumbersome user interfaces; and new approaches must consider how all students, including those with physical or cognitive limitations, will benefit from the approach to textbook design. Clearly, design and adoption of any electronic textbook solution should be based on non-biased research and should carefully examine issues associated with their use in classrooms. For example, Jakob Nielsen suggests that individuals read approximately 25 percent more slowly from a computer screen than from a printed page, and yet schools are adopting handheld devices at an astonishing pace.[21] To achieve screen resolution like that of a printed page, 300 dpi displays would need to be used, an unlikely option given the expense of these high-resolution displays at this time. It is likely then that handheld devices will be used without consideration of this limitation.

According to Steve Ditlea, "At some point in the future, however, e-books and print are bound to diverge. Lurking amidst e-publishing today is the notion of multimedia books that seamlessly incorporate hypertext, sound, and animation." [22] Eryn Brown suggests, however, that there won't be an electronic book business unless someone creates a model that makes the publishing business want to participate.[23] Assuming this is true, a logical approach to designing the dominant instructional media for classrooms might be to begin with what McKnight, Dillon, and Richardson describe as our most successful information technology—the printed book.[24] The Institute for the Advancement of Emerging Technologies in Education (IAETE) has developed a prototype interactive textbook using the digital watermarking technology commercially available from Digimarc.

The Institute for the Advancement of Emerging Technologies in Education (IAETE) is developing a prototype interactive textbook using the digital watermarking technology commercially available from Digimarc.



Adapted from Prentice Hall (2000). Human Biology and Health. Upper Saddle River, NJ: Author.

Digimarc MediaBridge technology creates an imperceptible digital watermark consisting of XML-based (eXtensible Markup Language) coding embedded in a graphic or other media element. With the aid of an optical reader device, such as a digital camera connected to a computer, Digimarc MediaBridge software reads the watermark, activates a standard Web browser, and delivers the user to a specified Web site. The Institute is exploring digital watermarking as a means to supplement print media with current, up-to-date information delivered via a safer, more efficient Web environment. It is important to note that this interactive textbook is an extension of text information. Any function now possible on the Web, including chat, interaction with experts, data visualization, simulations, and virtual reality environments, is plausible within the context of the interactive book.

IAETE has selected a widely adopted middle school science textbook as a basis for the prototype. Consider the following scenario. Typically, static information is organized and presented in a familiar textbook format (drawing upon known use metaphors). Using a portable, wireless, handheld device with a digital camera, supplementary information in the form of audio, video, or other multimedia-based digital formats is dynamically linked to the printed page with an imperceptible digital watermark, creating an interactive learning environment of the most current, reliable, and accurate information possible in a learning community that stretches far beyond the geographic boundaries of a classroom, school, or community. For example, students exploring the immune system use information created by content experts such as the National Cancer Institute or the National Institutes of Health. They view videos to better understand the experience and need for using an iron lung and listen to interviews of survivors of major epidemics. Students visit the Howard Hughes Medical Institute online and participate in a virtual lab simulation to better understand the role of antibodies. Students studying AIDS and HIV use real, up-to-date data provided by the Centers for Disease Control (CDC) and the AIDS Education Global Information System (AEGIS) for their own analysis and study.

The interactive textbook is more than a gateway to Web-based content. A graphical palette containing icons embedded with digital watermarks provides quick access to a suite of learning tools that allows the students to apply concepts and practice skills.

The interactive textbook is more than a gateway to Web-based content. A graphical palette containing icons embedded with digital watermarks provides quick access to a suite of learning tools that allows the students to apply concepts and practice skills. For example, a student can instantly check for understanding by pointing the camera on a wireless handheld device to an image representing an assessment activity. The embedded watermark launches a simple assessment, whether a series of text-based questions or a simulation allowing the student to respond to a few quick questions while receiving immediate feedback. The teacher also receives information regarding the student's assessment and exploration of the content. Differentiated instruction is possible as each child explores various layers of content appropriate for his or her needs and interests. This palette of tools, printed on the edge of the page, allows students to launch additional applications instantly from their hard drives to accomplish such tasks as editing a video clip, creating a concept map, or entering facts into a database.

Imperceptible digital watermarking is clearly an effective technology to consider in this context. The MediaBridge "reader" software can be downloaded free, the embedding process requires very little time or expertise to accomplish, and inexpensive cameras are widely available to read the watermarks. Images embedded with an imperceptible digital watermark do not differ in appearance from those found in traditional printed textbooks, and pages can be designed without bar codes, long URLs, or references to CD-ROM source material. The watermarks contained within the images are invisible and provide access to unlimited electronic resources from a familiar, unobtrusive interface.

In short, this approach to interactive textbook design retains the most salient aspects of print media while providing instant and convenient access to dynamic content, assessments, applications, and communication tools. Unlike other electronic books, the interactive textbook development process does not displace well-established textbook production methods. It is, therefore, more easily adopted by the textbook publishing industry and those it serves.

There appears to be some general migration to the creation of connected content. *The Heller Report*[25] recently announced Harcourt's agreement with Digital Convergence, maker of the :CueCat bar code solution. Harcourt will begin using the bar codes in more than 80 textbooks this fall. While this is encouraging in some ways, the widespread use of bar codes has some drawbacks. Bar codes are conspicuous and lack the elegance of the visual interface afforded by imperceptible digital watermarking.

As the electronic textbook industry continues to be defined, one thing is clear: Electronic textbooks are here to stay. Forrester Research has predicted that by the year 2005, 25 percent of the college textbook sales will be digital.[26] While educators are embracing the electronic textbook, textbook producers are facing a great responsibility to do it well. We believe IAETE offers a viable model.

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LEADERSHIP

2

ASK SMARTYPANTS! AN EVIDENCE-BASED EDUCATION PROJECT

Krista Burdette, M.A., Tammy McGraw, Ed.D., and Christopher Corallo, Ed.D.

Krista Burdette and her colleagues at IAETE present a summary of their efforts to assist educators in obtaining the most useful and current information about new and emerging technologies. Their Web-based tool, Ask Smartypants!*, was inspired by John Willinsky's work. In the Vision section, Dr. Willinsky presents his thinking about evidence-based education.*

ASK SMARTYPANTS! AN EVIDENCE-BASED EDUCATION PROJECT

Krista Burdette, M.A., Tammy McGraw, Ed.D., and Christopher Corallo, Ed.D.

INTRODUCTION

In this day of information overload, how can professionals keep abreast of useful information about new and emerging technologies? Amid literally thousands of journals and trade magazines, articles are published at astounding rates. It would be difficult for any professional to skim every publication and nearly impossible to read every article.

This problem is not exclusive to education. Similarly, busy physicians likely do not have time to read every medical research journal, but it is important for them to be aware of best practices and promising treatments. The evidence-based medicine model was developed by The Centre for Evidence-Based Medicine (Oxford) and helps busy doctors make use of medical research in their daily practice by providing two resources: *Best Evidence* CD-ROM and the *EBM Journal*. The CD-ROM reviews research on relevant conditions, symptoms, treatments, and diagnostic tests. The journal presents abstracts collected from approximately 70 journals that were screened by a panel of expert clinicians and deemed valid, as well as clinically important. The journal drastically reduces the amount of reading time needed to cull the significant studies from hundreds of journals.[1]

A similar effort recently began in the social sciences. Established in 2000 and named for a well-known psychologist, Donald Campbell, the Campbell Collaboration is "an emerging international effort that aims to help people make

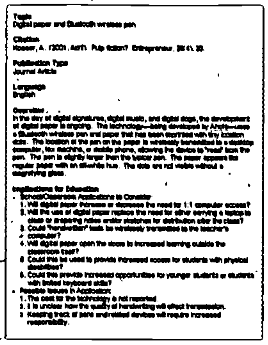
The Institute for the Advancement of Emerging Technologies in Education (IAETE) and Knowledge Management Software, Inc., have partnered to create a tool that will assist practitioners in finding research and other information relevant to their needs.

well-informed decisions by preparing, maintaining, and promoting access to systematic reviews of studies on the effects of social and educational policy and practices."[2]

Like the physicians mentioned previously, busy educators struggle to find time to read research and informative articles on promising technology practices and potentially valuable emerging technologies. To make things more difficult, information about new and emerging technologies is not always found in traditional education journals, because cutting-edge devices and practices, often developed with other industries in mind, may appear in popular or technical media first. Thus, even after reading about potentially significant ideas or resources in education or other industries, educators and administrators are often left without a clear understanding of how they can adapt or apply such ideas for use in classrooms, schools, and districts.

One good example is the personal digital assistant (PDA). The PalmPilot was introduced to the business community in 1996, but the technology is only now beginning to find its way into schools and classrooms. Users can record, store, and play MP3 music files; administrators can electronically synchronize their calendars and instantly check a student's schedule; teachers can manage attendance, grades, and seating charts; and students can use digital camera attachments or download math calculators from the Web. These are just a few examples of how PDAs can be used in schools.[3] Unfortunately, although a variety of technologies that hold tremendous potential for educators and students are being used in other fields, currently, little is being done to identify or adapt these technologies for school or classroom use.

The Institute for the Advancement of Emerging Technologies in Education (IAETE) and Knowledge Management Software, Inc., have partnered to create a tool that will assist practitioners in finding research and other information relevant to their needs. Modeled after the evidence-based medicine paradigm, this Web-based tool and review process is designed to assist practitioners in the identification, evaluation, interpretation, and application of the most relevant research related to new and emerging technologies.



DESCRIPTION

The tool—*Ask Smartypants!*—is powered by Deskartes, developed by Knowledge Management Software, Inc. An important part of this complex multi-neural network is the natural language processing component. Knowledge Management Software, Inc., explains, "The natural language process allows a question to be asked in English (or any other Western language, as all are supported). Deskartes will then extract the words from the sentence and create a pattern, which is then passed into the Neural Network and creates the input pattern."[4] This process is particularly beneficial to educators who may not have the technology vocabulary necessary to identify or find the information they seek. For ease of use, the natural language process automatically adjusts for misspellings, synonyms, and categories.

Although ease of use is important, the real value of the tool lies in Web-based access to summaries of current literature and, more important, it goes a step further to include school and/or classroom applications to consider and possible issues or challenges that may arise as a result of implementation. It is this feature that differentiates this tool from other electronic indexes.

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METHOD

More than 1,000 journal titles have been collected to represent 10 content areas: Aeronautics & Space Science, Biological Sciences, Business, Computer Science & Automation, Education, Engineering & Technology, Medicine & Health, Military, Physics, and World Wide Web & Internet. These publications were identified using recommendation lists from prominent associations and organizations, in addition to

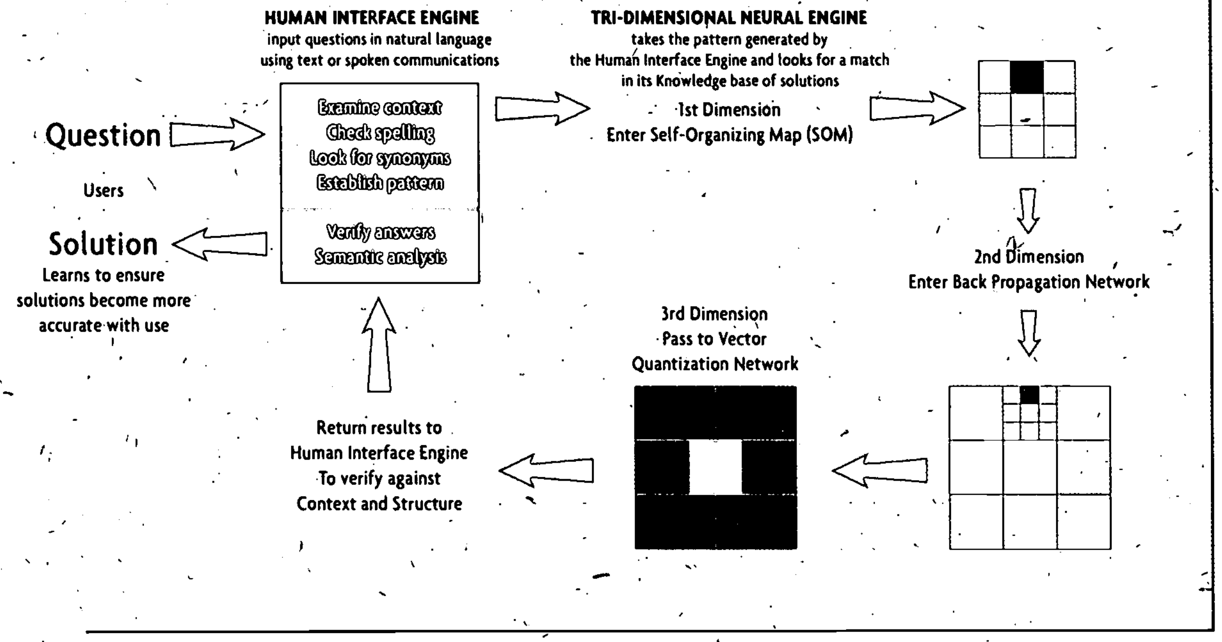

Illustration shows the Deskartes search process. Courtesy: Knowledge Management Software, Inc.

Magazines for Libraries, a publication used by academic and public libraries in collection development.[5]

Using a modified Delphi technique, IAETE is assembling the publications that provide reliable, valid, and useful research, as well as valuable information from trade journals and popular titles about potentially useful emerging technologies. The modified Delphi group comprises panels of experts representing each of the 10 content areas. Each member of every panel is asked to identify from the list of journals those that provide useful information about new and emerging technologies relative to his or her identified content group. The questionnaire requires members to indicate recommended retentions and deletions from the original list of journal titles. Members are also asked to suggest additional titles that should be included.

After the questionnaires are returned to IAETE, they will be analyzed, and titles will be divided into categories: 100 percent consensus, 75 to 99 percent consensus, 50 to 74 percent consensus, and under 50 percent consensus. A second questionnaire will then be distributed to the panels that includes the titles receiving 50 to 100 percent consensus and recommended additions. The process will be repeated. Once consensus is reached on the resource list, IAETE staff will arrange for subscriptions to the selected titles and a Tier-1 Review Group will be identified.

In essence, practitioners will begin to influence the research conducted by IAETE, as well as the entire research and development community.

The number of journals selected during this modified Delphi process will determine the number of members in the Tier-1 Review Group. (For example, there may be 15 members representing Education and only 5 members representing Aeronautics & Space Science.) Each member of the Tier-1 Review Group will be responsible for monitoring assigned titles, selecting useful articles from the publications, and composing summaries based on a template provided by IAETE. Guidelines for selection and composition are under development by IAETE and will be distributed to Tier-1 group members.

Once the Tier-1 Review Group has been launched, a Tier-2 Review Group will be assembled. The members of the Tier-2 Review Group will be experts in education who have hands-on school and/or classroom experience and who are thereby able to glean implications and evaluate the potential impact for education from the summaries completed by the Tier-1 Review Group. The Tier-2 Review Group will meet quarterly to develop school and/or classroom applications for consideration and to identify possible challenges that may arise as a result of implementing the applications.

In 2002, the knowledge base will be populated and the Web site (www.asksmartypants.org) will be fully operational. Educators will be able to type a natural language question on the Web site to receive a list of possibly relevant research reviews. Users will be asked to evaluate the usefulness of the returned reviews. Through the user's response, the software "learns" which reviews best answer each question. Using confidence ratings, future output is modified to reflect user satisfaction on previous searches.

Questions that are not answered to the user's satisfaction are forwarded via e-mail to the site administrator, resulting in a list of questions that are not being answered by current research. As a result, IAETE plans to draw on users' unanswered questions to shape future research agendas. As gaps are identified, research can be planned to address that need. In essence, practitioners will begin to influence the research conducted by IAETE, as well as the entire research and development community.

In addition to this interaction, users will be able to discuss and debate the applications and their experiences relative to the topics at the Web site. In this way, a closer alignment of research and practice will be achieved.

CONCLUSION

While this model is not as broadly based as the Campbell Collaboration, it is built on the belief that popular media, as well as empirical research, must be considered when charting the future of emerging technologies in teaching, learning, and school management. Furthermore, the application of technologies appearing first in other sectors must be adapted for education. This model prompts users to consider the potential value of these technologies in education.

Practitioners must be active participants in the design, application, and study of new technologies for schools. This model offers easily accessible information, provides a forum to share actual classroom practices, and enables researchers to narrow the focus of research to reflect the expressed needs of educators.

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3

COMBINING TELEPHONY AND INTERACTIVE TELEVISION TO FACILITATE EFFECTIVE COMMUNICATION BETWEEN SCHOOLS AND FAMILIES

Tammy McGraw, Ed.D., John Ross, Ph.D., Steven Greenspan, Ph.D.,

David Weimer, M.S., Andrea Basso, Ph.D., and Soleil Gregg, M.A.

Researchers at AT&T Labs and IAETE are working together to explore how common technologies, such as the telephone and television, can be used to provide an effective, affordable way to improve communication between teachers and parents. The idea of pervasive technologies is the basis of Dr. Bill Mark's paper in the Vision section.

COMBINING TELEPHONY AND INTERACTIVE TELEVISION TO FACILITATE EFFECTIVE COMMUNICATION BETWEEN SCHOOLS AND FAMILIES

Tammy McGraw, Ed.D., John Ross, Ph.D., Steven Greenspan, Ph.D., David Weimer, M.S., Andrea Basso, Ph.D., and Soleil Gregg, M.A.

INTRODUCTION

As education reform and accountability initiatives place demands on schools to help all students achieve at high levels, schools are seeking support from families to assist children in learning. Research has consistently shown that family involvement in school increases student achievement.[1] Families can, therefore, play a critical role in helping children—and schools—to meet performance goals. By working together as partners, schools and families can maximize efforts and resources to address barriers to learning and improve children's chances for school success.[2]

The types of partnerships that promote student achievement require new levels of cooperation and collaboration between homes and schools, yet many barriers prevent schools from connecting to families, particularly in rural and inner-city communities. Researchers at AT&T Labs and The Institute for the Advancement of Emerging Technologies in Education (IAETE) studied a possible solution—PhoneChannel, an innovative new technology application—to help schools reach out to families in rural Kentucky. Unlike other technology solutions, PhoneChannel maximizes two commonly used technologies—television and telephone—that are

Most teachers support family involvement and believe that their jobs are easier and that children learn more when families work with them as partners.

prevalent even in the most economically distressed and geographically remote communities. Furthermore, the learning curve to effectively use these tools is negligible, and even those citizens who grapple with basic literacy can easily and effectively use the telephone and television. Working in an underserved community, the researchers assessed the technology's potential to improve home-school communication and to forge partnerships with families that help students achieve.

THE IMPORTANCE OF FAMILY INVOLVEMENT

Research has consistently demonstrated that family involvement in children's schooling improves student achievement, behavior, attitudes toward school, attendance, and school completion rates.[3] These findings are more pronounced for children in low-income families, where parent involvement can afford children the same achievement advantage as those children having middle-class status.[4] However, family involvement is often lowest in the very schools where children have the most to gain from home-school partnerships.[5]

Although some of the greatest effects of family involvement on achievement have been found when families support children's learning at home, many parents do not know how to help their children learn.[6] Teachers can boost this type of involvement, and subsequently student achievement, by sharing information with families about how to help children complete schoolwork and develop the study skills needed for academic success.[7]

Most teachers support family involvement and believe that their jobs are easier and that children learn more when families work with them as partners.[8] In addition, teachers have higher opinions of parents and parents express more satisfaction with teachers and schools when levels of family involvement are high.[9] Studies show that frequent communication with families about school programs and their children's progress is one way that schools can increase family involvement in education both at home and at school.[10]

Frequent two-way communication has been identified as a characteristic of successful school-family partnerships, along with mutual trust and respect, common goals, and shared responsibility for students' learning.[11] Likewise, school practices linked to successful family involvement programs include frequent and meaningful two-way communication between homes and schools, a family-focused philosophy, written policies regarding family involvement, administrative support for programs and policies, training for school staff on ways to involve parents, a partnership approach, networking with community resources, and program evaluation.[12]

To promote partnership between schools and families, policymakers have included parent involvement components in several federal education initiatives. The Goals 2000: Educate America Act of 1994 added parent involvement as a national education goal. Both Title I of the Improving America's Schools Act of 1994 and the 1997 amendments to the Individuals with Disabilities Education Act defined new roles for families intended to empower them to participate as partners in their children's education. Despite such measures, however, family involvement remains an elusive goal for many schools, particularly those in rural areas and inner cities with high concentrations of low-income parents.[13]

OVERCOMING BARRIERS TO FAMILY INVOLVEMENT

Despite the overwhelming evidence that family involvement is vital to the improvement of student achievement, many barriers can prevent families from becoming more involved in their children's education. Research has identified at least six barriers to family involvement: (1) busy or conflicting schedules, (2) lack of information about the school and how to assist with schoolwork, (3) cultural or language differences, (4) transportation and child-care difficulties, (5) low parental education levels, and (6) unsupportive school policies and practices.[14] Such barriers not only keep parents from participating in school activities but also impede communication with teachers that could help them to assist their children with learning at home.

Many low-income parents feel alienated from their child's school, possibly in part because of workplace demands.[15] The majority of working parents report that they have too little time for their children, and 40 percent believe that they devote too little time to their child's education.[16] Both parents and teachers point to lack of time as the main barrier preventing meaningful home-school communication and family involvement in education. Parents are unable to come to school during the day because they are at work, and teachers are unavailable to take calls from parents because they are busy with students and cannot leave their classrooms unattended.[17]

Teachers in high-poverty schools perceive parents' lack of education as the second biggest barrier to their involvement in children's learning, a problem common to rural areas and inner cities.[18] Lack of education not only affects parents' ability to assist with schoolwork but also can make them feel uncomfortable at school and amplify social and cultural differences that impede communication.

Some families—such as rural, inner-city, disadvantaged, and single-parent—face multiple and overlapping barriers that together create vast obstacles to their involvement and make partnership a difficult and complex venture for schools and teachers. Schools can help to overcome barriers to home-school partnerships by reaching out to parents, especially those who are less likely to participate.[19] Studies show that parents want to be informed about their child's schooling. They particularly want to know about ways to help their child at home; information about school activities, programs, and policies; how their child is progressing; what teachers expect their child to do; and ways they can be involved.[20] However, the challenge facing schools is how to establish effective, ongoing communication with the hardest-to-reach families. Best practices for reaching all types of families include using a variety of communication strategies adapted to parents' needs (e.g., telephone calls, audio- and videotapes, and personal contacts) and relying less on printed materials.[21]

In many areas of the country, technology is helping to bridge the gap in home-school communication by eliminating barriers of time and space.[22] Phone messaging systems, homework hotlines, Web sites, and e-mail are some of the ways that technology is providing families access to school information anytime, anyplace. However, phone messaging systems do not allow direct communication with a child's teacher; and while Web sites typically post general school information, most, because of privacy concerns, do not yet provide information about an individual student's progress. Of these technology applications, only e-mail promotes the type of meaningful, two-way communication that encourages family involvement and builds successful home-school partnerships. Unfortunately, many families struggle with basic literacy issues, inadequate keyboarding skills, and computer access.

Disadvantaged families face greater barriers to participation because they lack access to the necessary technology. Although research shows that the digital divide is shrinking, rural, inner-city, low-income, and less-educated families are still less likely to own computers and to be connected to the Internet. For example, only 4 percent of households with incomes less than $15,000 and no high school diploma have Internet access compared to 80 percent for families with a college diploma making over $75,000.[23]

Recent technological advances in personal computers and telecommunications have decreased the expense and increased the functionality of multimedia communication.

While new communication tools provide unprecedented opportunities to connect families and schools, many solutions are not viable for some individuals or communities. In light of limited access to advanced technology in homes, one report suggests that "getting an old-fashioned telephone into every classroom might be one of the most effective ways to improve communication between families and teachers."[24] Although few teachers currently have telephones in their classrooms, most have access to telephones in a teacher workroom, school library, or school office. Further evidence to support using the telephone to improve school-to-home communications can be found in telephone penetration rates for private residences, with 94.1 percent of American households reporting phone access from home.[25]

MULTIMEDIA COMMUNICATION

Telephones provide adequately for vocal conversation, but face-to-face meetings also allow visual communication and can be invaluable in creating or restoring trust. Recent technological advances in personal computers and telecommunications have decreased the expense and increased the functionality of multimedia communication.

EXPRESSIVENESS THROUGH AUDIO AND VISUAL MEDIA

Research on audiovisual communication demonstrates the value of both audio and video. However, of the two, audio is more important for most types of communication.[26] Indeed, studies of videotelephony indicate that improving audio

Although many people are enthusiastic about the emotional value of seeing one another, the same people have expressed concerns about privacy and the difficulties imposed by poor camera angles and visual distortions.

quality, while maintaining a constant video quality, leads to perceived improvements in video quality. Conversely, poor voice quality can create severe communication problems.[27]

Audiovisual collaboration tools on PCs are becoming popular. However, most of these tools were designed for business use, not households.[28] Audiovisual collaboration tools (both the software and ancillary devices such as Web cams and microphones) are especially difficult for residential users to install, configure, and use. Web cams often distort the movements of the speaker, and the resulting abrupt changes in facial expression can be disconcerting.[29] Indeed, studies and field trials of videotelephony have yielded mixed results.[30] Although many people are enthusiastic about the emotional value of seeing one another, the same people have expressed concerns about privacy and the difficulties imposed by poor camera angles and visual distortions. Many field trials of videotelephony show reduced usage over time.[31]

However, some of the richness of face-to-face communication can be achieved without videoconferencing. Several researchers have argued that too much attention has been focused on "talking heads" and not on the other conversational artifacts that can facilitate communication.[32] Early marketing research by AT&T and more recent research highlight the importance of being able to see what the other person is talking about.[33] Sharing visual artifacts has been shown to significantly improve conversational efficiency and satisfaction.[34] The reason for this gain in efficiency is that shared visual artifacts allow speakers to more easily refer to physical objects. (For example, they can point to objects and use linguistic terms like "this" and "that.") Without the shared context, speakers and listeners have more difficulty establishing common ground and often have to refer to physical objects using more abstract and linguistically complex descriptions. For these reasons, we believe that the ability to augment normal phone conversations with shared visual information would be valued in parent-teacher communication.

INTERACTIVITY IN SYNCHRONOUS AND ASYNCHRONOUS COMMUNICATION

Audiovisual availability and synchrony influence what communication participants can assume about each other.

Audiovisual richness is one dimension that is used to describe communication. A second dimension describes the manner in which conversational participants interact. In synchronous communication, utterances are heard as they are spoken (or written) and responses can be swift. Face-to-face communication is the prime example of synchronous communication. E-mail and voice mail lie at the other extreme. The content is created long before the recipient receives it. (In the case of Web pages, the recipient is usually unknown.) Research on this distinction indicates that synchronous communication (e.g., face-to-face meetings) typically contains less formal, more expressive language. Synchrony also provides opportunities for real-time feedback, thus minimizing misunderstandings and demonstrating attentiveness. In contrast, asynchronous communication (e.g., e-mail) allows greater control over content creation and archiving.[35]

ESTABLISHING TRUST AND COMMON GROUND THROUGH MULTIMEDIA COMMUNICATION

Audiovisual availability and synchrony influence what communication participants can assume about each other. To communicate efficiently and successfully, people must assume a common ground of world knowledge and intentions.[36] In face-to-face conversations, people use audio and visual channels to establish meaning and correct assumptions about each other's perspective.

Establishing common ground is more difficult when participants are not in the same physical location. Telephones provide voice and real-time interaction but no visual information. Two-way videoconferencing provides real-time voice and visual exchange, but the visual channel generally provides a limited and sometimes distorted view of the other's physical body and surroundings.[37]

Empirical research on common ground tends to emphasize the mechanisms that establish reference to the physical and social world, and previously spoken utterances.[38] However, coordinated activities include emotional attunement as well as mutual knowledge. Speakers and listeners adapt to each other's communication style, sometimes taking on the accent or jargon of the other.[39] They learn to trust

Interactivity allows participants to attune to each other's needs and expectations, facilitating the development of trust.

or distrust one another, develop bonds, and form expectations about social roles and whether or not future interactions will be enjoyable.[40]

Common ground and attunement are complementary concepts. Common ground research tends to focus on the cognitive and linguistic elements of communication, and attunement tends to emphasize the emotional aspects. Attunement plays a role in the development of trust.[41] Trust develops, in part, through observable indicators that the other person is trustworthy. Individuals are often considered trustworthy, for example, when they appear to be competent, reliable, concerned about and attentive to the trusting person, and similar in background or social values.[42] Thus, a person can increase perceptions of his or her trustworthiness by being cooperative, showing solidarity with others, being reliable, releasing tension through jokes and laughter, showing passive acceptance and agreeing with others, indicating attention by asking for clarification, and giving suggestions that imply the other person has autonomy.[43] Interactivity allows participants to attune to each other's needs and expectations, facilitating the development of trust.[44]

PHONECHANNEL

PhoneChannel is a new communication service that allows a person with access to the Internet to display visuals on a digital-cable subscriber's television while the two are talking. (The concept works equally well with broadband, wireless, and switched video over xDSL.) A user can "push" information from a computer to a household TV. For example, a teacher might call a parent, ask the parent to tune to channel 77 on the household cable TV, and display a student's schedule, projects, or homework on that TV. It is also applicable in any service-based activity in which an individual can explain or talk through visuals, such as providing support for step-by-step directions or supplementing English-based directions in another language. See Table 1 for an example call flow.

	What the users do	What happens in the telephone and cable networks
1	IP or cable subscriber initiates a phone call.	Normal call set-up procedure.
	The other person answers the telephone.	Normal telephone call connection is created.
2	PC user launches client application, and ...	
	... asks the TV subscriber to tune their TV to the PhoneChannel (e.g., "83").	The TV subscriber's telephone number is used as an alias for the cable or satellite TV's network address; the call connection provides an implicit authorization to allow communication between the PC user and the TV viewer. (When there is no call connection, further visual communication is denied.)
	The PC user captures visual information with the application using a "send" button.	The PhoneChannel server is told to display the new image on the TV.
3	The sent image is displayed on the TV.	The image is sent through the IP network to the cable headend with addressing information. It is then broadcast but is receivable only by the appropriate set-top box.

Table 1: An example of a PhoneChannel call flow.

PhoneChannel utilizes readily available household devices to augment telecommunications with visual information. The telephone provides a channel for conveying socio-emotional information in real time, thereby allowing attunements to establish trust. The television enables the sharing of visual information to establish common ground and increases trust by reducing uncertainty related to task-oriented information.

By using the television, multiple conversation participants can sit comfortably while talking with others over PhoneChannel instead of crowding around a PC. Unlike PC applications based on co-browsing, the parent in a teacher-parent dialogue doesn't have to navigate a Web browser to find relevant information. Thus, it allows non-PC households to communicate with PC-enabled schools or classrooms, while minimizing device complexity for the non-PC users. Even in households with PCs, PhoneChannel via television may be desired because PCs are often situated on desktops away from the social center of the household. The application is robust enough, however, to be extended to PC-to-PC communication and other visual communication devices.

PHONECHANNEL RESEARCH

The influence of PhoneChannel on communication and interpersonal relationships has been investigated in two laboratory studies of e-commerce. One study involved real estate and the other catalog shopping. In both studies, PhoneChannel was compared to other types of communication media. In the real estate study, a real estate agent hired for the study received phone calls from study participants who were in the process of looking for a new house. The real estate agent either used PhoneChannel or just the phone to talk with the study participants. Other study participants used a Web browser to search for possible homes. Participants were asked to select several houses that they would like to visit. After making their selections, they completed a questionnaire. Results indicated that using a telephone or PhoneChannel led to greater ratings of trust than using the Web. However, using the Web or PhoneChannel was considered more convenient, fun, and efficient.[45]

In the catalog shopping study, participants were asked to select a blender as a gift for a friend using one of four methods: PhoneChannel, a standard Web browser, a Web browser augmented with audio descriptions of the blenders, and a Web browser augmented with a window for real-time instant messaging (i.e., text based) with a sales agent.[46] PhoneChannel and instant messaging resulted in higher ratings of interpersonal trust than the other two Web conditions, but using PhoneChannel was considered more comprehensive and efficient than using instant messaging. PhoneChannel also was considered easier, more pleasant, and more engaging than using any of the Web browsers. Given these findings, it is likely that PhoneChannel will support efficient, engaging conversation and should encourage trust between parent and teacher, relative to other forms of communication-at-a-distance. By using technologies readily available in most homes, families are more likely to have access to the tools necessary for effective communication with schools.

USING PHONECHANNEL

Instead of creating a network that integrates telephony and video, PhoneChannel loosely couples the Internet, telephone, and television networks.

Loose coupling means that they operate independently of one another but communicate status information through a shared database. PhoneChannel uses the telephone number as the logical address of a visual display, in this case the household TV that is otherwise unassociated with the telephone network. The telephone conversation is the authorization that allows the PC user to send the visuals to the TV. This has three benefits: (1) it makes addressing the TV display easy for the sender, (2) it prevents nuisance callers from displaying anything on a user's TV screen, and (3) it provides a secure connection so that interlopers may not view student data. The TV user must be willing to talk on the telephone and tune the TV to the proper channel.

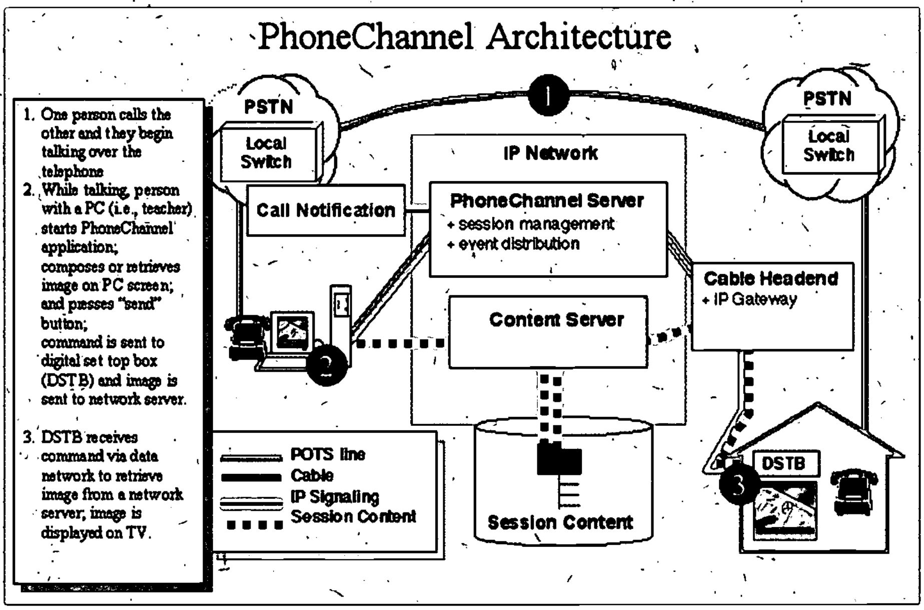
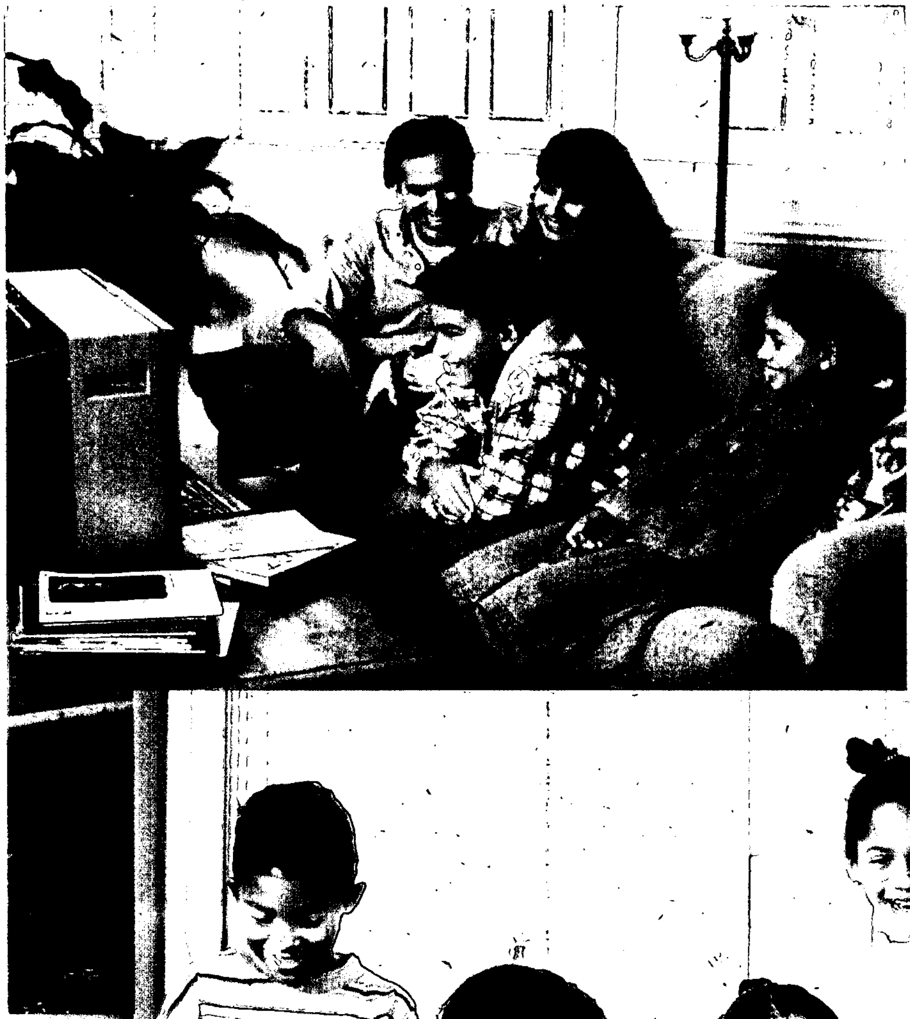


Diagram 1

Diagram 1 shows the architecture for PC-to-TV visual push for the education trials. A teacher initiates a telephone call through a standard phone connection and pushes content from a school-based computer to a Web site where access is restricted to session members (the household). The PhoneChannel server manages the session and opens the desired communication channel once the teacher manually inputs the designated household phone number through the PhoneChannel computer interface. During the session, the teacher can push any



digital information that can be displayed from the computer, including an electronic student portfolio, an electronic grade manager, pictures, and Web sites. In addition, through the use of a document camera, the teacher can push images of three-dimensional products or manipulate objects during the conversation, which can be useful for working through homework problems or discussing concepts for reinforcement with the parents. In diagram 1, teachers in School A and School B are running the application and pushing information to different set-top boxes for viewing on two different households' TVs.

PHONECHANNEL IN EDUCATION

The project described below was a pilot study of the PhoneChannel application in a school setting. Calloway County, Kentucky, is a large rural county in the southwest part of the state that has identified increased parental communication as a goal for improvement, based on data gathered from parents. Calloway County Schools employed Developmental Research and Programs, Inc., of Seattle, Washington, to administer the Communities That Care Youth Survey. The survey data was collected in October 1999, and the participants were district students in grades 6 to 12. Results indicated that 43 percent of students live in a single-parent household as compared to the national average of 33 percent. In addition, student households are widely distributed across the county, and distance is a significant barrier to successfully getting parents to the school for meetings and conferences.

The pilot study utilized a teacher at each of two elementary schools, one of which is designated as a Title I school. Each teacher used the PhoneChannel application to augment school-to-home communications while still having the option to communicate through more traditional means, such as written notes, phone calls, and face-to-face meetings. No teacher was expected to eliminate any mode of communication. The teachers in the study recorded their school-to-home communications by type and frequency and were asked to self-report on perceived quality and effect.

Several factors encouraged the successful deployment of the PhoneChannel application in Calloway County Schools. Preliminary surveys of target classrooms

When asked whether the system was easy to use, school personnel replied that if the Internet connection is reliable, the system is very easy to use.

indicated that all student households had at least one TV and all but one had phone access, even in the Title I school's households. All of the classrooms in the two schools had telephone service. In addition, the teachers used computers in their classrooms for instruction, lesson preparation, student management, or communication on a daily basis. The PhoneChannel application required minimal new technology competencies beyond teachers' existing skills. Calloway County Schools also use student portfolios that were easily shared over the PhoneChannel application.

The Calloway County Schools pilot was a key step in the evolution of a large-scale study in an educational setting, and lessons learned will be invaluable. In moving from the laboratory to the field, it was important to negotiate and adapt to the realities of delivering secure information over a cable television infrastructure. The realities of cost models and proprietary system protocols were compounded through the need to transmit the PhoneChannel signal via two different cable companies. Representatives from Charter Communications and MediaComm in Calloway County worked with the researchers and developers to establish a working solution to transmit information originating outside the cable network to subscriber homes. Future delivery of PhoneChannel will owe much to this pilot study, regardless of whether it is transmitted via cable television, broadband cable modems, the Internet, or satellite.

The Calloway County Schools pilot study helped to establish some user perspectives on the types of communication that are effective when using the PhoneChannel application. When asked whether the system was easy to use, school personnel replied that if the Internet connection is reliable, the system is very easy to use. In fact, one of the school technology coordinators who was going to offer technical support during one PhoneChannel session discovered that the teacher and home user in her school had actually gotten the system up and running prior to her arrival. School personnel generally agreed that the teachers could run the system on their own and could even do it from home computers.

While the original intent of the educational application was to share artifacts from an electronic portfolio, school personnel involved in the pilot offered several common school-related activities that could benefit from delivery via PhoneChannel. These activities include discussing assignments with parents, demonstrating progress, delivering school-based reports such as report cards and progress reports, sharing discipline referrals, delivering and explaining homework to absent students, obtaining missing assignments, and holding parent-teacher conferences. The District Technology Coordinator commented that three areas where she saw PhoneChannel making the greatest impact were supporting night classes, alternative school students, and especially homebound students. Teachers of the homebound work one-on-one and spend much of their time on the road driving between homes. PhoneChannel would reduce travel time, which could then be spent on instruction.

The greatest difficulty in terms of implementing the system was finding time to accommodate a PhoneChannel call. While the physical system worked well, parents are still not home during the school day when teachers are working.

The greatest difficulty in implementing the system was finding time to accommodate a PhoneChannel call. While the physical system worked well, parents are still not home during the school day when teachers are working. The existing structure of the school day also does not compensate teachers for working outside school hours. Several solutions were provided, however, including trying to schedule PhoneChannel conferences during teacher planning times, installing the system on teacher home computers or school laptops, and investigating novel scheduling practices. Some schools schedule half-day or part-day parent conference days, but these still occur while parents are not commonly at home. In order to contact parents not available during that time, schools could consider working with employers to allow parents access at work or giving teachers release time. Then, teachers could log comparable time on the system at night. All use would be logged by the server, and actual time spent would be very easy to corroborate.

During the trial, one feature of the system was discovered that had not been discussed earlier. Documents that are pushed to a home are stored in an archive. Home users can view these documents from their television at any time, regardless of whether they are involved in a session. The archive, accessible using the remote control from the set top box, generated further suggestions for solving the difficulty of scheduling. Teachers could push items to the student archive during their planning period and then could discuss the items at a later time when the parents were home. Teachers could use just a phone, such as a home phone, at night to discuss the archived items with parents. Another option is that parents could view the archived documents at night and then discuss the documents with the teachers during the day by phone only during a prearranged call, such as during the teacher's planning period. Use of the archive feature holds great potential for increasing the effectiveness of the PhoneChannel system and merits further investigation.

The future of PhoneChannel is bright. While the pilot study relied on cable dissemination, a variety of delivery modes are possible in subsequent applications—including wireless transmission. PhoneChannel also has opened the door to a variety of education-related activities that are not limited solely to traditional classroom support. The common ground for communication established by PhoneChannel can increase trustworthiness during the conversation and has immediate application to several scenarios. Based on this preliminary study, it appears that service providers can utilize PhoneChannel to support adult and family literacy programs, English as a second language (ESL) programs, distance-based and distributed learning and training, and services for disabled users. The retail market, too, can utilize the application to disseminate timely and targeted information designed to better meet consumer needs. This unique application has breathed new life into two common technologies that can now become powerful tools in education.

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LEADERSHIP

4

INTERNET2: PUTTING NEW TECHNOLOGIES TO WORK IN THE SCHOOLS

Compiled by Louis Fox, M.A.

Louis Fox captures our imagination with his discussion of several projects currently under way with the Internet2 K20 initiative. To understand how it all began, look at the article he and Ron Johnson present in the Vision section.

4 LEADERSHIP

INTERNET2: PUTTING NEW TECHNOLOGIES TO WORK IN THE SCHOOLS

Compiled by Louis Fox, M.A.

BACKGROUND

Internet2 is a consortium led by over 180 universities, many of which, along with industry and government partners, are the institutions and individuals who created the original Internet. The purpose of Internet2 is to develop and deploy advanced network applications and technologies, thereby accelerating the creation of tomorrow's Internet capabilities. It is important to note that this partnership—and the ensuing development cycle from research and development, to partnerships, to privatizations and, ultimately, to technology transfer and commercialization—is being deliberately and significantly accelerated in Internet2.

The primary goals of Internet2 are to (a) create a leading-edge network capability for the national research community, (b) enable revolutionary Internet applications, and (c) ensure the rapid transfer of new network services and applications to the broader Internet community. With the latter goal in mind, Internet2 has launched and will lead an Internet2 K20 Initiative to extend advanced networks, applications, and services to the rest of the education community. Unlike the first-generation Internet, which took nearly three decades to reach the mainstream of the education community and the public, the goal of this initiative is to bring innovators from across all education sectors to the table much closer to launch.

Potential areas to be pursued include advanced content repositories; advanced applications; middleware collaborations; advanced network services; broadband; and related research, evaluation, and information sharing.

The Internet2 K20 Initiative will engage K-12 schools, colleges and universities, libraries, and museums (and their government and corporate partners) in the development of partnerships and collaborations across a wide range of areas that leverage Internet2 technologies and networks. In addition, the Initiative will focus on programmatic and content efforts that are likely to facilitate teaching, learning, and access to educational opportunities for the broad education community and its constituencies. Potential areas to be pursued include advanced content repositories; advanced applications; middleware collaborations; advanced network services; broadband; and related research, evaluation, and information sharing. Some examples of these efforts, and the technologies that will support them, are described in this article.

Internet2 is a test bed for the use of a new class of media objects in teaching and learning. Internet2 experiments will help to inform the decisions of educators looking for ways to take advantage of diverse learning resources within their own communities and from other communities in the United States and around the globe. The following examples were taken from two states, Washington and Missouri, and represent forward-looking projects, some of which predated (and/or anticipated) the Internet2 K20 Initiative. Several of these projects involve substantive partnerships with researchers and developers from the corporate sector.

HIGH FIDELITY AUDIO AND BROADCASTING

LIVE UNCOMPRESSED AUDIO FROM KEXP-FM

www.kexp.org/

KEXP-FM Radio, the University of Washington, and Experience Music Project (EMP) in Seattle have formed an innovative partnership allowing KEXP-FM to build on the station's current format and to become an innovator in public radio programming and technology. Seattle-based KEXP 90.3 FM, an eclectic, noncommercial music station, in partnership with the Pacific Northwest GigaPoP and ResearchChannel, offers Washington K-20 Network listeners, and now Internet2 listeners, the opportunity to hear uncompressed CD-quality audio of its programming service over the Internet. KEXP-FM is the first station in the world to do this. This around-the-clock stream provides the listener with the highest audio experience at a rate of 1.4 Mbps. Streaming uncompressed audio over Internet2 high-performance networks represents the "gold standard" in delivering the richest and the purest musical content and also demonstrates how Internet2 networks can distribute the work of artists in the highest quality possible, enabling more people to experience and appreciate music the way it is meant to be experienced, as close to "live" as possible.

DIGITAL VIDEO

ResearchChannel
One bright idea after another

RESEARCHCHANNEL
www.researchchannel.com/

ResearchChannel is a nonprofit consortium of leading research institutions dedicated to building high-quality Internet, cable, and satellite-based channels to facilitate the communication of research information.

ResearchChannel is pioneering new methods of Internet-based streaming distribution of high definition television (HDTV) and better-than-broadcast-quality video through ongoing collaborative technology experiments. One of the major goals of the ResearchChannel is to use content, content creation, and manipulation processes as a workbench to test materials for future analog and digital broadcast and on-demand multimedia offerings, thus providing an unusual opportunity to experiment with new methods of distribution and interaction globally.

ResearchChannel programs feature information about a wide range of new and evolving scientific research studies and discoveries. These programs are regularly recorded at research institutions, universities, and academies for distribution to public and scientific audiences. ResearchChannel broadcasts continuously, premiering an average of 40 programs each month with subjects that include a wide variety of topics, among them astronomy, aeronautics, biology, bioengineering, computer science, medical and health sciences, social sciences, and the arts. All programming is produced by leading institutions offering an unmediated, highly credible source for information about research activities in progress around the world. Programming exemplifies meritorious, telegenic research, or peer-reviewed research in the context of broadcast-quality video. Information is presented in such formats as research reports by leading scientists, interviews with researchers, medical rounds, lectures by university professors, major conference proceedings, video news releases, and documentaries. This programming in better-than-broadcast quality, and often with supporting multimedia on the Web, is available to students, teachers, and classrooms participating in Internet2's Sponsored Education Group Participant program.

INNOVATIONS IN DIGITAL CONVERGENCE

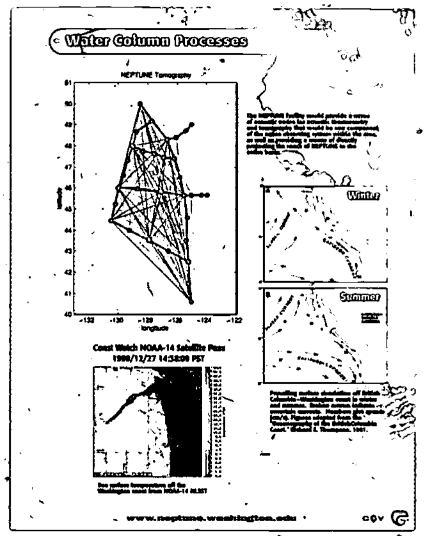
The ResearchChannel and KEXP experiments in on-demand video/audio streaming and archiving provide the opportunity to develop the necessary infrastructure to understand and use high-quality multimedia images, video, and audio objects. These experiments include the networking and computing infrastructure as well as the thought processes for finding, accessing, securing, and authorizing the use of rich, new media resources for an audience that is as varied as the types of video, audio, and interactive experiences that are possible.

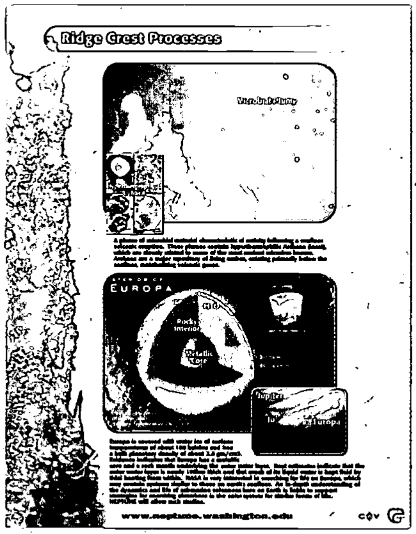
Using very large collections of high-quality video and audio, ResearchChannel and KEXP are exploring methods of responding to demand that can originate from personal digital assistants (PDAs) or desktops, from TV set-top boxes or Internet radio devices. As scalable and reliable methods for meeting this demand are developed, these experiments make possible new resources for classrooms anywhere in the world.

Using very large collections of high-quality video and audio, ResearchChannel and KEXP are exploring methods of responding to demand that can originate from personal digital assistants (PDAs) or desktops, from TV set-top boxes or Internet radio devices.

Also, the ResearchChannel consortium is enabling the publishing of material from many sources into a consistent supported environment, which in turn creates infrastructure for publishing that can be generalized.

REMOTE INSTRUMENTATION





NEPTUNE: A FIBER OPTIC TELESCOPE TO INNER SPACE

www.neptune.washington.edu/

The earth, ocean, and planetary sciences are on the threshold of major changes driven by rapidly emerging ideas and powerful enabling technologies. Historically, oceanographers have gone to sea in ships for short periods to collect data. Missing from this traditional approach has been crucial information on the fourth dimension of natural processes: time. Now, by combining advances in many different technological fields, we have the ability to enter, sense, and interact with the total ocean-earth environment for long periods. The NEPTUNE Project can be a key component in capitalizing on these new real-time, in situ approaches that will create a suite of new operational paradigms in the earth, ocean, and planetary sciences—allowing researchers to observe environments continuously and interactively within a selected, dynamic environment. Opportunities exist to couple this scientific-technical revolution with entirely new approaches to educating learners of all ages.

The NEPTUNE Project can be a key component in capitalizing on these new real-time, in situ approaches that will create a suite of new operational paradigms in the earth, ocean, and planetary sciences—allowing researchers to observe environments continuously and interactively within a selected, dynamic environment.

For the first time, researchers and shore-based learners of all ages will participate in detailed studies and experiments on a wide area of sea floor and ocean for decades rather than just hours or days.

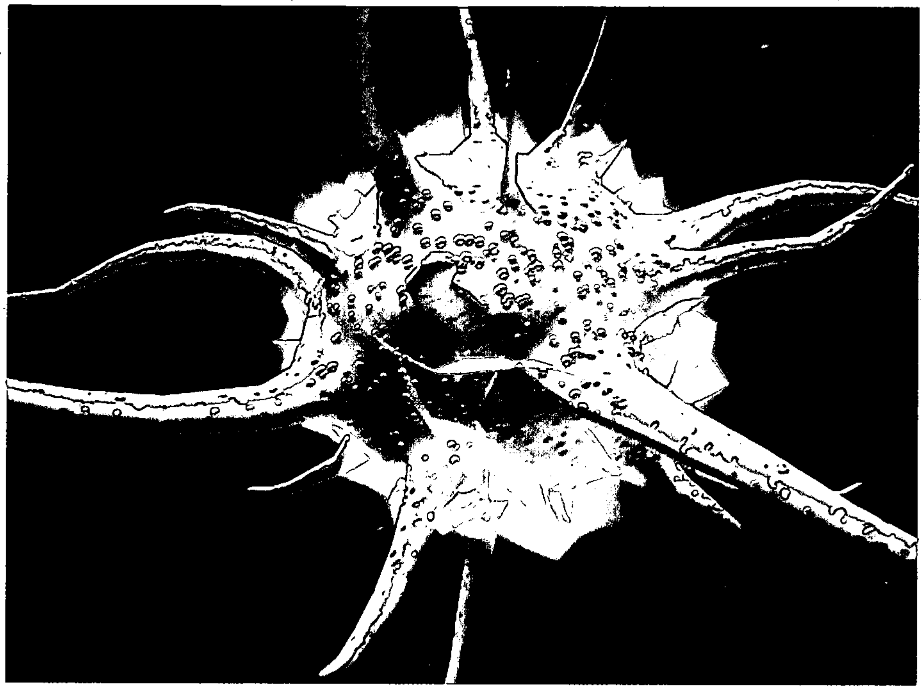
NEPTUNE is creating a network of undersea laboratories that will enable unprecedented real-time observations and experiments with changing earth-ocean systems. By laying 3,000 kilometers of fiber-optic/power cable on the sea floor, NEPTUNE will convert the Juan de Fuca tectonic plate and the overlying ocean to a suite of more than 30 extended natural laboratories spaced about 100 kilometers apart. This tectonic plate, one of a dozen or so plates that make up the surface of the earth, is in an ideal location in the northeast Pacific Ocean off the coasts of British Columbia, Washington, and Oregon, and it offers a representative spectrum of global earth-ocean processes.

In contrast to traditional modes of expeditionary science, NEPTUNE will operate 24 hours a day, 7 days a week, for a quarter century. Plans call for the project to begin operations in 2005. Data from the NEPTUNE network will flow in real time via the Internet to land-based laboratories, classrooms, and living rooms around the world. Scientists, students, decision makers, and the general public will interact with the NEPTUNE network to gain new understanding of earthquakes, tsunamis, fish stock assessment, marine mammal populations, metal and hydrocarbon deposits, and human influences on ocean and climate systems.

This interactive technology offers powerful educational potential and provides a wide range of new opportunities for learners of all ages to explore and investigate the dynamic processes of earth and marine science. NEPTUNE's capabilities, which include access to a wide variety of sensor packages and robotic vehicles via Internet2, will be significantly more engaging than the pages of a textbook. By capitalizing on real-time communication with an entire earth-ocean system, NEPTUNE could be used to develop fundamentally new approaches to scientific inquiry and human creativity.

For the first time, researchers and shore-based learners of all ages will participate in detailed studies and experiments on a wide area of the sea floor and ocean for decades rather than just hours or days. The system will provide real-time flow of data and imagery via Internet2's high-speed network to land-based research laboratories, universities, and K-12 school classrooms. It will permit researchers, teachers, and students to have interactive control over remote robotic vehicles, sensors, and data instruments. The major bandwidth consumers (Gbs/second) from these remote instruments will be video (standard and high-definition) and high-frequency acoustics. In addition, in order to efficiently manage and utilize the unprecedented amount of data that will be generated and collected by the NEPTUNE network, a robust data management and archiving system will allow scientists and educators to access online NEPTUNE data in an efficient and seamless way.

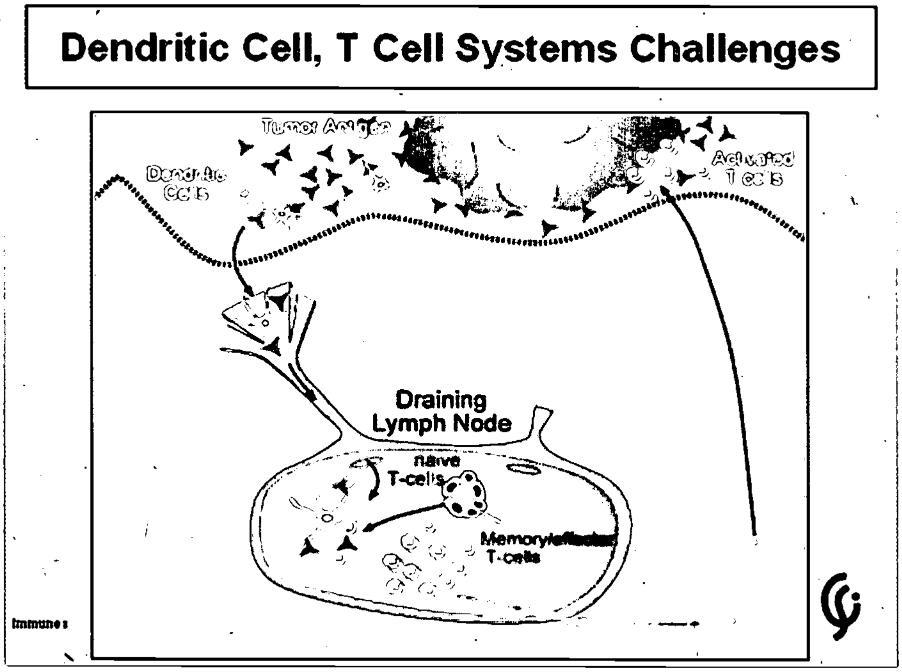
NEW LEARNING ENVIRONMENTS

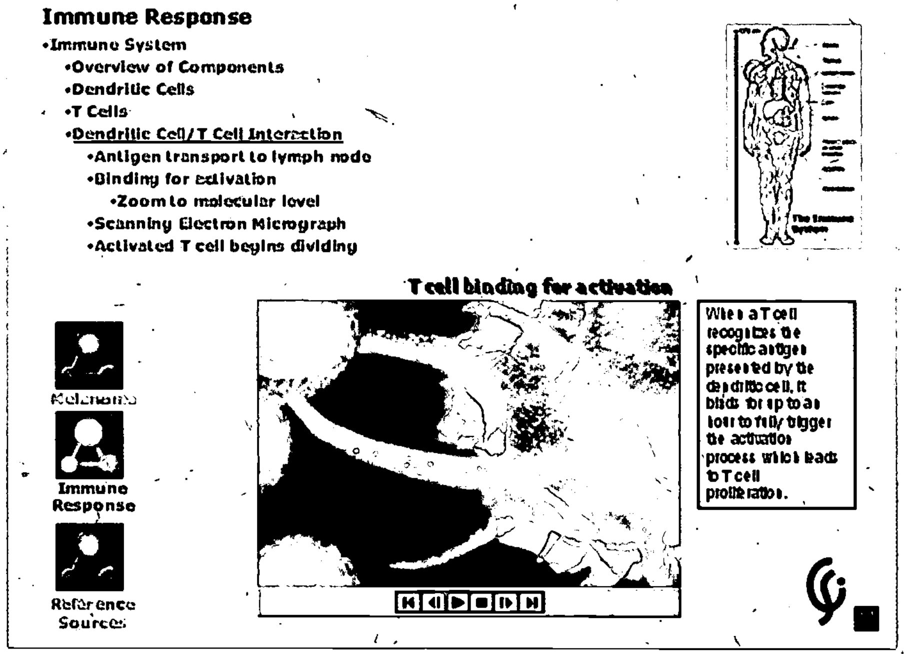


Dendritic Cell on a black background by David Hunt

CELL SYSTEM INITIATIVE
www.csi.washington.edu/

The Cell System Initiative (CSI) is a formative-stage, interdisciplinary research and education program being developed at the University of Washington. CSI's long-term mission is to understand the dynamic information control systems that operate within all living cells. In fulfilling its mission, CSI will contribute over the years to an increasingly comprehensive theory of the cell by creating predictive





models that aid our understanding of the normal cell, as well as our ability to therapeutically attack pathogens, cancers, and other diseases. The proposed system's biology effort requires the creation of novel theoretical, experimental, and pedagogical tools. These tools will evolve as a result of the fusion of expertise in biology, information technology, and micro-scale analytical technologies.

The creation of educational tools will be directed particularly at providing easy access to information to peers, mentors, and school classrooms that fosters collaborative learning anytime and anywhere utilizing Washington's K-20 Network and Internet2. CSI plans to leverage the already extensive digital animation technologies to capture the phenomena of cell development, allowing for linkages with hypotheses, experimental measurements, and quantitative analyses. The resultant venue for accessing and expanding biological knowledge will be made via Internet2.

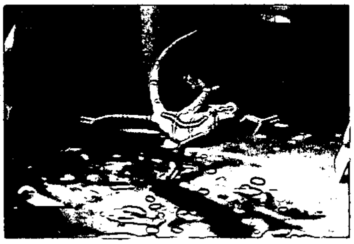
CSI's education mission is to create a virtual learning environment that enables learning through sophisticated use of available and future technologies. Specifically, CSI will (a) integrate expanding resources and technology in a comprehensive work environment, (b) create highly interactive learning tools that make use of new technologies, and (c) link abstract representation to the data that comprise the body of scientific research.

NEW COLLABORATIONS AND CONTENT REPOSITORIES

ANIMATION RESEARCH LABS PROGRAM AND A NATIONAL DIGITAL ANIMATION LIBRARY

www.cs.washington.edu/research/ap/arl.htm

The mission of the Animation Research Labs (ARL) program is to advance state-of-the-art animation through research, teaching, and computer-animated production. It is an interdisciplinary undertaking of the University of Washington's Department of Computer Science & Engineering and Schools of Art, Music, and Architecture. The ARL is a place where computer scientists, animators, artists, musicians, architects, story writers, and user-interface designers work together to create new algorithms, systems, and tools for computer animation. They then use these advances to create innovative and experimental animated productions, including interactive forms such as Web-based animation, games, storytelling, and illustrations for education. Over Internet2, videoconferences, exchanges of information, and projects with animation and graphics industry professionals and researchers from around the world will help enhance the curriculum for students in the program, assist with research and story development, and provide workshop opportunities for K-12, community college, and university teachers and students. A national consortium of groups in the K-12 community engaged in creating and studying animation is being formed among states participating in Internet2. These working groups will participate in many of these efforts.



In addition, a new digital animation library will serve as a national and international archive and educational resource of collections and catalogs of videos, source materials, and digital and animation techniques from all over the world. A project sponsored by the Bellevue (Washington) Art Museum is under way to document the history of the media arts in the Northwest (a national hub for media arts) over the past four decades. This research and the materials collected during this process will provide some of the foundational materials for the Digital Animation Library and the ARL. The University of Washington's Computing & Communications organization, University Libraries, and Department of Computer Science and Engineering will collaborate to further develop this national resource. Access to this vast collection of resources will be made possible through Washington's K-20 Network and Internet2.

NEW FORMS OF ACCESS TO EDUCATION: ENSURING OPPORTUNITIES FOR ALL STUDENTS AND COMMUNITIES

DO-IT: INTERNET2 ACCESS AND TOOLS FOR INDIVIDUALS WITH DISABILITIES

www.washington.edu/doit

Since 1992, DO-IT (Disabilities, Opportunities, Internetworking, and Technology) has served to increase access to computer and Internet technologies for individuals with disabilities to support their participation and success in challenging academic programs and careers. DO-IT has not only utilized the capabilities of Washington's K-20 Network to reach out to individuals around Washington and nationally, but it has served to make access to Washington's high-speed network more accessible to individuals with disabilities through the development of enabling programs and resources. The DO-IT program will work to ensure that Internet2 tools and applications are fully accessible to individuals with disabilities. As educational applications are developed for Internet2, universal design principles will be applied to those applications, as well as usability testing by DO-IT participants using a wide variety of adaptive technologies. To support persons with disabilities, DO-IT will also create programs that are not possible using current Internet applications. For example, schools in remote areas will be able to access sign language interpreters via teleconferencing to assist deaf students, enabling them to actively communicate in classroom discussions. With the capabilities of Internet2, other applications such as voice recognition and video-based training materials will be explored.

To support persons with disabilities, DO-IT will also create programs that are not possible using current Internet applications.

Though time zones should be considered for courses relying on advanced videoconferencing, in theory, geography should not be an issue at all, given Internet2 technologies.

VIRTUAL UW IN THE HIGH SCHOOL

Virtual UW in the High School builds capacity in rural and urban high schools to access advanced academic resources and to offer University of Washington college-level credit courses to their students. The program strengthens high school curricula and creates a pipeline program that will help more students, particularly those from rural or educationally underserved districts, to directly access postsecondary education at UW.

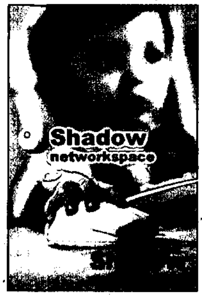
For students, the program provides increased knowledge in basic content areas and interaction with UW faculty members. Teachers can expand their own teaching and learning through collaboration with UW faculty and researchers. When taking Virtual UW in the High School courses, students meet together at least once a week on-site with a high school facilitator to ask questions and share their learning. Using Washington's K-20 Network's advanced videoconferencing capabilities, they also meet periodically with a UW instructor, their on-site facilitator, and participating students from partner schools. The UW's Catalyst Toolkit (described on the next page) also enables frequent online interaction and collaboration with UW faculty and students at partner schools and access to course materials and resources based at the university. Initial courses have been offered in geological sciences, foreign languages, college-level composition, and mathematics. One of the great benefits to universities of such programs is that, in areas such as foreign languages, a virtual college program allows the university to aggregate enrollments from across a state or region (from high schools and/or community colleges). They thereby broaden the curricular offerings to native university students, offering courses that typically could not enroll an adequate number of on-campus students. Many universities offer 40 or 50 languages. In addition, by adopting a virtual college approach, more universities can offer curricula representing some unique expertise or capacity and share this expertise throughout a broader geographical area. Though time zones should be considered for courses relying on advanced videoconferencing, in theory, geography should not be an issue at all, given Internet2 technologies.

CATALYST TOOLKIT

www.catalyst.washington.edu/

Commercial attempts to create Web-based tools for educators often limit them to a proprietary solution that cannot be customized to fit specific educational contexts and applications. The Catalyst Toolkit, created to meet the specific teaching needs of Washington educators, was designed to take advantage of the advanced capabilities of Washington's K-20 Network, one of the first state networks to participate in Internet2.

Developed at the University of Washington, the Catalyst Toolkit is a set of Web-based applications designed to improve student learning. Using only a Web browser, teachers can quickly and easily place complex content on the Web and create online learning activities to fit specific teaching needs. The Catalyst Toolkit helps teachers meet their learning goals and objectives by providing a set of applications that enable students to communicate and collaborate online. No programmer or expensive training is needed, and extensive online help is available to support teachers, anytime and anywhere. Students can take quizzes and surveys, participate in discussions, submit homework, and review each other's written work online using any computer with Web access. Teachers can easily evaluate online work and gauge student progress. With the aid of Internet2 middleware tools, parents, too, can become more active participants in school communities, communicating with teachers and participating more fully in the academic progress of their children. Catalyst was recognized by EDUCAUSE for innovation and received the inaugural Award for Teaching and Learning in 2000.



SHADOW NETWORKSPACE

http://sns.internetschools.org/

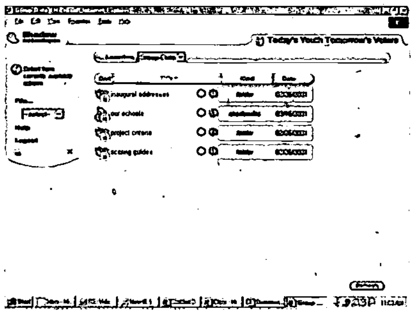
MOREnet, Missouri's education network, is collaborating with the University of Missouri-Columbia's College of Education on a project to accelerate the development of Shadow netWorkspace (SNS), an Internet-based workspace designed for the processes of learning-by-doing and learning communities. In addition to enabling traditional frameworks of online instruction, SNS supports student production, representation of knowledge, and sharing and collaboration among students. SNS is distributed with an open-source license and is available free. Schools can install it on their own computers and thus own the SNS implementation. Called Shadow because it follows students wherever they go, a student's netWorkspace is accessible from any computer that has a connection to the Internet. The SNS provides much of the functionality of a personal PC with the added benefit of being accessible from any computer anywhere via the World Wide Web. Key attributes of SNS include an online file system, graphics editor and media processor, calendar, gradebook and homework notifier, and chat and discussion forums. This application will be made available to support collaboration among Abilene participants, and it will continually be enhanced with new capabilities.

NEW CONTENT FOR K-12 AND COLLEGES

FLUENCY WITH INFORMATION TECHNOLOGY

www.cs.washington.edu/education/courses/cse100/

Building upon the recommendation made in the National Research Council's 1999 study, *Being Fluent with Information Technology*, the University of Washington has created Fluency with Information Technology (FITness) to help prepare students to thrive in higher education and the workplace. Computer literacy has traditionally meant proficiency with a few computer applications such as e-mail or word processing. Students who are computer literate may be adept at using basic, existing applications, but they do not have the fundamental understanding that accommodates the rapid changes in information technology. To use computers effectively over time, students must become lifelong learners, continually expanding their knowledge and upgrading their skills. FITness helps students build a fundamental understanding of Information Technology (IT), including the ability to synthesize complex information, to express themselves creatively, and to manipulate IT to achieve their goals. FITness will soon be piloted and scaled up in Washington K-12 schools and community colleges, with course resources and an online version made available over Washington's K-20 Network and Internet2.



TODAY'S YOUTH, TOMORROW'S VOTERS

Today's Youth, Tomorrow's Voters: Digital Discovery, Collaboration and Understanding is a collaborative project between Missouri Education Research & Education Network (MOREnet), Enhancing Missouri's Instructional Networked Teaching Strategies (eMINTS), and the University of Missouri-Columbia's College of Education, using resources of the Harry S. Truman Presidential Library via Project Whistlestop and Kansas City Public Television (KCPT). Today's Youth, Tomorrow's Voters will harness the power of Internet2 and leverage the opportunities available through the Abilene-sponsored Educational Group Participation Program, in particular multimedia and advanced videoconferencing capabilities. Ideally, over time, other presidential libraries will participate in this project, making it a true national resource.

In Today's Youth, Tomorrow's Voters, fourth-grade students, working as historical researchers and sociologists, attempt to identify important social issues facing American citizens as well as issues facing the new president of the United States. Through participation in collaborative, synchronous, and asynchronous activities using Shadow netWorkspace (SNS), students across the nation will have access to a wealth of online historical information available in rich multimedia formats. Access to these resources will allow students to gain an understanding of historical trends and to develop hypotheses and predictions about the future.

In Today's Youth, Tomorrow's Voters, fourth-grade students, working as historical researchers and sociologists, attempt to identify important social issues facing American citizens as well as issues facing the new president of the United States.

The mass-customization and security capabilities of mySCHOOL, which make extensive use of Internet2-related middleware, allow schools and teachers to provide pre-structured organization and access to the best, most effective, and most relevant materials for each student or group of students.

MYSCHOOL
www.myuw.washington.edu/

Many commercial attempts to create customizable Web-portals that meet an individual's preferences and interests have not met the needs of educators and students. Hence, the University of Washington and several other leading research universities and Internet2 participants, among whom are the authors of many key Internet technologies, have developed education portals. The University of Washington's portal, called "myUW," enables the broad use and custom-tailored delivery of the technologies, resources, and tools needed for UW learning and teaching spaces. mySCHOOL is a version of myUW created specifically for Washington's K-20 community. The mySCHOOL education-oriented Web infrastructure allows students and teachers to have fingertip access from school, home, or anywhere they may be to their own personalized workspace with private information and the powerful tools they need for specific work. This enables them to communicate, interact, share materials, collaborate, teach, learn, or advise much more effectively.

Over Washington's K-20 Network, mySCHOOL will extend innovative teaching and learning resources, sophisticated customizable information, messaging capabilities, and broadband multimedia content to meet the diverse needs of the K-20 community. K-12 teachers will have access to many of the same electronic resources, information-access tools, and content enjoyed by UW professors or teachers at some private K-12 schools. The mass-customization and security capabilities of mySCHOOL, which make extensive use of Internet2-related middleware, allow schools and teachers to provide pre-structured organization and access to the best, most effective, and most relevant materials for each student or group of students. The mySCHOOL approach is one that can be generalized and extended to other Internet2 participants and schools.

5

EXTENDING THE USE OF COLLABORATIVE VIRTUAL ENVIRONMENTS FOR INSTRUCTION TO K-12 SCHOOLS

Tom Morgan, Ph.D.; Ron Kriz, Ph.D.; Steve Howard, M.A.; Fernando das Neves, M.S.; and John Kelso, M.S.

Ron Kriz and Tom Morgan bring their respective teams together to share a promising approach to extending collaborative virtual environments to the K-12 learning environment. Jaron Lanier, a pioneer in virtual reality, provides an interesting perspective on learning technologies in the Vision section.

5

LEADERSHIP

EXTENDING THE USE OF COLLABORATIVE VIRTUAL ENVIRONMENTS FOR INSTRUCTION TO K-12 SCHOOLS

Tom Morgan, Ph.D.; Ron Kriz, Ph.D.; Steve Howard, M.A.; Fernando das Neves, M.S.; and John Kelso, M.S.

INTRODUCTION

Research on the development of virtual environments (VEs) has been limited to date to universities due to the high cost of equipment and high-speed Internet access. Applications of virtual environments using Cave Automatic Virtual Environment (CAVE) technology are numerous in medicine, architecture, military weapons systems, medicine, scientific research, and business training. However, the cost of this emerging technology has prevented the exploration of its use to enhance learning in the K-12 classroom. Virginia Tech's University Visualization and Animation Group of the Advanced Communications Information Technology Center, successfully developed the CAVE Collaborative Console (CCC), an overlay of the Electronic Visualization Laboratory CAVE-simulator and Limbo. CCC allows users at remote sites to interact in real time with each other at their desktop computers and with users in the Virginia Tech CAVE. This article describes the features of CCC software, what was learned from a pilot project using the software to deliver a collaborative virtual learning environment to K-12 students in remote locations across Virginia, and a perspective on future development of collaborative virtual environments for instruction in K-12 schools.

CAVE AUTOMATIC VIRTUAL ENVIRONMENT

Rather than having evolved from video games or flight simulation, the CAVE has its motivation rooted in scientific visualization. The showcase event at SIGGRAPH 92 advocated an environment for computational scientists to interactively present their research at the conference in a one-to-many format on high-end workstations attached to large projection screens. Designed as a useful tool for scientific visualizations, the CAVE was developed as a "virtual reality theater" to support the desired environment. "CAVE," the name selected for the virtual reality theater, is both a recursive acronym and a reference to "the simile of the cave" found in Plato's *Republic*, in which the philosopher explores the ideas of perception, reality, and illusion. Plato used the analogy of a person facing the back of a cave alive with shadows that are his or her only basis for ideas of what real objects are.

The CAVE, a multi-person, room-sized, high-resolution, 3-D video and audio environment, is shown schematically in Figure 1. In the current configuration, graphics are rear projected in stereo onto three walls and the floor and viewed with stereo glasses. As a viewer wearing a position sensor and stereo glasses moves within its display boundaries, the correct perspective and stereo projections of the environment are updated by a supercomputer; the images move with and surround the viewer, which creates the experience of "immersion." Hence, stereo projections on the walls and floor create 3-D images that appear to have a presence both inside and outside the projection room continuously, while the actual walls and floor surfaces effectively disappear. To the viewer with stereo glasses, this 3-D image space appears to extend to infinity. For example, a tile pattern can be projected onto the projection room floor and walls such that the viewer sees a continuous floor extending well outside the boundaries of the projection room. Three-dimensional objects such as tables and chairs would appear to be present both inside and outside this projection room. To the viewer, these objects are "really there" until they try to touch them or walk beyond the boundaries of the projection room walls, which have disappeared.

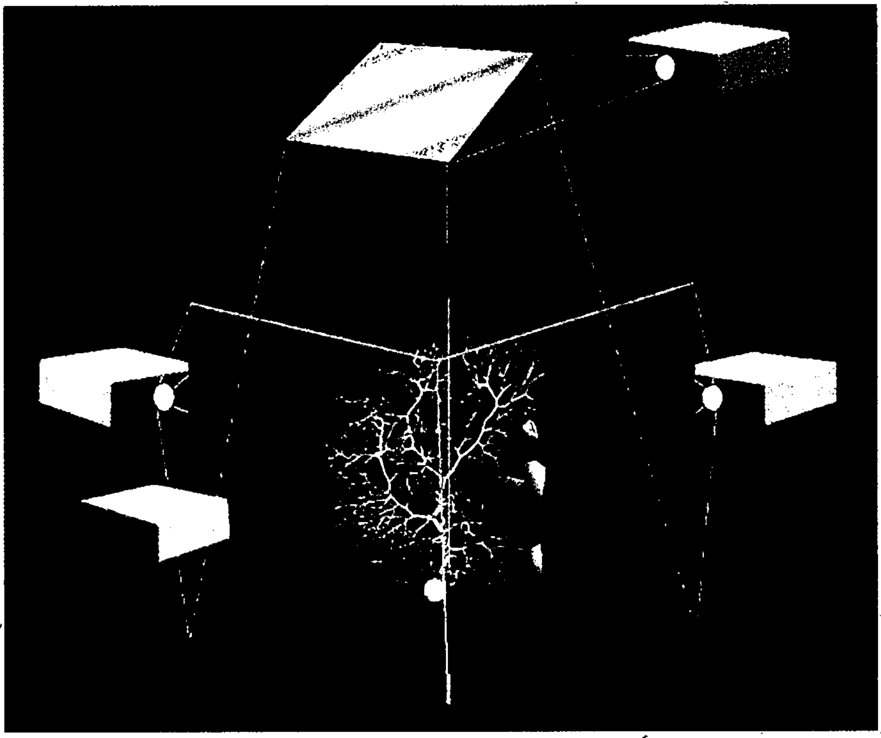


Figure 1. Schematic shows the minimal configuration of a CAVE projection room and the location of projectors.

Specifically, the CAVE is a 10x10x9-foot projection room, made up of three rear-projection screens for the front, right, and left walls, and the floor where images are projected through an open ceiling (see Figure 1). Electrohome Marquee 8500 projectors throw full-color workstation fields (1280x1024 stereo) at 96 Hz onto the screens, giving a 3,840 linear pixel resolution to the surrounding composite image. A computer-controlled quadra-phonic audio system provides realistic surround sound through four speakers located in the upper corners of the projection room. A viewer's head and hand are tracked with an Intersense IS900 acoustic-inertial system. Stereographics' LCD stereo shutter glasses, the large head-mounted glasses often associated with depictions of virtual reality, are used to separate the alternate fields going to the eyes. Optical emitters surround the room and synchronize the shutter glasses in all directions.

Very fast graphics are required to generate stereo images to four projectors, which must operate at 96 Hz (96 stereo frames per second). These

Participants running the CAVE-simulator see themselves as a red head and others as avatars, each with a head, torso, and hand—not as a red head. Movement of a participant's head in the CAVE is tracked and displayed in the CAVE-simulator as a torso with a moving head.

stereo images that are projected onto the walls and floor are created with a Silicon Graphics Inc. (SGI) Power Onyx computer with 8-R10K CPUs, 1.5 Gbyte memory, and three Infinite Reality "pipes" with two raster managers per pipe. This high-speed graphics system is realized in the SGI pipes and raster managers, not in the speed of the eight CPUs. The cost of such a system, which can easily exceed $700,000, requires that such a resource be shared. In addition, educators and researchers at Virginia Tech felt it was most important to develop the capacity to run the CAVE applications on less expensive desktop computers. This link to desktop computers was satisfied by the creation of the CAVE-simulator. The requirement of a link from the desktop to the CAVE also motivated the creation of shared virtual environments.

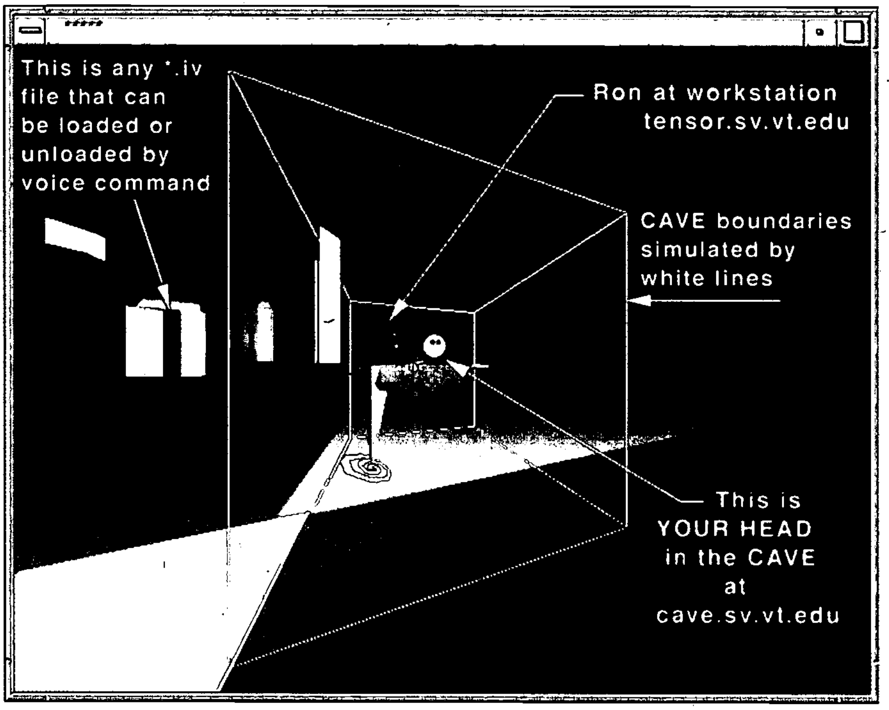


Figure 2. Screen capture of the CAVE-simulator running on a desktop SGI Octane computer. "Ron" is shown as an "avatar" working from a computer with an IP-name of "tensor.sv.vt.edu." The white lines simulate the boundaries of the CAVE projection room and provide a 3-D reference of participants who are working in a CAVE system.

Fortunately, high-speed graphics are not needed on the desktop computer to simulate the same 3-D scene-graph seen by a user in the CAVE projection room. Hence, a desktop CAVE-simulator was created by the Electronic Visualization Laboratory (EVL) at the University of Illinois at Chicago that could run on a desktop computer. However, fast graphics are still needed for moving through 3-D scene-graphs with a large number of polygons. Therefore, SGI ("UNIX") workstations provided the necessary speed for larger 3-D scene-graphs. The CAVE-simulator shown in Figure 2 simulates the CAVE projection room boundaries with white lines, and the user's head is simulated with a red sphere that has two black eyes. Both the CAVE projection room SGI Power Onyx computer and the CAVE-simulator desktop computer run the same executable software..

Because the CAVE computer and the desktop computer are executing the same software, it is possible to link these two computers over the network into a shared collaborative space using Limbo software also developed at EVL.[1] Using Limbo, the shared virtual environment is enhanced by transforming what was just a participant's head (displayed as a red head icon) into a full-bodied "avatar." An avatar is the graphic representation of a participant and is familiar to many game players. Figure 2 includes an avatar called "Ron." Participants running the CAVE-simulator see themselves as a red head and others as avatars, each with a head, torso, and hand—not as a red head. Movement of a participant's head in the CAVE is tracked and displayed in the CAVE-simulator as a torso with a moving head. Movement of a participant's hand is also tracked in the CAVE and displayed in the CAVE-simulator as a torso with a moving arm. Each participant attaches a headset with an earphone and microphone so that participants can see and hear each other in the shared virtual space. Standing in the fully immersive environment of a CAVE, the CAVE user will actually experience the other participant's avatar standing next to him or her and carry on a conversation while pointing at and looking at objects in this shared space. To the user at the desktop computer running the CAVE-simulator, the CAVE user is seen moving through this shared space as a walking and talking avatar.

CAVE COLLABORATIVE CONSOLE: NETWORKED SHARED VIRTUAL ENVIRONMENT

The CCC does not require the use of an expensive CAVE projection room system. Participants can collaborate using only desktop computers running the CAVE-simulator and a low-bandwidth network.

While colleges and universities have developed applications for new environments that utilize the CAVE simulator, the entry-level price tag is prohibitive for most public schools. Widespread use of these powerful virtual environments in primary and secondary education requires a less expensive utility. Educators and researchers at Virginia Tech provided that utility with the development of the CAVE Collaborative Console (CCC). The CCC is a software application that enhances collaboration by networking desktop computers into a shared virtual environment running a CAVE-simulator. This collaboration can include, but is not limited to, the fully immersive virtual environment of a CAVE.

The CCC does not require the use of an expensive CAVE projection room system. Participants can collaborate using only desktop computers running the CAVE-simulator and a low-bandwidth network. If participants set up a conference phone call using speaker phones, it is possible to use a modem to track the participants' heads and hands. Hence, CCC does not depend on high-speed networks or connection to an expensive CAVE running high-speed graphics. The CCC can be used for desktop-to-desktop collaboration without a CAVE.

The CAVE Collaborative Console (CCC) was first created by Kevin Curry and Kent Swartz to enhance the existing Limbo software with "collaborative-awareness" by including "participant lists," "two-dimensional (2-D) radars," and "three-dimensional (3-D) radars" for each participant in the shared space.[2] This effort started as a project in a class on computer-supported cooperative work and continued with funding by the National Science Foundation (NSF) Partnership in Advanced Computational Infrastructure (PACI) project. Early development of collaborative-awareness in CCC was the basis of Kevin Curry's Master's Thesis.[3] As an NSF-PACI partner with the University of Illinois, Virginia Tech's CAVE facility was used to develop the CCC as a collaborative tool for both the CAVE and the desktop CAVE-simulator as part of the NSF-PACI Team-C on Enabling Technology: Data & Collaboration. The CCC was further developed by Fernando das Neves, John Kelso, and Ron Kriz at Virginia Tech as a generic collaborative workspace for research collaboration and educational distance learning.[4] CCC was combined with *Atomview* into *CCC_atom* to enhance research collaboration. In *CCC_atom*, multiple users could view, interpret, and analyze physics-based simulation models of atomic structures.[5] The remainder of this article will describe how the CCC was used for education and distance learning.

While Limbo provided a shared space where participants could view each other as avatars, there was no provision to allow each participant to be aware of others' positions when their avatars were no longer in the field of view.

OVERVIEW OF CCC: FEATURES DEVELOPED FOR EDUCATIONAL DISTANCE LEARNING

With funding from the Institute for Connecting Science Research to the Classroom and an equipment grant from Silicon Graphics, Inc., the CCC was developed for an educational project in collaboration with the Central Virginia Governor's School and Central Shenandoah Valley Regional Governor's School.

The CCC was developed on top of EVL's Limbo software. While Limbo provided a shared space where participants could view each other as avatars, there was no provision to allow each participant to be aware of others' positions when their avatars were no longer in the field of view. Also, Limbo did not have any capabilities to coordinate actions among participating avatars.

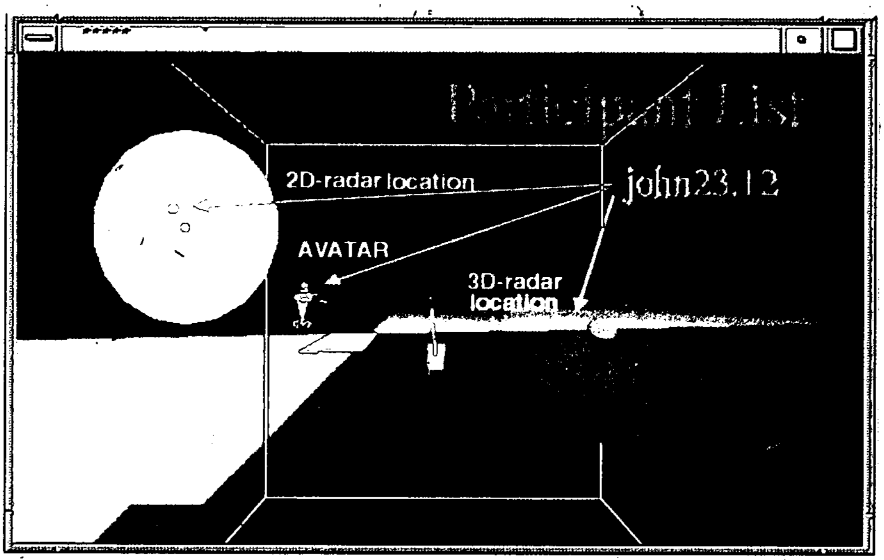


Figure 3. CCC session showing avatar location in participant list, 2-D radar, and 3-D radar.

The color of each blip is the same as the color of the participant's name in the participant list. The position of the avatar representations in the radar is continuously updated as avatars move around the shared virtual environment in any direction.

The need to know one's position in the world relative to others became evident after a collaborative session at Supercomputing '98, where researchers at different sites met in a shared virtual space. Due to the extension of that space, often an incoming participant couldn't see avatars either because avatars were beyond the horizon or occluded by walls and constructions. As a result of this experience and a lack of other tools, participants had to rely on verbal communication to discover common landmarks and describe their relative position to each other. Needless to say, this procedure was time consuming and frustrating.

CCC adds three tools to support awareness: the participant list, the 3-D radar, and the 2-D radar shown in Figure 3.

- The participant list displays names of the participants that are present in the virtual world, plus the distance to each avatar from one's current position. Every participant's name is a different color with the same color used in the radars to represent that user.
- The 3-D radar is an egocentric representation of the avatars in a shared virtual environment, where each participant is at the center of his/her radar, and each blip represents a different participant in the shared virtual environment. The color of each blip is the same as the color of the participant's name in the participant list. The position of the avatar representations in the radar is continuously updated as avatars move around the shared virtual environment in any direction.
- The 2-D radar is a flat representation of the 3-D radar corresponding to a projection on a horizontal plane of all the avatar positions. We added the 2-D radar because many people found it easier to understand than the 3-D radar. This is because 2-D is a flat view; perspective does not distort the representation of distance as avatars move farther away from the user.

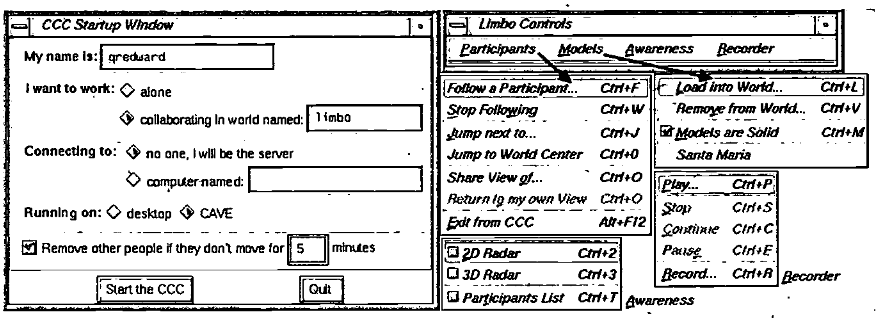


Figure 4. CCC GUI: Startup, menu: Participants, Models, Awareness, and Recorder

CCC capabilities evolved beyond the awareness tools to support avatar coordination. Participants can now share a range of experiences:

- Jump to another participant, so a group with a common activity can quickly gather around the activity organizer.
- Tether to another participant, so a more knowledgeable participant can lead a tour through the shared virtual environment and show the most prominent landmarks. While a participant is tethered to a leader, he or she will follow the leader wherever that leader goes, although the participant is free to detach at any point or to look around while being led on a tour.
- See through another participant's eyes ("shared view"). We discovered the need for this capability while testing a distributed class, where the teacher was describing a feature in a small space; it was difficult for many avatars to gather around the teacher without interfering with each other. Instead, we allow all of the students to virtually see through the teacher's eyes. When a student requests to see through the teacher's eyes, he or she sees, at the eye level, whatever the teacher is looking at. He or she cannot walk or grab objects in this mode to avoid conflicts, although a participant can look around from the position of the head of the participant he is connected to. All participants who are now seeing through another participant's eyes remain in the place they were before the participant started to share a view, until the participant returns to his or her original avatar. A sign on the participant's avatar indicates that the participant is not currently available for interaction.

All participants who are now seeing through another participant's eyes remain in the place they were before the participant started to share a view, until the participant returns to his or her original avatar.

The project was a joint venture between the Advanced Communications Information Technology Center, the Virginia Tech Institute for Connecting Science Research to the Classroom, the Virginia Governor's Schools, and Silicon Graphics Inc.

Although the CCC has yet to be formally tested, it had an iterative development cycle in which software developers invoked the principles of user-centered design. New features were evaluated by two groups: architects and teachers from the two Virginia Governor's Schools. The latter were particularly involved in the design, since the CCC was distributed to a chemistry class of high school students. In the CAVE, input is performed by using the wand and voice commands; however, both groups expressed the need to be able to collaborate with the CAVE using desktop computers. We designed the CCC to allow input from the mouse, keyboard, and a floating menu bar. All options, which are available via voice and menu, are coherent in naming and results.

Although time did not permit a formal usability evaluation, it was observed that very little training was required to teach the teachers from the Governor's Schools how to use the CCC CAVE-simulator from a computer keyboard. Development of the CCC also benefited from the fact that users in the CAVE or desktop computers can work with two separate input modes: either pull-down menus or voice-activated commands. Because these two separate input modes work coherently, training participants to move from the CAVE to the desktop CAVE-simulator was made easier. As a result, we have a community of CCC users with a range of preferences and settings that work in different environments, including full immersion of a CAVE, stereo displays projected on walls, and standard monitors.

DEVELOPING CCC FOR K-12 DISTANCE LEARNING PROJECT WITH VIRGINIA GOVERNOR'S SCHOOLS

A commitment of the University Visualization and Animation Group is to explore how collaborative virtual environments can be used to solve problems associated with distance learning, outreach, and research across the state of Virginia. This commitment led to a pilot project to demonstrate that users at the Virginia Tech CAVE could deliver a collaborative virtual learning environment to K-12 students in remote locations across Virginia. The project was a joint venture between the Advanced Communications Information Technology Center, the Virginia Tech Institute for Connecting Science Research to the Classroom, the Virginia Governor's Schools, and Silicon Graphics Inc. The project had four objectives:

1. to connect secondary students at two remote locations via the Internet to the Virginia Tech CAVE

2. to provide secondary students the opportunity to learn about and experience virtual environments

3. to allow secondary students to collaborate actively with professors who are using the CAVE for their research

4. to create and deliver a content-specific lesson to secondary students using a virtual environment that allows the students at remote sites to collaborate actively with each other as they investigate the subject matter

The project succeeded by connecting students at two remote locations in Virginia and researchers at the Virginia Tech CAVE via a collaborative virtual environment. The path to success was certainly more challenging than expected! However, information gleaned from the endeavor will be useful in extending collaborative virtual environments in the future to the K-12 education community. A summary of obstacles encountered and progress made is organized below by project objectives.

1. TO CONNECT SECONDARY STUDENTS AT TWO REMOTE LOCATIONS VIA THE INTERNET TO THE VIRGINIA TECH CAVE

The two schools connected to the Virginia Tech CAVE were the Central Virginia Governor's School for Science and Technology (CVGS) in Lynchburg, Virginia, and the Central Shenandoah Valley Regional Governor's School for Science and Technology in Fishersville, Virginia. Connectivity was a larger obstacle than expected. The CCC did not work going through a proxy server, which many school districts use as a low-level firewall to provide limited protection for their networks and to monitor use. Opening the ports on the proxy server designated for use by the CCC to communicate did not work. Eventually, all SGI traffic was routed around the proxy server. Under this arrangement, the CCC was used to connect the two schools with the CAVE at Virginia Tech.

Two recommendations were derived from this experience. First, work must be completed to allow the CCC to operate within networks using proxy servers. Second, for this to happen, a programmer with extensive network expertise must work with the

Because it is a tool in the formative stages of development, much of the actual work done during the project amounted to "alpha" testing of the software.

CCC programmers. The level of expertise available in the field is not sufficient to deal with the problems encountered. Although the T1 lines available at each school provided enough bandwidth to utilize the CCC technology, the network configuration prohibited its use.

In order to attempt a collaborative CCC session, a conference call had to be set up since the verbal communication is handled via a normal phone connection. Conference calls were always initiated from CVGS, which tied up the schools' two phone lines for as long as the session lasted. Extensive use of the CCC dictates that the sites have at least two phone lines that can be dedicated to the CCC for the duration of the sessions. Speaker phones did not work well in the high school classroom, and talking on a handset meant only one person could communicate at a time. No easy solution was apparent for this problem.

2. TO PROVIDE K-12 STUDENTS THE OPPORTUNITY TO LEARN ABOUT AND EXPERIENCE VIRTUAL ENVIRONMENTS

The CCC proved to be a tool that has the potential of extending the collaborative virtual environment found in the Virginia Tech CAVE to K-12 schools and other remote sites at a very low cost. Because it is a tool in the formative stages of development, much of the actual work done during the project amounted to "alpha" testing of the software. This led to many improvements that CCC programmers implemented:

- fixing numerous bugs that caused the CCC to crash when it was executing on SGI-O2 desktop computers at remote sites
- a binary version that can be downloaded, which avoids having to locate files in the appropriate locations and then actually compiling the CCC
- a dialog box with a list of loaded models
- the capability of "shared view"
- the capability to jump to the middle of the virtual environment if a user gets lost
- the capability to return models to their original orientation after moving them around
- the capability to choose whether or not models are solid or allowed to pass through one another

With each revision of the CCC software, a series of bugs was detected and corrected when the version was utilized on the remote SGI-O2s. Although this type of work was not envisioned in the proposal, the team feels that a lot was accomplished from utilizing a user-centered design approach. The CCC is much more stable when it is used in remote locations than it was initially.

It took a great deal of time for the high school students who participated in the project to become familiar with using the controls to "fly around" the virtual CAVE. The controls were awkward and difficult to master, particularly given the time constraints of K-12 classrooms. Revision of the controls to make them more user friendly is needed, but this level of programming was beyond the financial support provided by the grant. Another feature needed is the capability to load and remove multiple models at one time while retaining the capability to move them around individually in the virtual environment. Loading and removing multiple individual models during a lesson was a time-consuming task that often prevented completion of a lesson in the K-12 environment.

3. TO ALLOW K-12 STUDENTS TO COLLABORATE ACTIVELY WITH PROFESSORS WHO ARE USING THE CAVE FOR THEIR RESEARCH

The CCC provided the capability for K-12 students to collaborate actively with researchers in the VT CAVE. It is also apparent that the CCC can provide the means for students at remote sites to collaborate with each other on projects.

4. TO CREATE AND DELIVER A CONTENT-SPECIFIC LESSON TO K-12 STUDENTS USING A VIRTUAL ENVIRONMENT THAT ALLOWS THE STUDENTS AT REMOTE SITES TO COLLABORATE ACTIVELY WITH EACH OTHER AS THEY INVESTIGATE THE SUBJECT MATTER

Four lesson plans related to molecular structure of organic chemistry molecules were developed. The team's experience suggests that development of programs for use in the CAVE and CCC is currently beyond the time constraints and expertise levels of K-12 teachers. The molecules utilized in the lesson were generated via the VRML File Creator for Chemical Structures.[6] To use these chemical structures in the lesson, the following steps had to be accomplished.

The pocket-PC could be used to point to various objects in the shared virtual environment where participants could upload and download detailed information associated with these objects.

- Since the CAVE only supports "VRML version 1" type files, all molecules used in the lessons, which began as "VRML version 2" models, had to be converted to Performer Binary files (.pbf). The conversion process was done by importing these files into a 3-D CAD software package and then exporting the files as .pbf. This software was too expensive for the Governor's Schools to purchase just to convert files. Therefore, all conversions had to be done by VT staff or students.
- Since the lessons involved positioning the molecules in specific places in the CAVE, the original model's coordinates had to be translated using Pftransform. This special software was not available to the Governor's Schools, except at significant cost. Therefore, all translations had to be done by VT staff or students.

The team was successful in developing the lessons. However, it was apparent that development of a more complex CAVE program would require full-time programmers. It also was evident that to utilize the CCC at a remote site, a staff member must have a basic knowledge of UNIX administration.

FUTURE DEVELOPMENT OF CCC: CCC-DIVERSIFIED

Virginia Tech's virtual environment software development team has been funded to develop collaborative virtual environments, with an emphasis on shared design environments by the Office of Naval Research (ONR).

Developing shared virtual environments to include a design environment philosophy required creating a new "shared-memory" architecture that would include networked virtual environment devices. For example, a force feedback device allows participants to manipulate objects in shared virtual environments with their hands. These objects can be 3-D molecular structures, where users at the desktop or in a CAVE can feel six degrees-of-freedom (6-DOF) (3-forces and 3-movements) associated with docking a 3-D-drug onto a 3-D-protein. Another useful networked virtual environment device is a handheld pocket-PC attached to a 6-DOF tracking device, which could operate in either the CAVE or CAVE-simulator. The pocket-PC could be used to point to various objects in the shared virtual environment where participants could upload and download detailed information associated with these objects. Such a device would extend the collaboration after a shared virtual environment session: The pocket-PC could be detached from the 6-DOF device and the information could be downloaded and post-processed on other computers. Other devices used in virtual environments have been 6-DOF motion platforms, remote-site real-time physics-based simulations, atomic force microscopes, etc.

This idea of including network virtual environment devices into a shared virtual environment collaboration required a philosophical redesign of the underlying software Application Programming Interface (API) used in the CAVE and CAVE-simulator. At Virginia Tech, the virtual environment software development team created Device Independent Virtual Environment: Reconfigurable, Scalable, and Extensible (DIVERSE).[7] To foster future development as well as virtual environment research collaborations and educational virtual environment distance learning collaborations, the DIVERSE API was licensed GNU-General Public License (GNU-GPL). GNU-GPL follows the same development philosophy of GNU/Linux, where over time, significant software tools can evolve "freely." DIVERSE 1.0 was released in January 2001 and runs on Linux and SGI-Irix operating systems. Future development of DIVERSE with an OpenGL interface will allow participants to collaborate on MS-Windows, Mac OS10, Sun Solaris, and HP-UX operating systems. With DIVERSE being free, available, accessible, and running on a variety of operating systems, future development of CCC with the DIVERSE API will resolve many of the issues previously noted from this project, including reducing cost, reducing the complexity for user-development, and allowing the CCC to operate on computers other than SGI.

VIRTUAL ENVIRONMENT APPLICATIONS IN EDUCATION DISTANCE LEARNING: OBSERVATIONS AND FUTURE OPPORTUNITIES

The development of collaborative virtual environments for use in K-12 instruction is in its infancy. The project team believes it is an area that holds pedagogical promise in two main areas: applications allowing students at remote sites to share in the development of collaborative environments and content-specific applications providing students with a context for learning. In both types of applications, the virtual environment should be designed to support student learning from a cognitive perspective. The environment should help students relate what they already know to new concepts and actively involve students in the learning process. In other words, the virtual environments need to be designed to assist students in assimilating new information into their cognitive schemas. In the first case, the team envisions a virtual "toolkit" that allows students in geographically remote schools to collaborate on creating a virtual environment. Could students create virtual robots designed to perform specific tasks in a virtual environment much like they might use Lego Logo kits to build a model robot in their classroom? This type of application will provide students with the opportunity to use the emerging virtual environment technologies as they are used in the professional world: to collaborate with colleagues, to solve problems, and to create innovative designs in a cost-efficient manner. In the second case, virtual environments can provide students with a context for learning that affords them the opportunity to connect what they are learning with what they know.

Development of contextual environments should focus on topics that are beyond the realm of the student's daily experience. For example, what if a virtual environment were created allowing students to pilot a spaceship they could accelerate in real time toward the speed of light? The program would allow students to experience the effect of the phenomenon known as Lorenz Contractions in a virtual environment. Given that context, more students might understand the conceptual and mathematical tenants of relativity. Another example might be a virtual environment that allows students to investigate weather phenomena, such as how thunderstorms form.

The program would allow students to experience the effect of the phenomenon known as Lorenz Contractions in a virtual environment. Given that context, more students might understand the conceptual and mathematical tenants of relativity.

Based on our collective experiences and lessons learned from this project, the original CCC software development team at Virginia Tech with the Governor's School project participants are exploring opportunities for future funding to rebuild CCC using the DIVERSE API. This project has been "a road less traveled," but it was rewarding.

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Tammy McGraw is Chief Executive Officer of The Institute for the Advancement of Emerging Technologies in Education. Prior to receiving the appointment, Dr. McGraw served as Director of Technology and Innovation at AEL, Inc., which operates one of the nation's 10 regional educational laboratories funded by the U.S. Department of Education. An accomplished visual artist, her research interests are varied and include spatial perception and representation and advanced learning technologies. She holds an M.A.E. in art education from Virginia Commonwealth University and an Ed.D. in instructional technology from Virginia Tech.

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FACE TO FACE:
AN INTERVIEW WITH MARY BAKER AND NANCY BARBA

Mary Baker is Manager of Emerging Technology, Broward County Public Schools, Florida.
Nancy Barba is Director, Program Development and Alignment, Broward County Public Schools, Florida.

Jeanne Moreno, Vice President and Chief Information Officer at Citrix Systems, Inc., was asked these same questions during her interview. Her responses appear in the Vision section.

FACE TO FACE:

LEADERSHIP

AN INTERVIEW WITH MARY BAKER AND NANCY BARBA

Mary Baker is Manager of Emerging Technology, Broward County Public Schools, Florida. Nancy Barba is Director, Program Development and Alignment, Broward County Public Schools, Florida.

▶▶: *The trend toward wireless communication seems to be advancing, although not as quickly as some would like. In your opinion, what barriers impede widespread use of wireless technologies in schools?*

MB: I guess there are two variations of wireless. One entails going right to the desktop, while the other extends applications to handheld technology. I think a barrier in education is the lack of testing for the effectiveness of handheld devices with students (e.g., how robust they can be, the impact of screen size, and the ways in which students with disabilities are affected). Another issue is money. The school systems have put all of their financial resources into desktops that are connected to the WAN or the LAN. It's a matter of getting people to think differently. That's where we are. It isn't talked about a great deal in education, because vendors are still pushing the desktop models.

▶▶: *That's interesting. I know some students have cell phones, probably at their desks. They are already wireless.*

MB: Without a doubt. Then there's the perception by some groups that wireless is harmful to the body. You know that splinter group is out there.

▶▶: *Have the security concerns surrounding wireless devices been an issue in your district?*

MB: Yes, they have been an issue. Actually they are looking into equipping each school security officer with a handheld device. This would allow the officer to identify students by picture and to access students' schedules to know where they should or shouldn't be. I think administrative use of handheld technology is probably well accepted and doesn't have the implications of putting it in the hands of the children. We are currently exploring administrative uses.

NB: We are also using handheld technology in our pilot to benchmark assessment. Teachers can administer a mini-assessment on the concept they are teaching and find out immediately what students know and don't know. The teacher can adjust the teaching and learning process according to the results.

▶▶: *The long-predicted demise of traditional textbooks has not occurred. Why do you think this is so, and do you think it will still be the case 10 years from now?*

NB: In Florida, we adopt books every four, five, or six years, depending on the subject. I think they are moving to a six-year cycle for all books. The state provides money to the districts when a new book is up for adoption. Thus, in this 2002 school year, schools should not be using any primary textbooks older than 1996.

We have been looking into electronic textbooks. Although the technology exists, it doesn't seem to be reaching K-12 quickly enough. We have looked at various electronic book products, including the V-Slate, Compaq's iPAQ, and Palm handheld devices. One issue is the availability of the technology. There are not many electronic books available at this time for grades 6 through 12. A second issue is the cost. The textbook publishers do not appear to have worked out a pricing plan yet. Publishers may get $3 or $4 per textbook for the writing of the book. The printing industry gets its share. The distribution industry also gets its share. That will be a challenge, because electronic delivery eliminates a whole segment of workers the same way the automatic teller did with banks. Another issue in Florida is a contract between the publishers and the state that presents a problem for adopting electronic textbooks right now.

On the flip side, there is the issue of students carrying a heavy backpack filled with large, heavy books. An electronic textbook would allow students to access all their texts from one small, manageable device. There are definite advantages and some disadvantages.

▶▶: *The recent court case involving Napster has raised the public's awareness of intellectual property rights and safeguards for materials in electronic form. What is the impact of intellectual property issues on innovation in teaching and learning?*

NB: Currently, technology ethics courses for teacher education students or in-service teachers are not required. There are no technology ethics courses for students either. Although technology allows us to do so many things now, we have not stopped to conduct a discourse on what we should and should not be doing or why we should or should not be doing it.

That even goes for copyright. There's a section in our policies that talks about copyright for teachers. I don't think our teachers hesitate at all to use something that's copyright protected if they believe it benefits their students. Barbara Correll (Director of Learning Resources) has done a very good job of educating principals and teachers, specifying what they can and can't do. She's out there explaining intellectual property rights, but I don't think people are paying attention to it. They think about what's going to help the students. They think, "If this is what I need, then I'm going to use it."

▶▶: *When people first started talking about the digital divide, they referred primarily to the disparity in Internet access between the wealthy and the poor. But people are now talking about other divides among technology users, such as gender and geography. How do schools address this issue?*

NB: We have around 250,000 students, approximately 30,000 employees, and about 15,000 teachers. We are a large urban district. Florida uses county districts (not city school districts), so some districts are huge. Some 28 cities are included as well as incorporated areas. Our mobility rate is 41 percent. Probably 35 to 40 percent of our students qualify for free and reduced-price lunch. There are a lot of "haves" and "have-nots" here.

MB: All students have access to computers in school. We have provided access to computers in community centers, libraries, and churches. But that's access. That is not the same as having a computer in the home where a child can use it any time he or she wants. This is the discrepancy between "haves" and "have-nots." Home access is an issue for us, but we hope handheld technology might help with that.

In the school district itself, equity is a priority. We have a policy and a technology plan that establish minimum baseline technology in all schools. We have access in all permanent classrooms. We have computers in all classrooms. I am not aware of any programs that address take-home technology for use outside of class.

NB: I want to touch on the other issue relative to geography and gender. The state adopts a number of books, potentially eight or nine textbooks in each subject area. Then the district's adoption committees select two or three that could be chosen for the district. Those state and district adoption committees ensure that the chosen textbooks are not biased against a particular gender or culture. I don't think we've done that with software yet. We have not really looked critically at software like we look at textbooks. I think that is something that's missing.

▶▶: *There seems to be a widespread assumption that every child should have access to a computing device and be able to operate it. In your view, how important is widespread access and usage among school-age children? How realistic is it?*

NB: It's vital. It is absolutely vital for those students that are ninth grade and above. It's like having a pencil or pen. As students go into the world of work, which is technology driven, they need to be able to use technology. I think it's extremely important for students in grades 6 through 8 and very important for students in preschool through grade 5. Young children learn technology quickly.

▶▶: *In your opinion, how realistic is the notion that students will ultimately have personal access to some kind of computing device—handheld or other?*

NB: I think we are very close. Forget the schools for a minute, because the schools can only do as much as the available bond issues and dollars allow. I believe the schools will struggle and will always be years behind industry for many reasons. The biggest reason is money. But within a couple of years, I foresee the communications industry (telephone or cable) providing Internet access with handheld keyboards. That could potentially provide immediate Internet access to every home.

▶▶: *Is there anything else you would like to add?*

MB: I have a question or two for the staff at IAETE. I want to know what happened to virtual reality? It was on the forefront four or five years ago and then disappeared. What a wonderful educational tool.

NB: We talk a great deal about students and technology for students. Of course, the teachers must be involved. The universities have moved heavily to online training for students and faculty, but we really haven't seen much of that for K-12 teachers. Broward County can't be the only district having tremendous problems finding teachers, keeping them in the classroom, and finding substitutes so that we can train our teachers during their workday. Alternative training methods—online training or electronic training—are truly lacking for teachers. I'm talking about content. You can find training about the brain, but there's no content or strategy training available electronically yet. Keep that in the back of your minds at IAETE, because it is sorely needed.

CREATING A NEW WORLD WITH ELECTRONICS

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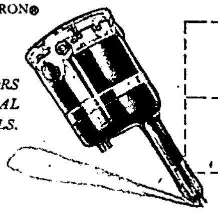

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