DOCUMENT RESUME

ED 477 705 IR 021 972

AUTHOR	McGraw, Tammy, Ed.
TITLE	INSIGHT: Vision & Leadership, 2002.
INSTITUTION	AEL, Inc., Charleston, WV.
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.
ISSN	ISSN-1536-6324
PUB DATE	2002-00-00
NOTE	203p.; A publication of the Institute for the Advancement of Emerging Technologies in Education (IAETE). Published annually. For the 2001 issue, see ED 459 688.
CONTRACT	ED-01-CO-0016
AVAILABLE FROM	INSIGHT Editor, IAETE, P.O. Box 1348, Charleston, WV 25325-1348 (yearly subscription, $50). Tel: 304-347-0400; Tel: 800-624-9120 (Toll Free); Fax: 304-347-0487; e-mail: insight@iaete.org; Web site: http://www.iaete.org/.
PUB TYPE	Collected Works - Serials (022)
JOURNAL CIT	INSIGHT; v2 n1 2002
EDRS PRICE	EDRS Price MF01/PC09 Plus Postage.
DESCRIPTORS	*Educational Development; Educational Planning; *Educational Technology; Elementary Secondary Education; Futures (of Society); *Instructional Leadership; Internet; *Technology Uses in Education; Telecommunications
IDENTIFIERS	*Visions

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: "The Future of Reading and Learning To Read" (Michael L. Kamil); "Biometric Authentication" (Anil K. Jain, Salil Prabhakar); "Students as Creators in the Real World" (Terence Rogers); "Tele-Immersive Environments for Education" (Kostas Daniilidas, Ruzena Bajcsy); "Mobile Usability Requires Telephones To Die" (Jakob Nielsen). This section also includes an interview with Senator Jay Rockefeller of West Virginia. Articles in the "Leadership" section include: "The Effects of Pervasive, Consumer-Based, Interactive Multimedia Games on the Reading Disorders of ADHD Children" (Tammy McGraw, Krista Burdette, Virginia Seale, Soleil Gregg); "Biometric Technology Goes to School" (Mary Axelson); "An American Sign Language Finger-Spelling Translator" (Ryan Patterson); "From Conference Room to Classroom: The 'Magic' of Teleportation" (Tammy McGraw, Krista Burdette); and "Formative Visions: Using Handheld Computers To Support Diagnostic Instruction" (Larry Berger, Elizabeth Lynn). This section also includes an interview with Janet Copenhaver, director of technology at Henry County Public Schools in Virginia. (MES)

IN SIGHT

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

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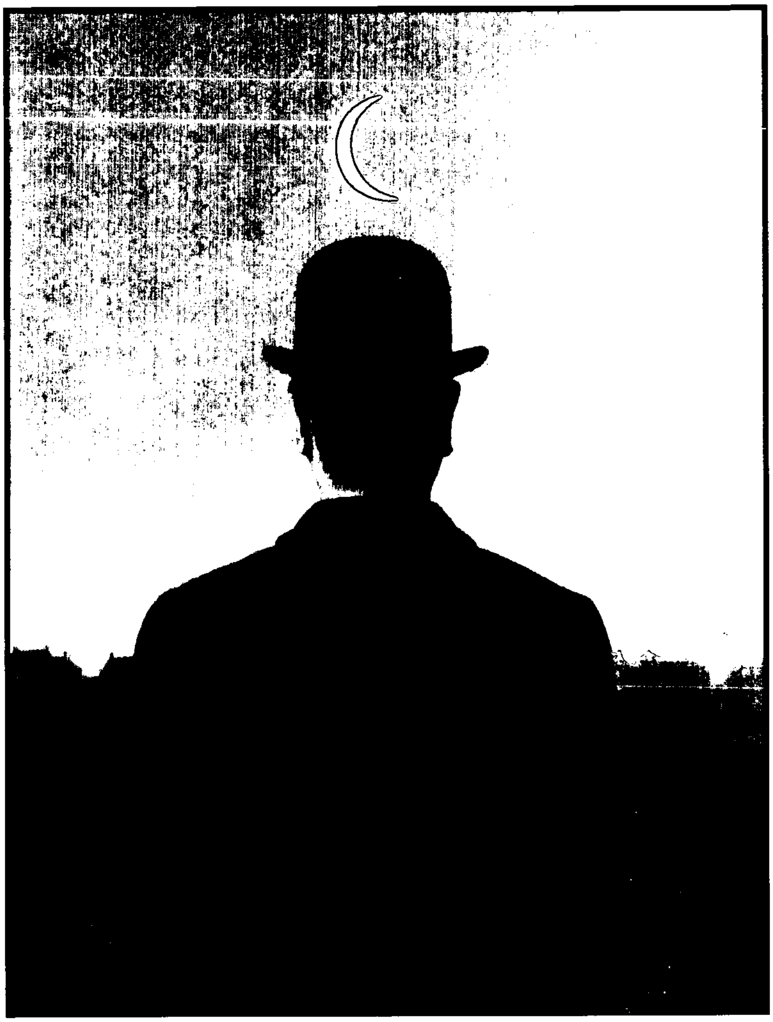

VISION

2002

V I S I O N

CONTENTS

The Distinguished Achievement Awards program recognizes diverse learning resources exhibiting superior content and educational value.

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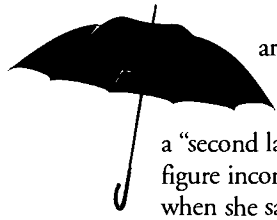
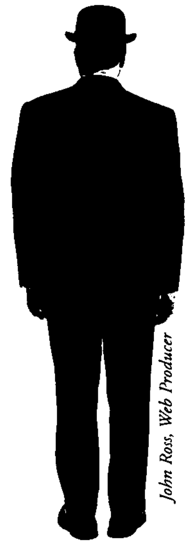
V I S I O N

IAETE

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

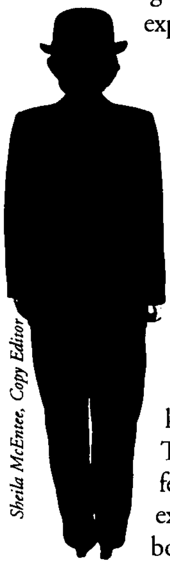
On the cover: René Magritte's *Le Maitre d'ecole (The School Headmaster)*





John Ross, Web Producer

Technology is empowering students to think and act creatively in ways that we are only beginning to understand. Recently I had the opportunity to talk with a 17-year-old entrepreneur about her Web site development business. She told me that she learned HTML when she was 10 years old, and that since then, it has become a "second language" to her. She has used this second language in recent years to earn a five-figure income annually—not bad for a part-time high school job. This student impressed me when she said, "I can accomplish anything with PhotoShop." Her words reminded me that digital tools and media offer unprecedented opportunities for student expression.



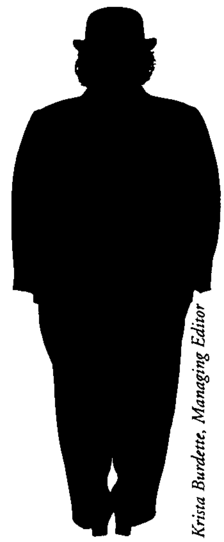
Sheila McEntee, Copy Editor

Sara Marchio, Executive Assistant

Nicholas Negroponte talked about the new "E-xpressionists" in his 1995 book *Being Digital.* He suggested that we are entering an era when expression can be much more participatory in nature, allowing the viewer or listener to transform the work of art to meet his or her personal needs or preferences. Digital manipulation is beginning to empower students to participate fully in the creative process, instead of just assuming the role of consumer.

So how do "peer-to-peer" file sharing and other Napster-type issues affect this new era of creative possibility? It is difficult to know, but there are early instances that might inform our thinking. The work of René Magritte, whose painting *Le Maitre d'ecole* is featured on the covers of this issue of IN ▸▸SIGHT, might be the perfect example. Magritte's art has been widely reproduced on everything from book covers to product packages, posters, and television advertisements. It is reported that Magritte was never angry about this blatant copyright infringement. In fact, he encouraged reproduction of his paintings in any form and viewed it as a surrealistic way to display his work. Only after his death in 1967 were copyright infringement penalties enforced. I believe Magritte would have greeted the idea of sharing his work over the Internet with great enthusiasm.

Nancy Balow, Senior Copy Editor



Krista Burdette, Managing Editor

We, too, are enthusiastic about sharing our work over the Internet and invite you to visit www.iaete.org/insight to participate fully in the exchange of information inspired by IN ▸▸SIGHT. The articles presented here represent a starting point for what we hope will be a rich and productive discussion about these topics. We believe vision and leadership must be viewed in tandem. Vision is important for illuminating possibilities while leadership helps us explore areas where more rigorous work is needed. It is important to view these papers in this context and to remember they represent the authors' perspectives at a given point in time.

Tammy McGraw

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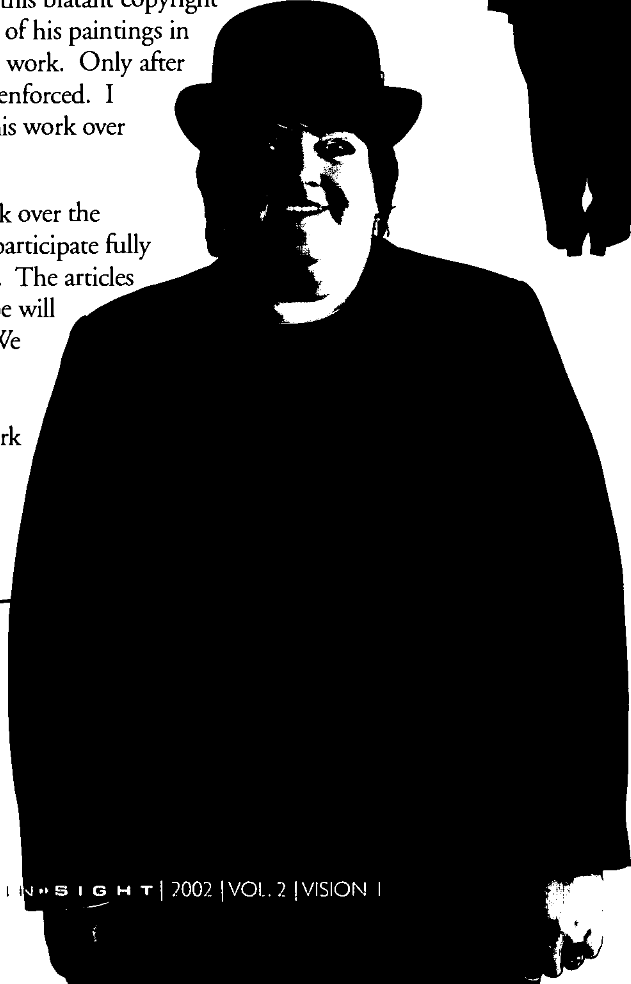

Tammy McGraw, Editor in Chief

Carla McClure, Senior Copy Editor

V I S I O N

"I can't understand why people are frightened of new ideas. I'm frightened of old ones."

—*John Cage*

V I S I O N

1

THE FUTURE OF READING AND LEARNING TO READ

Michael L. Kamil, Ph.D.

Michael Kamil presents his vision for the future of reading. He describes how technology can be used to support reading instruction and the process of learning to read. In the Leadership section, IAETE staff discuss their work with recreational, interactive multimedia games as a means to address neural impairments thought to underlie reading and attention disorders.

1

VISION

THE FUTURE OF READING AND LEARNING TO READ

Michael L. Kamil, Ph.D.

The Current View of Reading Instruction

If one walks into an elementary classroom today, one sees a setting that has changed little in the past century. There are 20 to 30 students seated at individual desks, a teacher at a larger desk, blackboards or greenboards along most of the walls, a classroom library, an alphabet chart, and other traditional literacy elements. Posted around the room are classroom rules and student work. A computer (or two or three) might sit in the back of the room or in an isolated corner. In some classrooms, the computers are connected to the Internet. The computers are among the few artifacts added to the classroom during the past 50 years.

Reading is taught with basal readers, written for the grade level of the students in the classroom. The social organization of the classroom comprises small groups of 6 to 10 students. Students read aloud in their groups and do independent work when they are not in groups. The independent work often employs conventional literacy materials—paper and pencil. Sometimes, students use the computer for independent tasks such as writing or some form of learning. In upper grades, the computers are used for research and often have a greater role in the curriculum. In some classrooms, there are adult aides who work with students. The teacher attends to a few students at a time but generally focuses on an individual even when students are in groups.

Not all classrooms follow this pattern but it represents an "average" classroom of today. How might classrooms look in the future?

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A Futuristic View of Reading Instruction

It is important to explore the definitions of literacy and literacy learning—both the contemporary and potential future definitions—and how they might affect future teaching, literacy, and learning.

In *The Diamond Age*, Neal Stephenson describes a "book," "a young lady's primer," which serves as a complete learning environment—a replacement for teachers and parents.[1] It adapts instruction to the state of the learner, the learner's environment, and the needs of the learner. It teaches anything the student needs to know, based on the student's knowledge, the events occurring in the environment, and what is most critical in terms of content. This "book" has only a single page, which can be refreshed electronically without physical connection to a computer network. It has both audio and video capabilities. The *Primer* Stephenson envisions is fully interactive and independent except for the speech handled by live individuals who are connected to the book's network and provide real-time performances.

This could be the ultimate learning environment—capable of teaching whatever is needed, "just in time," individualized to the learner. Stephenson presents a fanciful and provocative account of future learning. How much of this is possible? How much of it is desirable? And how much of it would be effective? Will literacy, as well as content, be taught by such devices in the future?

To answer these questions, let us consider the factors involved in developing or implementing a device that would approximate the *Primer* Stephenson describes. These factors can be roughly divided into two groups of considerations: one set deals with issues of software and the other set involves hardware issues. Before considering these two factors, it is important to explore the definitions of literacy and literacy learning—both the contemporary and potential future definitions—and how they might affect future teaching, literacy, and learning.

Literacy and Learning Definitions

We need to be clear about what we mean by literacy. Not only has its definition changed dramatically over the years, it now includes the notion that *learning* from text is as important as being able to read text. It will probably be even broader in the future.

Definition of Literacy

Literacy was once defined as the ability to read and write. In recent years, the definition of literacy has expanded to include the ability to learn from text. More important, the definition of *text* has dramatically expanded to include not only print but also various forms of multimedia information.[2] Moreover, the definition of literacy now expands the definition of writing to include creating multimedia documents and augmenting text with all sorts of annotation. Even elementary school students are using programs like *Kid Pix* to produce "presentations" instead of simple text documents.[3]

Consider the "new" types of text that students (and adults) encounter in the real world:

- Web pages and Internet sites
- e-mail
- multimedia documents
- electronic books

These are not fanciful—they represent a very large amount of text that continues to grow exponentially.

A visit on June 28, 2002, to the search engine Google (www.google.com) revealed that the number of indexed pages was 2,073,418,204. In comparison, there are an estimated 6,500,000,000 library books in the world.[4] When one adds the books in private libraries and those belonging to individuals, it is clear that the amount of conventional text far exceeds that of electronic text. Regardless of the disparity, there is simply no question that dealing with electronic text is, and will be, increasingly critical for educated persons.

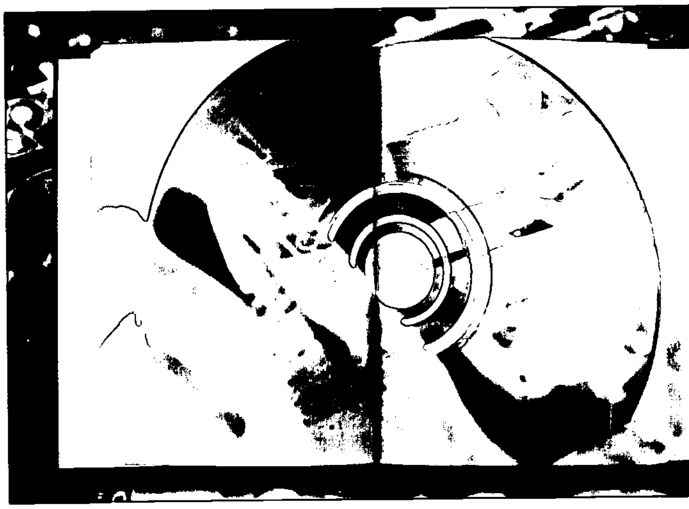
Moreover, the use of multimedia information is vast and increasing. Woodruff, Aoki, Brewer, Gauthier, and Rowe found in 1996 that more than 72 percent of all Web pages contained GIFs (a graphic picture format), JPEGs (another graphic format), or video clips.[5] The number of existing multimedia documents has increased since then.

Literacy instruction for students will have to take into account the demands placed on students by these new types and formats of text. Very little is currently done to prepare students for reading and processing electronic and multimedia text.

Adaptive Instruction

One of the great hopes of computing in instruction is that, like Stephenson's *Primer*, instruction might be adapted to the needs of individual students. The earliest attempts at teaching reading with computers were reported by Atkinson and Hansen in 1966-1967.[6] The hardware was far more primitive than that available today, and the software was only text with accompanying audio provided by tape recorders. However, the important advance was that instruction delivered by computers did teach students to read.

Software Issues



We turn now to think about the software that might be used to teach reading or to present text to readers. One desirable feature of software for reading instruction is that it should deliver the necessary information to a student when it is needed. Presenting the information in this way is often referred to as *scaffolding*. This information can include all sorts of information—feedback, analysis of difficulty, explicit instruction in skills, and definitions of words, for example. From the outset, immediate feedback was a critical innovation in the use of computers to teach. Using online dictionaries has been one of the most-investigated scaffolding configurations.

Because instruction is individualized and can be tailored to the needs of a single user (or many different users at the same time), computer instruction has been viewed as delivering some aspects of reading instruction more effectively than any other method.

Use of Multimedia

What types of multimedia information are used in reading instruction software? Are they the same as those used more generally in multimedia documents? We will next consider the various types of multimedia information and what we know about the ways in which they are read and processed.

Speech Synthesis

Incorporating speech with text has been a staple of the use of computers for reading instruction. The National Reading Panel report lists this as the major focus of instructional studies that use computers to teach reading.[7] Allowing students to hear text as they see it presented by a computer improves reading achievement. Almost all of early reading instruction is rooted in oral language methods. The addition of speech to print should continue to be a major feature of computer technology for reading instruction.

Speech Recognition

Kamil, Intrator, and Kim argued, however, that a major barrier to improving computer-based reading instruction is the lack of highly effective speech recognition.[8] That is, for the computer to function in a stand-alone manner, it must be able to understand what a child reads, judge the accuracy of oral reading, and provide feedback based on the oral performance. Unless we discover or develop new techniques for teaching reading that do not depend on oral methods, speech recognition will continue to be as essential for computer instruction as it is for conventional teaching.

Progress made so far in speech recognition technology demonstrates that it is possible to apply this technology to the teaching of reading. Mostow and Aist have developed a tutoring system that uses it.[9] Commercial programs for reading instruction utilizing some aspects of speech recognition are beginning to appear on the market. As the technology develops, reading instruction by computers will become even more effective.

Another use for speech recognition, as an alternative device for controlling computers, is now available for navigation and for dictation. Could it be that in the future we might not need keyboards to input text? Current accuracy rates for dictation are in the neighborhood of 90 to 95 percent, requiring a great deal of correction—promising, but not yet sufficient to eliminate other forms of navigation and input.

The reader must be more aware of the text and the processes involved in reading, as well as the potential interruptions in fluent reading when he or she leaves the current text to explore a hyperlink.

Hypertext

This is text that links to other text electronically. A reader can access and process text in a nonlinear way by making use of the links. Many have speculated that hypertext will be the standard form of writing in the future. Some applications of hypertext, particularly for learning, do seem successful. Studying seems to be more efficient when a hypertext environment is involved.[10]

Reading hypertext involves a substantial amount of skill—both with conventional print and with new forms of text. While hypertext opens up a world of possibilities for the reader to explore, free from some of the linear constraints of conventional text, it adds to the burden of reading. The reader must be more aware of the text and the processes involved in reading, as well as the potential interruptions in fluent reading when he or she leaves the current text to explore a hyperlink. Researchers have begun to explore these new reading behaviors in some detail and have found there is very little instruction that helps students learn to read in this new medium.[11]

The following brief synthesis describes what we know about how *adults* read hypertext.

Preference for paper. Readers prefer hard copy to electronic versions of documents. This is partly a reflection of the issues raised earlier and partly a matter of convenience: Electronic documents are not accessible without a connected computer.

Urge to click. Many adult readers explore every hyperlink in the text. They say they believe the links are important or they would not have been put in the text in the first place.

These findings suggest that we need to be systematic about teaching students to read hypertext.

Postponed exploration of links. Other adults report finding the links distracting. They don't bother to explore the links until after they have read the passage by itself.

Self monitoring. Adult readers of hypertext may try to decide if a link will help them understand the text. That is, if comprehension is difficult, readers report exploring links for help with understanding the text. This is similar to what readers do in conventional text, but the possibility of accessing information beyond the printed word makes this more important in hypertext.

URL tracking. Finally, many adult readers use the mouse to focus on the link and attempt to decipher the URL. Knowing (or guessing) that, for example, the URL *www.stanford.edu* is likely to lead to the home page for Stanford University may help the reader to make an informed decision about whether the link will be helpful. Moreover, it is clear that domain names carry different connotations. For example, *.edu* is viewed as more trustworthy than *.com.* While such generalizations may be useful, readers need to learn that some information on *.com* domains is highly trustworthy, while some on *.edu* might be suspect.

Many readers report that they approach reading hypertext and conventional text in very different ways. This is in line with Nielsen's finding that readers skim hypertext passages, rather than reading them word for word.[12] We teach students how to adapt their reading for different genres of conventional text. We should do the same for electronic and multimedia text.

These findings suggest that we need to be systematic about teaching students to read hypertext. Since many adults are "self-taught" hypertext readers, we need to determine which of the strategies they use are most effective, which are ineffective, and which are simply irrelevant.

Adaptive Text

Adaptive text describes the text found in Stephenson's *Primer.* It is a text environment that can prompt the student in reading or learning.

In recent studies, Kim and Kamil have found that using adaptive learning agents in text can improve students' comprehension.[13] Adaptive learning agents (or guides) can give advice or feedback to readers. (An infamous example of such an agent is the animated paper clip that comes with Microsoft Office.) The most sophisticated of these agents are interactive in that they respond differently to reader inputs by offering help in any number of dimensions. At one level, the help might be simply to guide the reader through understanding what is important about the text. At other levels, different scaffolding might be offered—vocabulary or background knowledge about a particular topic. For readers in an unfamiliar language, these guides might offer translation services. Ultimately, adaptive learning guides would be able to instruct students in particular skills that might be necessary for fluent reading of the passage.

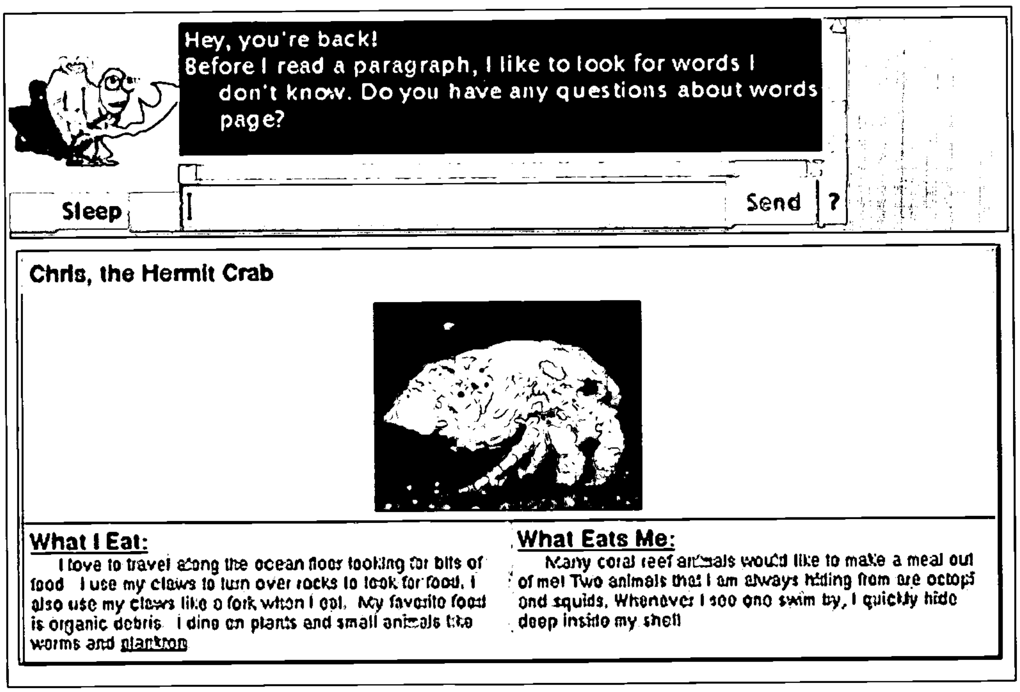


Figure 1. Screen Shot of Smart Text[14]

(Editor's note: The student scrolls right to see the complete sentence, "Do you have any questions about words on this page?")

The screen shot in Figure 1 shows an example of how the animated agent gives the student reading assistance with a passage by modeling proficient reading strategies. In this particular example, the crab is "thinking aloud" about a reading strategy it likes to use: scanning for unknown words before reading a passage. At the same time, the

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agent is inviting the reader to become actively involved in reading the text by applying the strategy to the passage. When the reader types unknown vocabulary words or concepts into the text box, the agent can provide the reader with definitions or additional assistance. In addition to modeling reading strategies and providing vocabulary assistance, the agent also asks questions to monitor comprehension and help the student attend to salient information. Through repeated interactions with the agent, students become more proficient readers.

Cognitive Aspects of Reading Multimedia Text

The addition of multimedia elements to conventional text has great potential for assisting students in reading and learning to read. Presently, however, instruction is rarely, if ever, offered to students to enable them to become adept at processing documents that combine print and other media.

Existing research suggests what we need to do to create multimedia documents that can be optimally useful for readers. These same findings have implications for what students should be taught about reading these documents. Such instruction can also be generalized to teach students about creating multimedia documents with programs like *Kid Pix, HyperStudio*, or *PowerPoint*. The following five points summarize what we currently know about the reading of multimedia documents. They come from a synthesis of research on electronic text by Kamil, Kim, and Lane.[15]

Appropriate visual representations can support text comprehension. Learners are apt to pay more attention to pictures when they accompany descriptions that are complex or difficult to visualize.[16] Superfluous visual information is often ignored by students and therefore cannot support comprehending and remembering other information presented in conventional text information or otherwise in the document. Effective multimedia documents should have visual supplements that are well elaborated, clearly identified, and well integrated with the text so readers can make connections between the visuals and text information.

Dynamic visual images may facilitate comprehension. When a great deal of complex spatial and visual information is presented, dynamic (rather than static) visuals may help readers to form mental images. They are particularly useful for visualizing changes in spatial relationships and remembering salient information. This is especially true when the concepts involve change over time.

Students with little prior knowledge perform better when presented with fewer choices about what to read and how to read it.

Verbal and visual information should be presented together. Information that is processed in more than one modality may be more memorable because there are two ways to remember it instead of one. For example, visual information, such as pictures, video, and diagrams, should have the verbal descriptions integrated with the visual and should be presented simultaneously, rather than serially. The verbal information can be printed or spoken as it accompanies the visual information. In this arrangement, the reader is able to process the information as needed.

Prior knowledge affects comprehension of multimedia documents. These documents often present the reader with choices about what elements to read and in what order. When readers have little prior knowledge, they find it harder to decide what information will help with comprehension. Students with little prior knowledge perform better when presented with fewer choices about what to read and how to read it. Research suggests that these readers should have multimedia text with fewer user-controlled options for hypertext navigation and browsing.

Developmental factors affect the way multimedia documents are processed. In multimedia documents where pictures, diagrams, graphs, and charts give supplementary information, proficient readers can integrate the verbal and visual information. Younger children may not be proficient at such integration. Moore and Scevak studied how students in grades 5, 7, and 9 read science texts with multimedia components.[17] The older students displayed a greater ability to link text and visual information than younger students did. Small, Lovett, and Scher noted that many adults do not attend to information in visuals unless explicitly instructed to do so. They cite research finding that children, too, often need directions to pay attention to visuals.[18] These developmental considerations suggest dimensions of instruction that are critical for readers in the age of electronic text and need to be incorporated in the software that delivers the instruction as well.

Future software should include many assistive features to be delivered to readers as needed.

Assistive Technology for Reading and Writing

Reading is often taught in tandem with writing. We look at uses of computers as assistive technologies for reading and writing. Assistive functions are those functions that help readers or writers with text. That is, the computer can help readers and writers who are not able to process text in the same way that most other people can. The assistance can take many forms—from changing the size of the print to having the computer speak the text for sight-impaired readers.

Other work in technology and literacy reflects the interventional use of technology to benefit individuals who may not learn as easily or effectively from traditional modes of instruction. These individuals may include persons with learning disabilities, persons facing physical challenges, and pre-literate children. Relevant here is technology use intended to remediate specific difficulties in literacy acquisition. Ferrier and Shane have noted that the computer can offer a diverse array of assistive tools because of its many functions and forms of output, including visual representations, print, and voice/communication.[19]

Conventional applications of computers to facilitate literacy acquisition for learners with sight impediments have included large-print text, audio descriptions, braille displays, and screen magnifiers. As multimedia texts increasingly offer new modes of representation and the versatility to create unique learning environments, studies continue to assess the best ways to utilize these benefits. Steelman, Pierce, and Koppenhaver highlight several advantages of using computer technology to develop literacy in children with severe speech and physical impairments, including the flexibility to tailor programs to different learning styles and the ability to allow physical access to literacy materials.[20] Future software should include many assistive features to be delivered to readers as needed.

Second Language Issues

What about learners who speak or read a language different from that in which the text is written? Much of the current research on multimedia support for second language learners involves learning styles and individual needs. Preliminary findings

appear to be quite promising. Plass, Chun, Mayer, and Leutner found augmented story comprehension and recall of word translations with the support of verbal and visual learning preferences to be effective in teaching English language learners.[21] Using a hypermedia-assisted second language learning program, Liu and Reed also found positive gains in vocabulary and improvements in the correct use of words in context by a group of international students learning English.[22]

Computer networks make access to text in any language possible. This capability provides for materials that can enhance content learning in other languages. The second language issues become even more important as we consider the trend toward globalization in commerce and education.

Social and Collaborative Uses of Computer Technology

As technology becomes more prominent in literacy instruction, the social milieu of the classroom and the interactions between learners and teacher will change. Intrator and Kamil noted an increase in research exploring the role and impact of technology on literacy communities and on social interaction in the classroom.[23] Much of this work is based in the social constructivist tradition and focuses on the interactive complexities of teaching and learning in technology-rich environments. Studies exploring social interactions in literacy learning can be sorted into three categories: (1) the effects of collaborative literacy practices in the classroom, (2) the effects of collaborative writing in the professional environment, and (3) the effects of technology on the interactional patterns and relationships between teachers and students. The first and last are discussed on the following pages.

Students must be able to function in networked, collaborative teams as well as individually. Moreover, instruction must promote this type of learning.

Collaborative Literacy Practice in the Learning Environment

A long-standing concern about computer use is that students could become isolated from one another and from the social context of the classroom. Research suggests the opposite: Using computers fosters higher levels of interaction and collaboration, particularly in the domain of writing.

Dickinson studied a writing program in a grades 1-2 classroom.[24] He found that collaborative work at the computer created a new social organization that affected interactions. During conventional individual writing assignments, students rarely spoke to one another. During collaborative computer writing, students discussed plans, revisions, and issues of meaning and style.

This reveals another instructional dimension that is critical to developing proficient readers. Students must be able to function in networked, collaborative teams as well as individually. Moreover, instruction must promote this type of learning.

Teacher-Learner Interactions

Some have predicted that, despite the rhetoric about technology's potential for driving innovative practice in the classroom, dominant cultural beliefs about teaching, learning, and proper knowledge will inhibit computer use and deter shifts in both practice and in teacher-student relationships.[25] As a result, the teacher's role and pattern of interaction with students will undergo little change with the infusion of computers into their literacy practices.

Burnett found that teacher-student writing conferences in an elementary school involved more sophisticated interactions when a word processor was used.[26] The writing of the word-processed compositions also improved, perhaps due to the interactions. Other research has reported that the frequency of student-teacher interactions increased when word processing was used and computer networks were available.[27]

In summary, the evidence seems to support the proposition that computers do encourage students to interact more with one another and with their instructors. Despite dissenting voices, the effects of computers in collaboration appear to be positive.

Hardware Issues

This set of considerations reviews the hardware necessary to create the kind of device described in *The Diamond Age*. Some of the relevant promises and limitations of technology are explored.

Electronic Paper

The *Primer* employs futuristic technology wherein a sheet of "paper" assumes electronic characteristics. That is, while the *Primer* looks like a conventional book, it has only one page that is constantly updated much as a computer screen is updated. The content on the page of the *Primer* changes as the user reads. It is sensitive to the state of the reader, but more important, the text on the page of the *Primer* is not constant but changes as a function of the reader, the environment, and some sort of curriculum that dictates what needs to be learned and in what order.

This concept of the *Primer* is much closer to reality than most of us would expect. Several projects are close to producing a commercially viable, digital paper.[28]

Size and Portability

One design problem has to do with the portability of devices on which the appropriate software could be used for reading or learning. Current versions of electronic books, PDAs, and pocket PCs are portable and many of these have wireless capabilities. They can connect with other computers and provide access to the Internet. Although they are not as capable as full-blown computers, they are becoming more powerful by the day. Many of the present devices are as portable as, and comparable in size to, the *Primer*.

Bandwidth

The speed with which Stephenson's *Primer* operates is real time. Few, if any, current portable devices can operate in real time when they are connected to other machines. Connection speeds are far too slow to provide the total interactive communications that Stephenson posits.

Power

Perhaps the biggest item that hampers our ability to produce something like a *Primer* is the power requirement. All the interactive elements in the *Primer* would require large amounts of power. Given the problems surrounding the costs and availability of power in recent years, this is an issue that we are far from resolving. Without the cheap and nearly universally-available power sources Stephenson describes, we can't predict implementation of a *Primer* that could be used anywhere at any time.

Display Issues

When it comes to the displays, we have a reasonable understanding of the issues in reading from computer screens compared to hard copy. In the following paragraphs, these issues are explored in some detail.

General

Several researchers have established that reading from a computer screen is anywhere from 15 to 25 percent slower or less efficient than reading from a printed page.[29] That is, it might take more time to read the same material or comprehension of the material is less. Either way, reading a great deal of text from conventional computer screens is difficult. Even today's experienced computer users prefer reading from hard copy.

Resolution

One of the major overriding factors contributing to the decreased speed or efficiency of reading from computer screens has been the resolution of the screen. Today's desktop monitors are far more capable than the earlier monitors in use when

previous research was done. While monitors have gone from fairly low to extremely high resolution in a very few years, the display resolution of PDAs, cell phones, and pocket computers is far less than that of desktops—even those in use when the research cited earlier was conducted. This will continue to be a problem, mostly because of the imposed design limitations of portable devices.

Getting from page to page in a text displayed on a screen eats up a great deal of time, and the problem becomes greater as the display becomes smaller.

Amount of text

When size of font is held constant, the amount of text that appears on a desktop monitor screen is typically far less than that on a printed page. As I write this, my word processor displays the document at the same size as the printed version. However, instead of the approximately 60 lines of print on a typical hard-copy page, I can view only about 30 lines at a time. (These numbers vary but do represent averages.) More text can be put on the screen, but the font and document sizes will be proportionally smaller, making it more difficult to read.

The problems become ever more acute as the size of the screen decreases. Most PDAs currently have a display that is a fraction of the size of a desktop monitor. The time necessary to scroll makes reading quite a bit slower, particularly when combined with relatively slow refresh rates on the screen.

Type fonts

There is a long-standing belief that serif type fonts are easier to read than sans serif fonts, at least in large amounts of text. However, because of the resolution problems with computer screens, serif fonts are typically displayed with anti-aliasing. That is, the serifs are "grayed" to make them appear sharper. This may mean that computer monitors will display sans serif fonts with more clarity. Resolutions on handheld devices are much more limited and will exacerbate this problem.

Navigation

The variables discussed above are clearly important issues in reading at a computer screen. Getting from page to page in a text displayed on a screen eats up a

great deal of time, and the problem becomes greater as the display becomes smaller. Navigation difficulties might be ameliorated by using speech interfaces, but they will not be completely solved.

On the positive side, searching for items in the text is far more efficient when a computer does the searching than when the reader has to manually turn pages. There will be some navigation issues that remain problematic for reading, but there will be some wonderful advantages in search capabilities. Even searches for information beyond the text are available on the Web at any number of search engines. They could all be available to the user of a *Primer*-like device.

What Will the Future Look Like?

How close are we to realizing the potential of the *Primer*? In 50 years, will we find an entirely new classroom environment, populated by much more technology; adaptive, interactive texts; and "books" that can teach as well as be read? Clearly, the influx of new technologies in the classroom will have an impact. More computers, more Internet connections, more PDAs, and other devices are shaping literacy and its demands on students. Many of the problems mentioned above will be worked out; others will remain.

Realistically, we cannot now do the sort of fanciful instruction that we have described. We may never get to the point where learning to read can be a fully independent endeavor. We do not know enough to build a truly intelligent *Primer*, one that can adapt in the ways Stephenson describes. Our knowledge of artificial intelligence is limited—and some may argue that its use for this purpose may never be appropriate.

We do not have a sufficiently rich knowledge of cultural information to put into the instruction a *Primer* would deliver. And we are far from knowing what we would need to teach children in any (or every) possible situation they might encounter. We also cannot build into our learning environments all of the possible ethical principles of all subgroups of students. There are simply too many intangibles involved—and too many possibilities. Our ability to produce such infinitely adaptive software is not up to the job and will probably remain so for a long time to come.

However, in many other ways we are very close. Many of the technologies needed to create a *Primer* are already available or on the horizon. One of the largest remaining problems will probably be the technology of teaching itself. What are the optimal conditions under which children can be taught? How should information be presented for optimal learning to occur? We are making progress, albeit slowly, in codifying how teachers teach. We are further behind when we try to get software to emulate the behaviors of expert teachers. This problem will require intensive research and development before we can create fully independent learning environments like the *Primer*. It is a worthy goal, however, and one that will pay large dividends if we succeed.

We cannot predict how much of Stephenson's vision for learning and how it could be taught will ever apply to learning to read. Reading will continue to be influenced by electronic text in all its forms, and we need to prepare our students for new forms of literacy. This does not mean that conventional reading skills will be unimportant. Readers in the future will need to be increasingly proficient at both reading conventional text and processing new forms of multimedia information. Similarly, when it comes to writing, new skills will be important, even as the traditional ones remain critical. Computers will become even more universal tools for both reading and writing.

We cannot simply sit back and hope that students will acquire this new constellation of skills on their own. We need to incorporate the new technologies and new literacy demands in the education of students now and continue to do so in the future.

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V I S I O N

2

BIOMETRIC AUTHENTICATION

Anil K. Jain, Ph.D. and Salil Prabhakar, Ph.D.

Since September 11, 2001, biometrics have been mentioned frequently on the news and in popular media, yet most people know little about these fascinating technologies. Anil Jain and Salil Prabhakar explain biometric authentication and various applications of biometric systems. In the Leadership section, Mary Axelson looks specifically at the application of biometric systems in educational settings.

2 VISION

BIOMETRIC AUTHENTICATION

Anil K. Jain, Ph.D. and Salil Prabhakar, Ph.D.

Is this person authorized to enter this facility? Is this individual entitled to this information? Is this service being provided exclusively to the enrolled users? Questions such as these are routinely posed in a variety of situations. They create a need to know the answer to one of the dual questions of authentication and identification:

Is this person who she *claims* to be?

Is this person who she *denies* being?[1]

The purpose of the first question is known as "positive" authentication. It aims to prevent more than one person from using the same identity. For example, if Alice is authorized to enter a facility, a "yes" answer to the first question will grant her access. The purpose of the second question is "negative" identification, and the goal is to prevent an individual from using more than one identity. For example, if Alice has already received her free lunch at the school cafeteria and now she denies that she is Alice (and claims that she is Becky), a "yes" answer to the second question will deny her the second serving of lunch.

This article focuses mainly on automatic authentication. It uses the terms *authentication* and *identification* somewhat interchangeably and lets the context resolve the precise meaning.

Traditional Methods of Authentication

The two most commonly used methods for positive authentication are (1) knowledge-based and (2) token-based. The knowledge-based approaches use "something you know" to verify identity. Passwords or personal identification numbers (PINs) are used in knowledge-based authentication systems. Token-based approaches use "something you have" to verify identity. Identity cards, credit cards, and keys are examples of items used in token-based authentication systems.

There are a number of disadvantages to these traditional methods of authentication. Complex passwords can be easily forgotten and simple passwords can be easily guessed (e.g., many people choose passwords based on names and birthdays). Tokens can be lost, stolen, copied, and shared. A combination of knowledge-based and token-based approaches might be expected to work better than either one alone. However, a surprising 25 percent of people write their PINs on their ID cards, thus defeating the protection offered by a PIN when an ID card is stolen. As a result, these commonly used approaches do not distinguish between authorized users and impostors who fraudulently acquire the "knowledge" or "tokens."

Biometrics: Definition

Biometric authentication, or simply biometrics, refers to verifying the claimed identity of a person by using physiological or behavioral characteristics.[2] The word *biometrics* comes from the Greek words *bios* (life) and *metrikos* (measure). Biometrics relies on "who you are" or "what you do" to verify identity. It is inherently more reliable than knowledge-based and token-based approaches because many physiological and behavioral characteristics are distinctive to each person.

Which biological measurements qualify as biometric characteristics? Any human physiological or behavioral characteristic with the following properties can be used as a biometric: (a) *universality*: every person should possess the characteristic, (b) *distinctiveness*: people can be differentiated based on this characteristic, (c) *permanence*: the property does not vary considerably over time, and (d) *collectability*: the characteristic can be measured manually or by using automatic sensors.

In addition to these properties, a biometric characteristic can also be evaluated based on *performance, acceptability,* and *circumvention.* Different biometric characteristics have different information and may therefore produce different authentication accuracies. Additionally, the resources required—for computation and memory—to achieve acceptable accuracy and robustness must be considered. The extent to which users are willing to accept a biometric system depends on factors such as intrusiveness, convenience, and religious beliefs. Circumvention refers to how difficult it is to fool the system by fraudulent techniques. For example, mimics can easily fool a voice-based biometric system, and makeup and plastic surgery can change facial appearance to defeat a system based on photographic images.

Automatic fingerprint-based identification systems have been commercially available since the early 1960s. Until the 1990s, these systems were used primarily by the police and immigration services and in certain security applications.

History of Biometrics

Humans have used body features such as face, voice, gait, and the like to identify one another for thousands of years. Our ancestors also used distinctive characteristics, such as scars, or a combination of features, such as complexion, eye color, height, weight, and so on, to verify an identity. These methods have worked well enough in communities or villages with small populations.

Alphonse Bertillon, chief of the criminal identification division of the police department in Paris, France, conceived and industriously practiced the idea of using a number of body measurements to identify criminals in the middle of the nineteenth century.[3] This was perhaps the beginning of the modern era of biometrics. Shortly after his idea began gaining popularity, however, it was eclipsed by the discovery of the distinctiveness of human fingerprints. Soon after, many major law enforcement departments embraced the idea of "booking" the fingerprints of criminals to make their records readily available. Later, using left-behind fingerprint smudges (latents), they could identify criminals. British scientist Sir Francis Galton wrote a detailed study of fingerprints in which he presented a classification system using prints of all 10 digits, which continues to be the basis of identification systems used by the forensics community.[4] Automatic fingerprint-based identification systems have been commercially available since the early 1960s. Until the 1990s, these systems were used primarily by the police and immigration services and in certain security applications.

Biometrics has emerged from its extensive use in forensics to become more familiar as a method of establishing personal identity in civilian applications.

System cost and system performance have been the most important factors in the widespread adoption of biometrics. Some biometric sensors (such as microphones for speech input, low-resolution digital cameras for facial imaging, and fingerprint pads) are already inexpensive (less than $50). With advances in data storage and microprocessor technology, the costs of storing biometric data and of the computing power required to process and match biometric measurements continue to decrease. System performance, specifically the identification accuracy, still needs to be improved for certain applications involving large databases and requiring extremely high authentication rates. Another factor affecting the adoption of biometrics is the perception that biometrics leads to invasion of privacy. However, this perception seems likely to diminish as it becomes clear that biometrics effectively provides both enhanced security and privacy protection.

Biometric Characteristics

A number of human characteristics are used in biometric systems including face, facial thermogram, fingerprint, hand geometry, eyes (iris and retina), voice, and signature (see examples in Figure 1). Among these, face, hand geometry, eye, and fingerprint are predominantly physiological characteristics, while signature and voice are predominantly behavioral characteristics. No single characteristic can be expected to meet the requirements of all biometric-based authentication applications. The suitability of a biometric characteristic for an application is determined based upon the properties of the biometric (i.e., universality, distinctiveness, permanence, and collectability) and the requirements of the application.

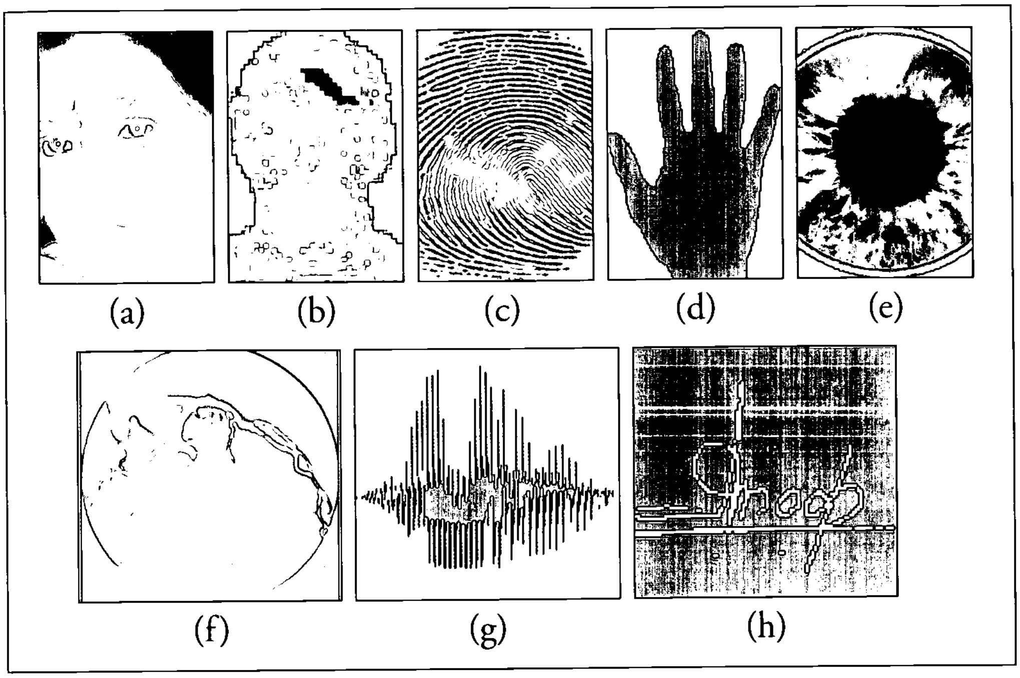


Figure 1. Commonly used biometric characteristics include: (a) face, (b) facial thermogram, (c) fingerprint, (d) hand geometry, (e) iris, (f) retina, (g) voice, and (h) signature

Most of the biometric systems on the market today do not store the captured image of the physical characteristic in its original form; instead, they store a digital representation, called a *template*, in an encrypted format. This serves two purposes. First, the actual image cannot be recovered from the digital template, thus ensuring privacy. Second, the encryption ensures that only the designated application can use this template.

Face

Face recognition is nonintrusive, and most people do not have any problem in accepting the face as a biometric characteristic. Facial images are probably the most common biometric characteristic used by humans to make a personal identification. The applications of facial recognition range from a static, controlled, "mug-shot" authentication to a dynamic, unrestricted face identification against a cluttered background. Identification based on the face is one of the most active areas of research. The most popular approaches to face recognition are based on (1) location and shape of

A facial thermogram can be captured using an infrared camera even in very low light; and the vascular structure is rich in information and remains invariant to changes in visual appearance caused by aging, hairstyle, makeup, and the like.

facial attributes, such as the eyes, eyebrows, nose, lips, and chin and their spatial relationships; and (2) an overall global analysis of the image, which represents a face as a weighted combination of a number of canonical faces. While the authentication performance of commercial face recognition systems is reasonable, these systems impose a number of restrictions on how the facial images are obtained. (They sometimes require a simple background or special illumination.) These systems may have difficulty recognizing a face if images are captured from drastically different views or under different lighting conditions. It is questionable whether a frontal face image itself, without contextual information, is sufficient for identifying one person out of a large number of people with a high level of confidence. For a facial recognition system to work well in practice, it should automatically detect whether a face is present in the acquired image, locate the face if there is one, and recognize the face from a general viewpoint (i.e., from any pose).

Facial Thermogram

The human body radiates heat. When heat passes through tissue and is emitted from the skin, the underlying vascular system of the body produces a distinctive signature. An infrared camera can capture this signature (called a thermogram) in an image. A thermogram of any body part can be used for identification purposes, but facial or hand thermograms are the most popular. It seems that a facial thermogram is unique to an individual, can distinguish between identical twins, and is not vulnerable to disguises. Even plastic surgery has no effect on facial thermogram if it does not reroute the flow of blood through the veins. In addition, a facial thermogram can be captured using an infrared camera even in very low light; and the vascular structure is rich in information and remains invariant to changes in visual appearance caused by aging, hairstyle, makeup, and the like. However, facial thermograms can be affected by factors such as the emotional state of the subject and body temperature. Like face recognition, facial thermogram recognition has difficulty in recognizing faces if the poses vary greatly from those of the stored templates. A thermogram-based system is challenged in uncontrolled environments, where heat-emanating surfaces in the vicinity of the body (e.g., room heaters and vehicle exhaust pipes) may drastically affect image

acquisition. Infrared sensors are very expensive, which is a major factor inhibiting the widespread use of thermograms.

Fingerprint

A fingerprint is the pattern of ridges and valleys on the surface of a fingertip; it is formed during the first seven months of fetal development. Fingerprints of identical twins are different and so are the prints on each finger of the same person. Today, fingerprint-based authentication systems (software and hardware) are available for less than $100, and the marginal cost of integration into various applications has become affordable. The accuracy of current fingerprint recognition systems is adequate for small-scale identifications involving a few hundred users.[5] Multiple fingerprints of a person provide additional information, allowing larger-scale recognition involving millions of identities. One problem with fingerprint technology is its acceptability. Because fingerprints have traditionally been associated with criminal investigations, some users feel uncomfortable with the technology's use in civilian applications. However, this perception has recently changed with the high demand for increased security and fraud reduction. Another problem with current fingerprint recognition systems is that they generally require large computational resources when operating in identification mode. Further, fingerprints of a small fraction of the population may be unsuitable for automatic identification because of genetic factors, aging, environmental issues, or occupational reasons (e.g., manual workers may have a large number of cuts and bruises on their fingerprints that keep changing).

Hand Geometry

Hand geometry systems use a number of measurements taken from the human hand, including its shape, size of palm, and lengths and widths of the fingers. These systems have been installed at hundreds of locations around the world. The technique is very simple, relatively easy to use, and inexpensive. Operational environmental factors such as dry weather or individual anomalies such as dry skin generally have an adverse affect on fingerprint-based systems but do not appear to have negative effects on the authentication accuracy of hand geometry-based systems. The main disadvantage of

this technique is its low discriminative capability. Hand geometry is not known to be unique and cannot be scaled up for systems requiring identification of an individual from a large population of identities. Further, hand geometry information may vary during the growth period of children. In addition, an individual's jewelry or limitations in dexterity (e.g., from arthritis) may pose further challenges in extracting the correct information. Because the physical size of a hand geometry-based system is large, it cannot be used in certain applications, such as log-on for laptop computers. There are authentication systems available that use measurements of only a few fingers (typically index and middle) instead of the entire hand. While these devices are smaller than the devices for hand geometry, they are still much larger than fingerprint devices.

Iris

The iris is the annular region of the eye bounded by the pupil and the sclera (white of the eye) on either side. The visual texture of the iris is formed during fetal development and stabilizes during the first two years of life. The complex iris texture carries very distinctive information useful for identification of individuals. The accuracy and speed of current iris-based identification systems are promising and point to the feasibility of large-scale identification systems. Each iris is unique; even the irises of identical twins are different. The iris is more readily imaged than the retina, and it is extremely difficult to surgically change the texture of the iris. Further, it is rather easy to detect artificial irises (e.g., designer contact lenses). Although the early iris-based identification systems required considerable user cooperation and were expensive, the newer systems are more user friendly and cost effective.

Retina

The pattern formed by veins beneath the retinal surface of an eye is stable and unique and is, therefore, an accurate and feasible characteristic for recognition. The digital images of retinal patterns are acquired by projecting a low-intensity beam of visual or infrared light into the eye and capturing an image of the retina using optics similar to a retinascope. In many identification applications, the degree of cooperation

required in imaging a retina may not be acceptable to the users, because the user must get close to the eyepiece and focus on a predetermined spot for the sensor to acquire a fixed portion of the retinal vasculature needed for identification. Like the infrared camera used for facial and hand thermograms, retinal scanners are expensive. However, the commercial retinal identification systems are very accurate, and a number of these systems have been installed in high-security environments such as prisons.

Although speech authentication is most appropriate for phone-based applications, the quality of a voice signal transmitted by phone is typically degraded by the microphone and communication channel.

Voice

Voice combines physiological and behavioral biometrics. The physical characteristics of voice are based on the shape and size of the appendages that synthesize sound—vocal tracts, mouth, nasal cavities, and lips. The physiological characteristics of human speech are invariant for an individual, but the behavioral aspect of speech changes over time due to age, medical conditions (such as common cold), emotional state, and so on. Voice is also not very distinctive and may not be appropriate for large-scale identification systems. Commercial speech-based authentication systems can be divided into two categories: (1) text-dependent or (2) text-independent. A text-dependent system authenticates the identity of an individual based on the utterance of a fixed, predetermined phrase. A text-independent system verifies the identity of a speaker independent of specific words. The latter is more difficult to design than a text-dependent system but offers more protection against fraud. One disadvantage of voice-based authentication is that speech features are sensitive to such factors as background noise. Although speech authentication is most appropriate for phone-based applications, the quality of a voice signal transmitted by phone is typically degraded by the microphone and communication channel. Speech-based systems may also be tricked by people who are good mimics. For these reasons, current speech-based systems are typically used in low-security applications.

Signature

Each person has a different style of handwriting and, therefore, a distinct signature. On the other hand, no two signatures of a person are exactly identical, and the variations from a typical signature may depend on the physical and/or emotional

state of a person. We routinely use signatures on legal documents and when making credit card purchases, so this is a very acceptable and convenient biometric. However, the authentication accuracy of automatic systems based on this highly behavioral biometric is not sufficiently high to provide a large-scale identification. The commercial handwriting recognition systems are typically based on one of two approaches: static or dynamic. Signature authentication systems based on the static approach use only the geometric features of the signatures, whereas the systems based on the dynamic approach also use features such as acceleration, velocity, pressure, and trajectory profiles of the signature. An inherent advantage of a signature-based biometric system is that the signatures are accepted as a valid form of personal identification in a large number of applications (such as credit card transactions) and can be transparently incorporated into existing business processes.

Each biometric characteristic discussed here has its advantages and disadvantages. A brief comparison of these eight characteristics based on the seven desired properties is provided in Table 1. The applicability of a specific biometric depends greatly on the requirements of the application domain. An authentication application requiring very high accuracy (e.g., access to a nuclear facility) cannot be satisfactorily met by, say, a speech-based system. No single method can outperform all others in every operational environment. In this sense, each biometric is *admissible* and there is no *optimal* biometric characteristic. For example, it is well known that both the fingerprint-based and iris-based systems are more accurate than voice-based ones. However, in a telebanking application, the voice-based technique may be preferred since it can integrate seamlessly into the existing telephone system. It is expected that future generations of identification systems may rely on systems that integrate multiple biometric characteristics and technologies to obtain a more accurate performance.

Although each biometric characteristic has its strengths and the choice of biometric depends on the application domain, *fingerprints* appear to meet all the desired properties. Every human being has fingerprints, with the exception of people with hand-related disabilities. Fingerprints are known to be distinctive, and fingerprint details are permanent. (They may change slightly due to cuts and bruises on the skin or weather conditions, but those changes are temporary and original fingerprint structure

Table 1

Biometric Characteristics Compared by Property Based on the Perceptions of the Authors (High, medium, and low values are denoted by H, M, and L, respectively).

Biometric Characteristics / **Desirable Properties**	Universality	Distinctiveness	Permanence	Collectability	Performance	Acceptability	Circumvention
Face	H	L	M	H	L	H	L
Facial Thermogram	H	H	L	H	M	H	H
Fingerprint	M	H	H	M	H	M	H
Hand Geometry	M	M	M	H	M	M	M
Iris	H	H	H	M	H	L	H
Retina	H	H	M	L	H	L	H
Voice	M	L	L	M	L	H	L
Signature	L	L	L	H	L	H	L

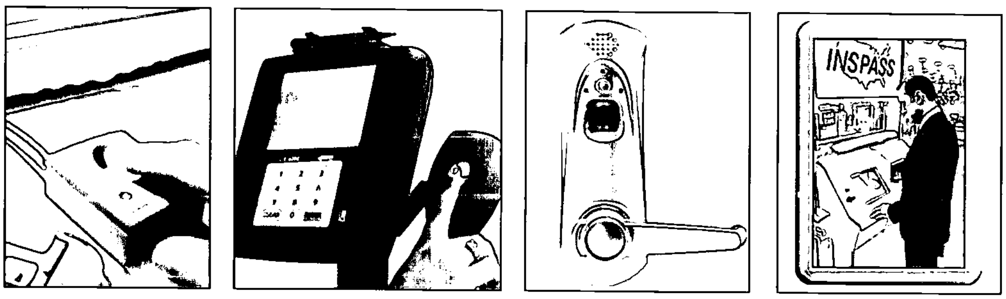
Fingerprint-based systems offer excellent performance-versus-cost tradeoff. With the integration of fingerprint identification, cryptographic techniques, and vitality detection (to ensure that the finger is not fake), fingerprint systems are becoming quite difficult to circumvent.

typically grows back.) Live-scan fingerprint sensors can capture high-quality images that can be easily separated from the background (e.g., unlike face recognition). However, fingerprints are not suitable for covert applications such as surveillance since fingerprints cannot be captured at a distance. Fingerprint-based systems offer excellent performance-versus-cost tradeoff. With the integration of fingerprint identification, cryptographic techniques, and vitality detection (to ensure that the finger is not fake), fingerprint systems are becoming quite difficult to circumvent. All these factors make fingerprint identification one of the most mature biometric technologies and one that suits a large number of authentication applications.

Application Domains

The most successful applications of biometrics are in the following domains:

- *Information system/computer network security* for user authentication and remote log-in (see Figure 2a for a product example).
- *Electronic commerce and electronic banking* for fund transfers, ATM security, check cashing, credit card security, smart card security, online transactions, point-of-sale terminals, and the like (see Figure 2b for a product example).
- *Physical access control* for restricting access to premises (see Figure 2c for a product example).
- *Government benefit distribution programs* for deterring multiple claimants to welfare or other payments.
- *Customs and immigration initiatives* such as Immigration and Naturalization Service Passenger Accelerated Service System (INSPASS) for enabling faster processing (see Figure 2d for a product example).
- *National ID systems.*
- *Voter and driver registration.*
- *Time and attendance monitoring systems.*
- *Keyless automobile entry.*



(a) (b) (c) (d)

Figure 2. (a) A fingerprint authentication system manufactured by DigitalPersona Inc., is used for computer and network log-in. (b) A fingerprint-based point-of-sale (POS) terminal manufactured by Indivos, Inc., verifies customers before charging their credit cards. (c) A fingerprint-based door lock manufactured by BioThentica Corporation restricts access to premises. (d) The INSPASS immigration system operated with hand geometry authentication technology developed by Recognition Systems, Inc.

Design of a Biometric System

A *biometric authentication system* is essentially a pattern recognition system that makes a personal identification by determining the authenticity of a specific physiological or behavioral characteristic. Important considerations in designing such a system include the operating mode, the system architecture (i.e., interaction of various modules), and measurement of system performance and error. Usually, the design that delivers the fewest authentication errors is chosen.

Operating Mode

The most important parameter in the design of automated personal recognition technology is whether the biometric application requires user *authentication* or user *identification.*

An authentication system verifies a person's identity by comparing the captured biometric characteristic with the biometric template(s) stored in the system. It conducts a one-to-one comparison to determine whether the identity claimed by an individual is true. For example, a fingerprint from a person claiming to be John Smith is compared only against the stored fingerprint of John Smith.

An identification system recognizes an individual by searching the entire template database for a match. It conducts one-to-many comparisons to establish the identity of an individual. For example, a fingerprint from a person who wishes to enter a secured facility is compared against the fingerprints of all the persons who are authorized to enter the facility. It is easier to design a biometric system for authentication than for identification, because an authentication system requires fewer computational and storage resources.

Depending on the application domain, a biometric system could be either an *online* system or an *offline* system. An online system performs an authentication or identification quickly (~1 second) so an immediate response can be provided (e.g., a network log-on application). An offline system usually does not require immediate authentication or identification so a relatively long response delay is allowed (e.g., in an employee background check). Typically, online systems are *fully automatic*, where the

biometric characteristic is captured using an online sensor, the registration process is unattended, there is no (manual) quality control, and the matching and decision modules are autonomous. On the other hand, offline systems are typically *semiautomatic*, where the biometric acquisition could be through an offline sensor (e.g., scanning a fingerprint image from a latent or inked fingerprint card), the enrollment may be supervised (e.g., when a criminal is "booked," a forensic expert or a police officer guides the fingerprint acquisition process), a manual quality check is performed to ensure good biometric data acquisition, and the matcher may return a list of candidates to be manually examined by a human expert for a final decision.

System Architecture

Logically, a biometric system may be divided into four distinct units or modules: an enrollment module, a system database, a user interface, and a verification (i.e., authentication or identification) module (see Figure 3).

The enrollment module registers a person into the system. First, a sensor scans the biometric characteristic of the user to acquire a digital representation of the characteristic. For example, a fingerprint sensor captures the digital image of the user's fingerprint. The feature extractor then processes the digital representation to generate a more compact internal representation. For example, the template of a fingerprint may include the locations and orientations of ridge endings and bifurcations. The template for each user is stored in the system's database or recorded on a smart card, a small plastic card containing a microchip that can store personal data. If the template is recorded on a smart card, the card is issued to the user. To be identified as the valid user, the cardholder must match the characteristic recorded on the card at the point of access.

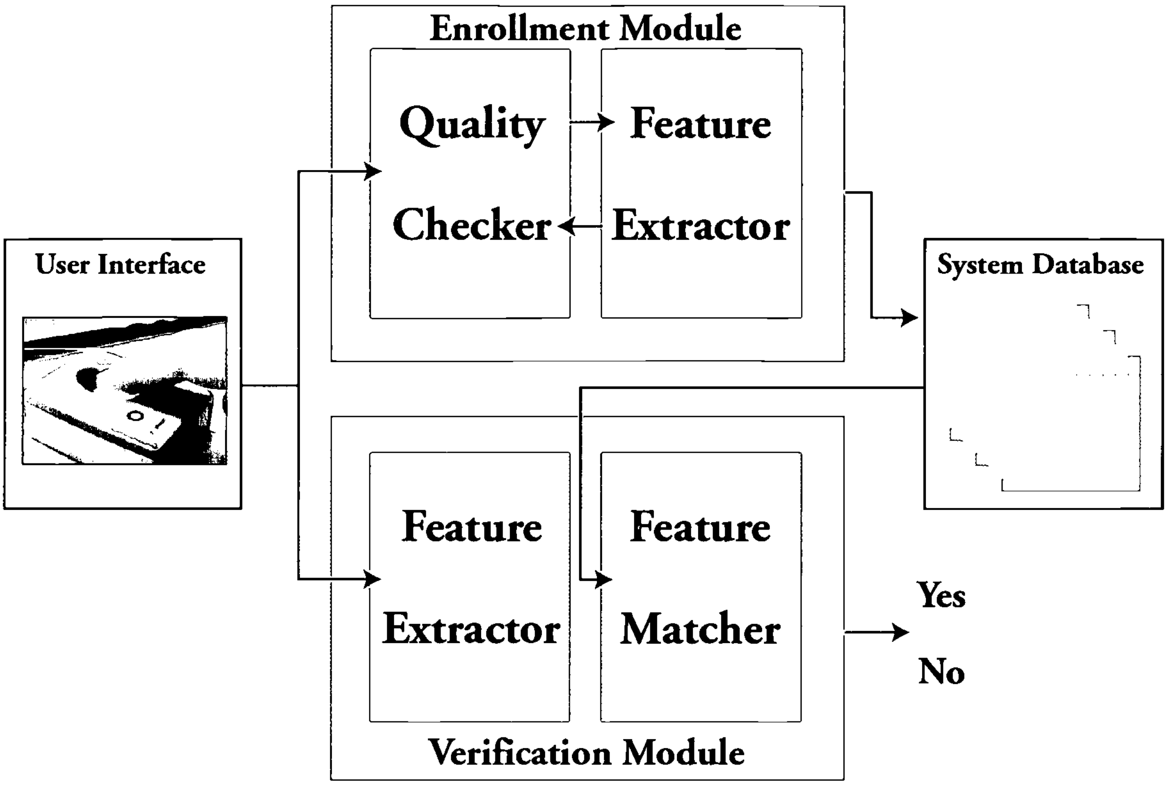


Figure 3. The four main modules of a generic biometric system are user interface, enrollment module, verification (i.e., authentication or identification) module, and system database.

During verification, the biometric sensor scans the characteristic of the person to be identified through the user interface, then uses the feature extractor to convert it to the same digital format as the template. The resulting representation is then passed to a feature matcher, which compares the representation against the user's template stored in the database. An authentication system will conclude that the person is correctly identified when the scanned characteristic and the stored template for the claimed identity are the same. Otherwise, it will reject the person. An identification system will assign the user the identity associated with the template in the database that best matches the scanned characteristic. However, if the scanned characteristic does not match any template in the database, the system will reject the person.

System Errors

A biometric system does not always make a correct identification. Typically, errors occur because of the inherent variations, called *intra-class variations*, present in any physiological or behavioral characteristic. For example, a person's facial image may change with hairstyle, the presence or absence of eyeglasses, or the use of cosmetics. A biometric system can verify an identity only up to a certain level of accuracy. Based on the output of the feature matcher, the authentication process has four possible outcomes: *true accept*, where a genuine individual is accepted; *true reject*, where an impostor is rejected; *false accept*, where an impostor is accepted; or *false reject*, where a genuine individual is rejected. The outcomes of true accept and true reject are correct, whereas outcomes of false accept and false reject are errors.

The performance of a biometric system may be measured by assessing the frequency of false accept and false reject errors. For this purpose, system designers use two numbers: *false accept rate* (FAR) and *false reject rate* (FRR). The FAR is the probability that the system accepts an unknown person as a genuine individual. The FRR is the probability that the system rejects a genuine individual as an unknown person.

Ideally, a biometric system should have extremely low values for both FAR and FRR. In practice, however, a lower FRR usually means a higher FAR, while a lower FAR usually means a higher FRR. The practical accuracy requirements of a biometric system are very application related. On the one extreme, a low FRR may be the primary objective for some applications. For example, in criminal identification, it is the FRR that is a major concern and not the FAR (i.e., we do not want to miss a criminal even at the risk of examining a large number of potential matches—innocent civilians—identified by the biometric system). On the other extreme, the FAR may be the most important factor in a high-security, access-control application, where the primary objective is to keep out impostors even at the cost of inconvenience to legitimate users. Between these two extremes are several civilian applications, where both FAR and FRR need to be kept at moderate levels. For example, in applications like ATM card authentication, a false accept could mean a loss of several hundred dollars, and many false rejects may irritate bank customers. Obviously, in civilian

applications, an FAR is not desirable as the main advantage of automation is defeated if human experts must examine a long list of false accepts. Figure 4 graphically depicts the tradeoffs between FAR and FRR.

Any application that requires an authentication of identity is appropriate for a biometric solution. The choice of a biometric largely depends on the requirements of the application.

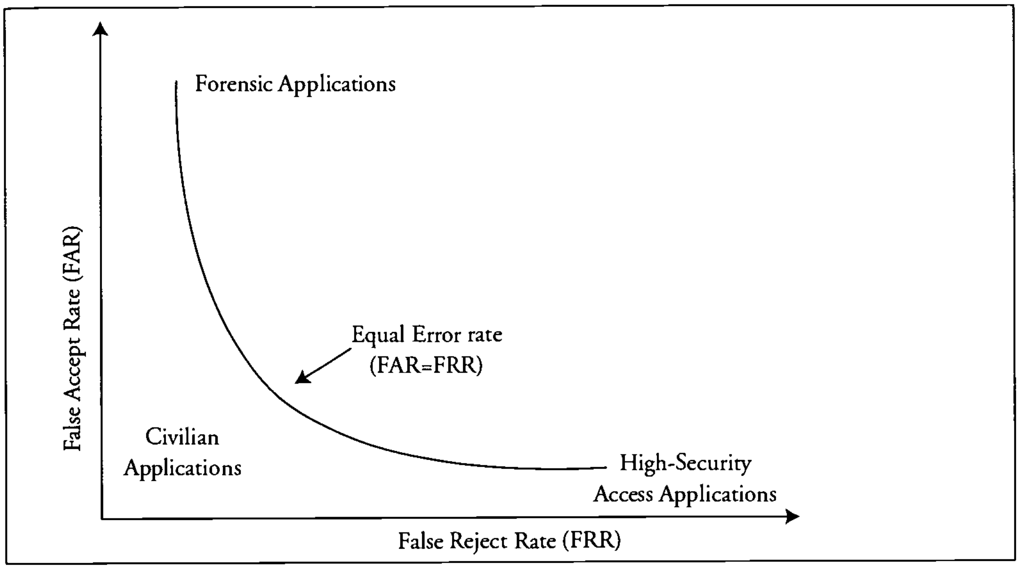


Figure 4. The receiver operating characteristics (ROC) curve illustrates the false reject rate (FRR) and false accept rate (FAR) trade-off in a biometric system.

Biometric Applications

Any application that requires an authentication of identity is appropriate for a biometric solution. The choice of a biometric system largely depends on the requirements of the application.

Wayman suggests that all the biometric applications may be categorized into seven classes.[6]

1. cooperative versus noncooperative
2. overt versus covert
3. habituated versus nonhabituated
4. attended versus nonattended
5. standard versus nonstandard operating environment
6. public versus private
7. open versus closed

Cooperative versus Noncooperative

This classification refers to the behavior of an impostor in interacting with the system. For example, in a "positive" authentication system, it is in the best interest of an impostor to cooperate with the system to be accepted as a valid user. On the other hand, in a "negative" identification, it is in the best interest of the impostor not to cooperate with the system so as to avoid being recognized. For example, the accuracy of biometric systems in a cooperative application can be increased by incorporating the traditional methods of identification (knowledge or token-based), thus requiring the biometric system to operate only in the authentication mode. On the other hand, users in a noncooperative application cannot be expected to provide a correct password or token, and therefore the biometric system needs to operate in an identification mode. Thus, the accuracy and speed of a noncooperative application may be lower than a cooperative application. Electronic banking is an example of a cooperative application; an airport application to identify terrorists who will try to break the system is an example of a noncooperative application.

Overt versus Covert

If a user is aware of being subjected to a biometric authentication, the application is categorized as overt. If the user is unaware, the application is covert. Facial recognition can be used in a covert application but fingerprint recognition cannot. Most commercial uses of biometrics are overt, while government, forensic, and surveillance applications are typically covert. Also, most authentication applications are overt, and identification applications generally fall in the covert category.

Habituated versus Nonhabituated

This use of a biometric system refers to how often the enrolled users are subjected to biometric authentication. For example, a computer or network log-on application typically has habituated users (after an initial "habituation" period) due to their use of the system on a daily basis. On the other hand, a driver's license application

typically has nonhabituated users, because a driver's license is updated only once in several years. This is an important consideration when designing a biometric system, because user familiarity affects the authentication accuracy.

Attended versus Nonattended

This classification describes whether the process of biometric data acquisition in an application is observed, guided, or supervised by a human (e.g., a security officer). Further, an application may have attended enrollment but nonattended authentication. For example, a banking application may have a supervised enrollment when an ATM card is issued to a user, but the subsequent uses of the biometric system for ATM transactions will be nonattended. Noncooperative applications generally require attended operation.

Standard versus Nonstandard Environments

This classification refers to whether or not the system is operated in a controlled environment (e.g., temperature, pressure, moisture, lighting conditions, etc.). Typically, indoor applications such as computer or network log-in operate in a controlled environment. Outdoor applications, such as keyless car entry or parking lot surveillance, operate in a nonstandard environment. This classification is important to the system designer because a more rugged biometric sensor is needed for a nonstandard environment. Similarly, infrared face recognition may be preferred over visible-band face recognition for surveillance at night.

Public versus Private

This classification describes the relationship of system users to the organization deploying the biometric system. For example, a network log-in application is used by the employees and managed by the information technology manager of the same company. Thus, it is a private application. On the other hand, the users of an ATM

are the customers of the bank that manages the ATM. This is an example of a public application.

Open versus Closed

This refers to whether a biometric template is used for a single application or multiple applications. For example, a fingerprint-based authentication system may be used to enter secure facilities, for computer log-in, electronic banking, and ATM use. Should these applications use separate templates, or should they all access the same template? A closed system may be based on a proprietary template; an open system will need standard data formats and compression methods to exchange and compare information among different systems (most likely developed by different commercial vendors).

Note that the most common commercial applications (e.g., an ATM) have the following attributes: cooperative, overt, habituated, attended enrollment and nonattended authentication, standard environment, closed, and private.

Privacy Issues

The acceptance and, therefore, success of biometric-based identification systems will be connected to ease and comfort of user interaction. If a biometric system is able to measure the characteristic of an individual without touching him or her (e.g., capturing face, voice, or iris), it may be perceived as being more user friendly. Additionally, biometric technologies requiring very little cooperation or participation from the users (e.g., face and facial thermograms) may be perceived as being more convenient. On the other hand, the biometrics that do not require user cooperation can be captured without the knowledge of the user. Many people perceive this as dehumanizing and as a threat to privacy.

The identification process leaves trails of private information. For example, if a person is identified at every point of purchase, information about shopping and buying habits can be easily collected and used by telemarketers. The issue of privacy becomes more serious with biometric-based identification systems, because biometric

characteristics may provide additional background information about an individual. For example, retinal patterns may provide medical information about diabetes or high blood pressure. Having determined a high risk level for an individual, an insurance company may use this information to deny the person coverage or benefits. A major fear is that biometric identifiers could be used for linking personal information across different systems or databases.

Conversely, biometrics can be a more effective means for protecting individual privacy and safeguarding identity. For instance, a biometric-based patient information system can reliably ensure that access to medical records is available only to the patient and authorized medical personnel. Nevertheless, many people are uneasy about the use of biological characteristics in corporate or government authentication systems. To alleviate these fears, companies and agencies that operate biometric systems must assure users that their biometric information remains private and is used for the sole purpose for which it was collected. Legislation is necessary to ensure that such information will remain private and that its misuse will be appropriately punished.

Notes

[1] J. L. Wayman, "Technical Testing and Evaluation of Biometric Identification Devices," in *Biometrics: Personal Identification in Networked Society*, edited by A. K. Jain, R. Bolle, and S. Pankanti (New York: Kluwer Academic Publishers, 1999).

[2] See Biometrics Research at Michigan State University, http://biometrics.cse.msu.edu, for research updates and useful links on biometrics.

[3] H. T. F. Rodes, *Alphonse Bertillon: Father of Scientific Detection* (New York: Abelard-Schuman, 1956).

[4] F. Galton, *Finger Prints* (London: McMillan, 1892).

[5] R. S. Germain, "Large Scale Systems," in *Biometrics: Personal Identification in Networked Society*, edited by A. K. Jain, R. Bolle, and S. Pankanti (New York: Kluwer Academic Publishers, 1999).

[6] See note 1 above.

About the Authors

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V I S I O N

3

STUDENTS AS CREATORS IN THE REAL WORLD

Terence Rogers, Ph.D.

Terence Rogers discusses how and why students will become more actively engaged in shaping their environment and learning experiences. He views students as ideal creators of real-world objects. In the Leadership section, meet Ryan Patterson—a student who exemplifies the "student as creator" idea.

STUDENTS AS CREATORS IN THE REAL WORLD

Terence Rogers, Ph.D.

Probably one of the great shifts in the twenty-first century will be in the role students (children) play in their own education and in shaping their environment. Perhaps future generations will see this as an extension of the twentieth century trend for youth to become the focus of society's attention, a process we adults seem to regard with both favor and dismay.

As one of the adults involved with the ThinkQuest program, I can say that we believe there is more at stake than such a broad picture would suggest. This article examines three reasons why this shift is likely and why we should embrace it and take it seriously.

Creativity as a Key Part of Learning

Focusing on creativity is important because encouraging children to create is a vital part of the learning experience—arguably the most important part. Now we tend to place barriers around what children can aspire to, maybe out of habit, but often because of perceived or actual economic constraints. This results in limiting their creativity to school projects that classmates, parents, or friends will see. Creating for an audience can be a vitally important motivation for children to do the work. In some models for school organization—Sizer's Essential Schools, for example—it plays a crucial role as a form of authentic assessment. The students are required to do "exhibitions" of their work before their peers, parents, and invited guests.[1]

However, in most cases the project does not contribute to the real world. It is more in the spirit of a tryout for the real world. This is not intended to criticize, but to point to a change that is starting to occur. To demonstrate, let me use the example of the ThinkQuest Program created by the nonprofit Advanced Network & Services.

Over a six-year period, approximately 120,000 students, ranging in age from 10 to 19 years, with only guidance from adults, have created a library of more than 5,000 Web sites.

ThinkQuest challenges and supports children in the collaborative act of creating educationally meaningful Web sites. These sites follow the ThinkQuest Learning Model, which includes a set of values, a process for carrying out the project, and a set of criteria for success. It uses a student-centered, constructivist approach to learning that leans heavily on the children's urge to create and provides a disciplined framework within which they are supported. ThinkQuest has been used to teach parts of the curriculum and as an after-school program. Its international form (the ThinkQuest Internet Challenge) requires students to take the lead in all aspects of a project, including using the Internet to find other team members in other countries. This latter part of the process requires a quality closely allied to creativity, though we usually call it entrepreneurship. We think of it as creativity applied to practical and organizational problems. In an interesting parallel to the Essential Schools exhibitions, the final assessment of the 100 best Web sites entered in the ThinkQuest Internet Challenge was done by an exhibition before an invited panel, whose members inquire not only about the site but the role of each student as part of the team.

For this discussion, we can extract two lessons from the ThinkQuest program.

First, the phrase *educationally meaningful* is taken very seriously by both the students and the judges. It is clearly intended that these Web sites should seriously aspire to teach and should compare with professionally developed materials in style and content. While not all reach these levels, the results are impressive. Over a six-year period, approximately 120,000 students, ranging in age from 10 to 19 years, with only guidance from adults, have created a library of more than 5,000 Web sites. The value of this library is attested to by the visits of more than 2,000,000 people month after month. Every attempt to find out why people visit this library produced the same answer: Because it is useful. These Web sites are useful for homework, research, solving crosswords, and many other reasons, and they are useful to people of all ages. In a very

The very fact that the students knew their work was going to be published for the world at large increased their commitment to producing a high-quality Web site.

real sense these students are creating objects of value in the real world on a scale that would have been hard to imagine prior to the Internet.

The second ThinkQuest lesson is this: The very fact that the students knew their work was going to be published for the world at large increased their commitment to producing a high-quality Web site, so sometimes they labored for thousands of hours in their "spare" time. Some of them also became adept at receiving "customer" feedback and improving their sites. Their sense that they were interacting with the real world made them far more aware of what it means to design something for a specific audience. It helped them define audience requirements and characteristics and find ways to reach that audience. The more sophisticated teams weighed the desire to reach an audience that had very modest technical infrastructure against their wish to use the latest technology to enhance their Web site. Leaving aside the technical skills they acquired, we observed how some children sharpened their general understanding of what it means to communicate, to make tradeoffs of time available versus difficulty of the goals, of using technology to support the learning versus dominating it, and many other transferable skills. I am convinced their learning was sharpened by knowing the result would be seen by the world at large.

You may ask whether it makes sense to go one step further and explore the commercial value of these Web sites. This is a very interesting question given the perspective of this article, because it raises some deep issues about the role of children in society and the "purity" of their educational experience. ThinkQuest remains completely noncommercial, so the following discussion is based on my personal thoughts. As a basis for the discussion, let us reconceptualize ThinkQuest as a publisher for a worldwide network of creative artists who happen to be children. Let us imagine a demand for their Web sites such that people are willing to pay appropriate fees for access or for products derived from them. As in a traditional publishing house, editors take the raw material created by children and adapt it to the needs of the customers. For example, in the United States it would be valuable to relate content to state standards. This is a cost that would need to be recovered. Using this rough model of commercialization, let us think about the implications.

Historically, the idea of children working is associated with sweatshops and the worst excesses of the industrial revolution. In many countries that remains a serious issue. We should be very careful about the possibility of exploiting children when we consider commercializing their work. In addition, we would worry about if and/or how a profit motive might interfere with the learning value of the experience. Would children start to bias what they do and how they think toward selling their work, rather than being free to explore the ideas? For example, would they tailor their work to meet state standards instead of expressing their ideas in a way that was natural to them? I suspect that beneath each specific worry there would be another deeper one. Would we be tainting the whole childhood experience by introducing the world of commerce too soon?

There are no simple answers to these questions now, but it is worth offering points that favor introducing some form of commercialization. We hope these points can help us look for creative approaches that ultimately best serve the children.

Watching some 8-year-old children sell lemonade on a hot day by the side of the street stimulated one line of inquiry. The parents saw this carefully controlled commercial enterprise as both a time-honored experience remembered fondly from their own childhoods and as a valuable introduction for their children to buying and selling, setting prices, and haggling (nicely) with their customers. It was done in a spirit of fun, but from the children's faces, I would judge they were also taking it very seriously and learning some powerful lessons. This throws a chink of light on this potentially fraught subject. U.S. parents seem to believe that, under the right conditions, a commercial experience is helpful for their children. I would add to this example experiences such as baby-sitting, car washing, and other teenage jobs that parents find acceptable.

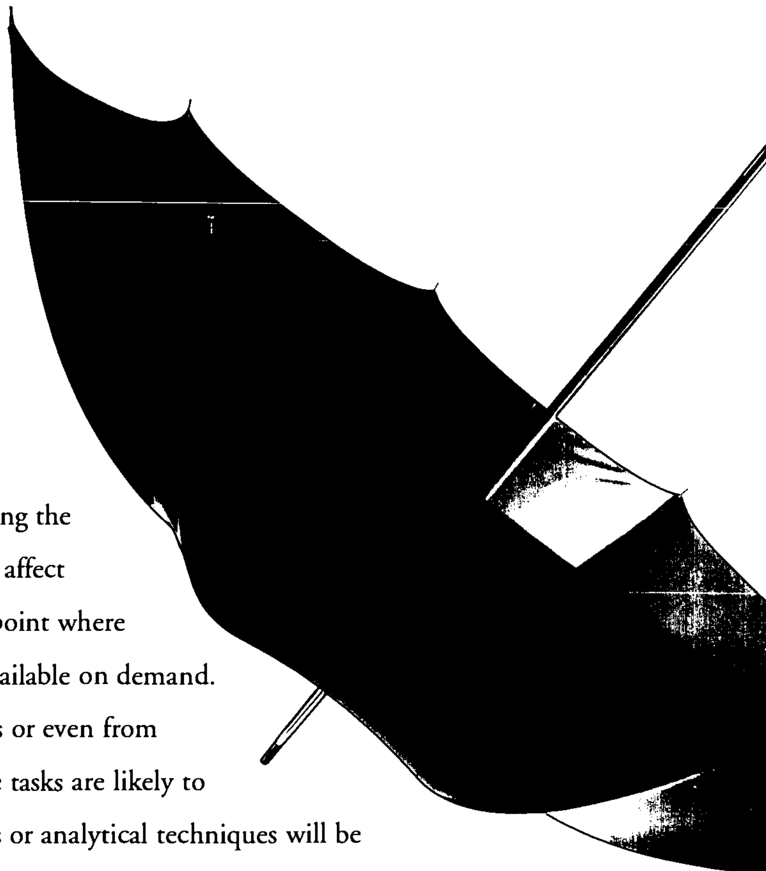
When asked if there is a modern Internet form of these time-honored jobs, I think the answer is obviously yes. Under the right circumstances, the creation of Web sites for pay by a group of children will probably be regarded as a useful introduction to the real world. As time passes, this will naturally generalize to objects more complex than Web sites. With some hesitation, I would also point to the notorious case of the teenager who dispensed investment advice over the Internet, simply to illustrate that services and advice will also surface as natural offerings.

We might gather from these examples some useful ideas about "the right circumstances" to see if they can be generalized. One circumstance is close parental supervision: It seems that a combination of having lived the same experience and being able to step in to head off any bad consequences works for parents. A second circumstance is placing tight boundaries on children's experiences. It takes a small part of the children's time, it does not directly affect their regular learning, and it does not happen in the same environment (the classroom) as their regular learning. Probably each of these circumstances can translate naturally to an Internet-based world. But a third circumstance cannot. The traditional commercial experiences children have today are local; they mow the lawn or baby-sit in neighborhoods familiar to them and their parents. However, with the Internet or other recent technology, there is the real possibility that many parents will not be familiar with the environment or with what their children are doing. This presents many real and imagined dangers and will probably inhibit the growth of commercial experiences that would otherwise have widespread support. Finally, let us observe that none of the above examples includes commercial classroom activities, and I think this will remain true for a long time.

To close this brief excursion into a territory fraught with issues, I want to make one very general assertion. We should always ask whether our children are receiving enough preparation to enable them to survive and prosper in their future world. If we were all living in a village surrounded by natural dangers, this would be obvious to us, and I am sure that children's learning in such an environment would include an awareness of dangers and learning how to avoid or deal with them. This dilemma is similar, but our temptation is to protect our children with a castle mentality. While children are at school they must be protected from dangers, if possible, by keeping the dangers outside the walls. So, do we do better by keeping advertising out of our schools or by making sure it is acknowledged as a fact of life outside school and spend the required energy in school ensuring that children can assess it critically? The same is true for many of the concerns we feel as our children roam the Internet. Do we keep looking for filters and erecting barriers, or do we concentrate on educating children to deal with the dangers to prepare them for life outside of school? Engaging with the commercial world falls under the same heading; it is dangerous but a fact of life "outside."

While I would always err on the side of protecting children, my personal preference is to give them controlled engagement with the real world, with a view to better preparing them for it. Technology certainly raises the stakes in this discussion by increasing its benefits and dangers to children. If we continue the castle approach, we will cut off our children from a wonderfully rich learning environment. If we tear down all protection, we leave them open to risks. Though neither of these is acceptable, they are unfortunately the positions that surface most easily in political debates. Those of us who care to have our children safely benefit from technology need to start finding acceptable answers to these dilemmas.

Returning to our noncommercial world, we can make the interesting conjecture that under the right circumstances, children (currently mostly teenagers) are capable of creating meaningful real-world objects on par with those produced by adults. Notice that the right circumstances include two new Internet-related factors: the possibility of children mastering the skills needed to design and build the object (Web-authoring skills) and the relatively cheap cost of distributing the results to significant numbers of people (through Web publishing). Had we been talking about children creating new automobiles or even toasters, both the design and distribution challenges would have made this infeasible.



Is this an interesting but temporary phenomenon? I think just the opposite. Following the trend that some predict for how the Internet will affect society (see for example Schank[2]), we arrive at a point where facts, and even many forms of analysis, will be available on demand. No benefits will accrue from trying to retain facts or even from doing routine manipulation of those facts. These tasks are likely to be counterproductive. Which tiny subset of facts or analytical techniques will be worth committing to memory? Having them available on demand also undermines the learning value of many of these facts or skills.

Assume for the moment that we are indeed entering a world where technology is even more pervasive than today, where the balance is shifting toward the ability to rapidly master that technology, and where creating valuable objects using that technology is one of the critical skills.

We can debate exactly how to interpret these pointers, but it seems clear that in the future the human premium will be on the ability to pose the interesting questions, especially the ones that have not yet been programmed into the generalized Internet. Our children will concentrate more and more on learning the skills to identify these questions and to create answers to them. This will lead to a focus on critical and creative skills. To solve the dilemma of overwhelming information and available techniques, we will need to teach a set of underlying skills that can address the issues and decisions we will face. The facts to which we apply those skills as we learn will be seen as a chosen context rather than as a generic set that all people should know. We will probably continue to debate whether all educated Americans should know facts about the Constitution, our history, and the like as part of the lore that makes us all Americans, but it will become increasingly hard to justify spending 12 years of our children's lives learning a body of knowledge that is but a tiny fraction of the interesting and easily available knowledge that exists. However, I find it hard to foresee avoiding the need for the particular combination of critical analysis and inspiration that I would loosely call creativity. In that sense I believe learning and creativity will become almost synonymous!

Children as the Ideal Creators

Let us consider a second reason why children's ability to create useful real-world objects is important. Assume for the moment that we are indeed entering a world where technology is even more pervasive than today, where the balance is shifting toward the ability to rapidly master that technology, and where creating valuable objects using that technology is one of the critical skills. There is a persuasive case to be made that the ideal age for contributing to that world will be *before* maturity, while a person is still mentally flexible enough to absorb the technology and to see how to put it to new uses. This trend is already visible, although we tend to see it as a peripheral phenomenon (e.g., in terms of children being better at adjusting the VCR or using the Internet for social purposes). The shift I am proposing occurs when children also have the skills to create meaningful real-world objects. Ironically, these objects are most likely to be what we now call *virtual objects.* They will exist on the Web as virtual environments, games, entertainment objects, and the like, but they will have practical

and perhaps commercial value. It may even be that for certain objects, such as children's games, children will be the preferred creators.

I think there is little doubt that children will increasingly be seen as having a unique role to play in creativity in our society. There will be an expansion of asking for their opinions in the form of focus groups. This tends to confine their input to predetermined areas of interest. We will broaden from there. For example, there is currently considerable interest in connecting children with practicing scientists, to give them a better understanding of what it means to do real science. We adults typically approach such ideas from what we can offer them. When we relax our approach, we rapidly discover that the children have something to offer us. I can, therefore, foresee the time when children participate in real science as a part of their normal learning experiences and contribute in usefully creative ways. They may simply ask a question the adult scientists have forgotten. They may contribute to a brainstorming session and reframe the conversation in an interesting way. Thinking back on my own learning about science, I see that, despite being able to answer the exam questions, I was totally unprepared to do real science when I began working on my Ph.D.

I believe that as we recognize the ability of children to make more than token contributions to real world situations we will integrate them and their learning experiences more naturally into the real world, and they will have a more seamless transition from learning to doing. In an interesting way, we will be recreating the learning format of past ages, with examples drawn from the great painters to the humble blacksmith. That was learning by contributing to the real world, under the guidance of someone working in that real world. The Internet will help to bring us back to this valuable form of learning by giving children access to adults who are not local. However, that alone does not make the difference. In keeping with the main thrust of this article, I want to repeat that the difference comes when we take seriously the children's contributions in the real world.

Before we get too carried away by this projection into the future, we should ask some hard questions. For example, even if children have mastered sophisticated tools, to what sorts of things are they unlikely to be able to contribute? Let me give an example. We (Advanced Network & Services) recently ran a project called Imagining

So there remain natural limits to where children (or any of us) can make meaningful contributions in those contexts that we have had time to internalize. That is why musicians tend not to make great discoveries in science and scientists do not typically expand our range of music.

the Future, in which we asked about 30 teams of high school students to learn something about emerging technologies and to imagine what learning would be like in 10 years, assuming those technologies were widely available. We neither got nor did we expect to get a proposal for a new system of education, not even in the barest outline. We did get individual ideas about classes, subjects, or types of learning space. I think this was not related to time limitations or even to perceived restrictions on what they were "allowed" to propose. More likely, none of them had the context to think about the *system* of education. Lacking that context, they had no large arena for applying their creativity. So there remain natural limits to where children (or any of us) can make meaningful contributions in those contexts that we have had time to internalize. That is why musicians tend not to make great discoveries in science and scientists do not typically expand our range of music. As our understanding of the cognitive sciences grows, we may find that there are classes of contexts to which children of a certain age are able to contribute but not others. It may be useful to distinguish the contexts that a 12-year-old can reasonably internalize, as compared to those of a 16-year-old. Most likely, 25 years from now our current understanding of these areas will seem pitiful, as will our current attitudes toward children's potential for creative contributions.

While much of this discussion has focused on teenagers, it is fascinating to note that Allison Druin and her collaborators at the University of Maryland have worked with children aged 7 to 11 and 4 to 6 as codesigners of the tools and the environment of the "Classroom of the Future."[3] This work has some interesting similarities to and differences from the ThinkQuest Program. The age groups studied are almost exactly complementary, 4 to 11 years for Druin and 10 to 19 years for ThinkQuest. The emphasis for Druin is codesign, where the adults and the children are peers. The emphasis for ThinkQuest is child-centered, with the adult providing coaching without directly contributing. A point of independent similarity is that each determined the need for a supporting process after several years of experimentation. Each approach recognizes that some structured support works better than none, and one structure works better than other structures. Also, I think each group would express delight and some surprise at the level to which children can contribute creatively to solving real problems.

I find this work particularly interesting in two respects. First, it pushes down to four years the practical age limit at which children can make meaningful design contributions. This suggests that better understanding of the methodologies will enable us to engage children across the full spectrum of K-12 learning. Second, the work of Druin and colleagues specifically focuses on how children can contribute to their learning environment. This provides a neat segue into our third reason why children's creativity may become very important.

The Coming Crisis of Learning Materials

Let me return to the near future, say 5 to 10 years from now. In that time, there will be dramatic changes in what is available over some form of Internet in the way of commercially generated materials. They may be described as entertainment, news, edutainment, business- or health-related information, or any of an amazing variety of visually attractive offerings. It is likely that outside of school our children will be inundated by these offerings, making today's television pale by comparison. However, if we continue with today's model, there will be no economic incentive for anyone to produce equivalent high-quality learning materials for schools. The skills to produce attractive offerings will likely be used for the most profitable ones, which are unlikely to be school materials. This is beginning to happen today and will become more true with the next explosion of high-bandwidth Internet offerings.

What can we do about this? One potential answer is to have children (and teachers) become the creators and authors of high-quality material for other children (though not the exclusive creators). This would actually have a useful advantage over adult-produced content. As we discovered in the ThinkQuest program, children can often present material to other children more comprehensibly than adults would. At least certain children show potential ability to interpret adult-written materials into something more appealing to children of their age group. As an example, I remember one young child pointing out that his team could find nothing written about civil rights that suited his age group. His ThinkQuest team spent a great deal of time with their teacher figuring out what that meant, and then the children produced a wonderful Web

site on civil rights that has attracted children from all over the world. In the process, the children who created the site became fascinated and learned much about civil rights.

Several problems must be overcome before this could be an effective method for getting high-quality, high-technology materials to schools. Typically, as technologies evolve, the (authoring) tools needed to use them are initially suitable only to full-time professionals; the easier-to-use tools follow later. However, even the primitive Web tools available in 1996 were used by ThinkQuest learners to create remarkable Web sites. Today they regularly master C++, Java, and other arcane tools. So this may turn out to be a challenge of scaling to large numbers of children. Another issue is the verifiability of the educational soundness of the output. Today our schools rely on a small number of texts that have been validated by some authority, such as a board of scholars. What would we do if thousands of groups of children were producing interactive virtual worlds or games intended to help other children learn about pollution or Shakespeare? Who would validate their accuracy?

I can only guess at how this might work. First, the system would probably need to be self-sustaining. That is, the validators would be other children and teachers. For example, a teacher might decide to have students learn about the science and social implications of pollution by creating an interactive environment for other students. The creating students would need to master the scientific and social issues well enough to create interesting ways to help other children learn. This interactive environment might include student-filmed material, material from news archives, online games, quizzes, text references, and an online discussion forum. It might also include virtual worlds where the effects of the pollution and maybe even some alternative treatments could be explored more directly. The children would contribute most of the technical expertise and learn the science as part of the challenge to build the project. The teacher would ensure the accuracy of the science.

To convert this with very little overhead from an in-class experience to a useful contribution to the learning of others, these "others" must be able to find the work and know that it is reputable. It is not economically feasible to assume that there are experts who would review such materials and put their imprimatur on them. That process would be reserved for materials that were either deemed "core" or that could justify the

additional cost. The approach proposed here organizes what is essentially a peer-reviewed process. For example, there could be an agreement to use and validate this work by three other groups, in return for having their own work validated. The act of critiquing others' work can often be turned into a useful learning experience in its own right. I once watched an 11-year-old give a sophisticated analysis of someone else's Web site as a precursor to creating one of his own. With appropriate coaching, this can embrace far more than the communication aspects.

While you may think this scenario too difficult to achieve, it is important to realize that this challenge is not limited to material produced by children. It applies to the current explosion of potentially useful learning materials in general. The notion that we can continue to validate useful learning materials, whether produced by Disney, Harvard University, or PS 100, by passing them through a rigorous expert process is not feasible. We face adopting another "castle" approach of excluding all but the most rigorously tested materials; of allowing incomplete, misleading, or plainly wrong materials; or of struggling to find an approach that acknowledges the massive increase in diversity and provides a balanced answer.

Conclusion

We have been discussing the extent to which we will and should see children contributing their creative skills to produce objects of real world value. Three reasons for doing so have been proposed: (1) it is a vital part of a child's learning experience, (2) children have characteristics as ideal creators, and (3) it may be a viable solution to the potential lack of suitable learning materials.

One general driver for each of these points is the limited ability to scale up our current approaches. Powerful forces are changing by orders of magnitude the quantity and the associated complexity of issues we face. Neither our "castle" solutions nor the economics of many of our time-honored approaches can scale up to deal with the numbers or complexity. Easy answers are hard to find, but having no answers poses unacceptable risks. Yet I am confident that the essential starting points are embedded in what we do today. We need to identify what is scalable and what should be discarded.

For example, the creative role of children has always been embedded in the best learning practices. We have overlaid it with our current sense of what is practical, safe, and consistent with school practices. The challenge is to bring it out into the sunlight and look at it afresh and with a keen eye to the future.

With that in mind, I offer the following conclusion. In isolation, each of these detailed suggestions is open to many forms of practical objection. However, if we look at them as trends, they cause us to think seriously about what can and should happen. In the future, children's learning will be based much more on creating than on absorbing or remembering facts or techniques. Our children will become very proficient at using technological tools of amazing power. Many of the objects and services they create will be useful in the real world. Other children will use some of these objects to learn. It may be possible to turn this into a virtuous cycle, where each generation of children profits from the efforts of children who have gone before them. All of this seems to me to be very likely in the next 10 to 50 years.

Whether there will be a model that allows children to have some limited form of commercial involvement with the real world is harder to see. It would have advantages and dangers that deeply impact our sense of what we want for our children and our society. For the moment, it looks like an optional addition to the main scenario outlined above.

I find this future world much more appealing than the one we have today. In this future world, children are important and central to their own learning. Early on, they make a contribution to the learning of others. They grow up knowing what it is to make a productive contribution to society without waiting for 20 years before they are deemed useful for something other than baby-sitting. Our job as adults will be to nurture and guide their creativity, as it always was, and is in the hands of the best educators.

Notes

[1] T. R. Sizer, *Horace's Hope* (Boston: Houghton Mifflin Co., 1996).

[2] R. C. Schank, "Are We Going to Get Smarter?" in *The Next Fifty Years: Science in the First Half of the Twenty-first Century*, edited by Brockman (New York: Vintage Books, 2002).

[3] A. Farber, A. Druin, G. Chapman, D. Julian, and S. Somashekhar, "How Young Can Our Design Partners Be?" (paper presented at the Participatory Design Conference, June 23-25, 2002, Malmô University, Sweden).

About the Author

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V I S I O N

4

TELE-IMMERSIVE ENVIRONMENTS FOR EDUCATION

Kostas Daniilidis, Ph.D. and Ruzena Bajcsy, Ph.D.

In this article, Kostas Daniilidis and Ruzena Bajcsy present a compelling overview of tele-immersion and its potential applications in education. In the Leadership section, IAETE staff look at a Texas high school's experience with digital teleportation, a technology that also enables people who are geographically dispersed to share the same physical space.

4 VISION

TELE-IMMERSIVE ENVIRONMENTS FOR EDUCATION

Kostas Daniilidis, Ph.D. and Ruzena Bajcsy, Ph.D.

Anybody who reads or listens to news understands that our educational system is not meeting twenty-first century needs of business, politics, or society. If all Americans are to benefit from technology-driven prosperity, learning enterprises must accommodate the needs of young and old, citizens and recent immigrants regardless of race, and people who have been poorly served by earlier educational experiences.

While our children have been exposed to sophisticated movies and computer games, classrooms are still dominated by text and lectures. Even in many up-to-date learning environments where texts are digitized and lectures recorded and rebroadcast, the interactivity is limited to point-and-click hypertext references. Dissemination of digital lectures and lab assignments enables wider access to educational material that might be more interactive than the experience of sitting in a large classroom.

However, we believe a new approach is needed to develop and assess a new learning strategy around new technologies. We shall concentrate on one such technology called tele-immersion.

As Henry Kelly, president of the Federation of American Scientists, argues:

> By combining advances in learning science and information technology, it is possible to create learning environments in which
>
> 1. A learning process can be adjusted to reflect the knowledge, background, interests, and temperament of each learner.

2. Complex scientific, engineering, and social phenomena can be simulated.

3. Learners can be connected to information and with each other, teachers, coaches, and experts worldwide.

4. Problems, challenges, stories, and other traditional motivational tools (such as simulations coupled with monitoring and coaching tools) can be used to engage and encourage learners.

5. Learning systems can be continuously improved, gathering experiences from every learner and teacher.

6. Vast amounts of information (text, video, sound, and other forms of data) can be stored and retrieved quickly and efficiently.[1]

We hope to convince the reader that this tele-immersive environment encompasses all of the above-listed considerations.

What Is Immersion?

We characterize a display environment as immersive if it tries to create the illusion of being in another physical environment. With display we are quite inclusive regarding senses; technology has mainly experimented with vision, though sound and the more-challenging touch are coming, too.

It is worth mentioning that before tele-immersion, immersion always referred to being in a virtual environment consisting of objects that were graphically modeled in a computer. Immersive environments use techniques of virtual reality, though virtual reality encompasses a wider spectrum of graphic and interactive technologies that may be displayed in many ways. An immersive display must react to the participant's head movement and refresh the screen from the new perspective. This is possible only with real-time graphics and a head-tracking device that gives the position of the head in

space at any time. If hands or other body parts are involved in the interaction, they must also be tracked.

Early developers thought that being immersed in a virtual environment meant excluding the physical environment. Hence, they focused on head-mounted displays, which proved quite successful in military and scientific applications. However, such displays caused a nauseous discomfort, and the user generally could not wear them for longer than 15 minutes. Most problematic was the disembodiment of the user, who could not see feet or hands. With regard to learning, the most negative effect was that only one person at a time could have the experience!

In the 1990s, researchers turned their focus to wall displays with stereographic projection.[2] Here the user wears only stereo glasses and a tracker to preserve the screen update from the correct viewpoint. Although quite successful, such displays are not yet widely used. In isolated experiments, students can visit virtual models of ancient sites, historical battlefields, and undersea environments. They can study the motion of artificial bees or 3-D chemistry models.

Immersion must include as many senses as possible. Immersive sound is almost a commodity in the home-theater market, but what about touch? Wouldn't it be nice to have the user lift a virtual object and feel its weight? Or bounce off virtual objects instead of going through them? What can be summarized under force display (as opposed to visual display) can be implemented with a small robot in the immediate physical environment of the user. For example, SensAble Technologies' small arm, called the Phantom, can display forces of small magnitude and can be easily used in virtual sculpting. Imagine that the artist holds a scalpel, which is attached to the Phantom: He or she feels the exact pressure of the medium and simultaneously sees the change on the virtual model.

Wouldn't it be nice to have the user lift a virtual object and feel its weight? Or bounce off virtual objects instead of going through them?

Real Environments

At the end of the twentieth century, we experienced the revolution of networking and the installation of backbone lines that can transfer several gigabits per second. For most people, high bandwidth brings to mind songs, movies, or, in the best case, transmission of remote lectures (indeed, this is how the network is mostly used today).

Some of us thought the time was right to immerse a user—or even a group of individuals—not in a virtual environment, but in a remote physical environment. What about taking a safari in a real jungle with animals all around you? What would such a technology encompass? A simple stereo video would not be enough because the immersed viewer would follow exactly the path of the man (or even the robot) holding the camera. A partial solution would be to capture everything from an omnidirectional camera—a camera with a hemispherical field of view like an extreme fish-eye. Then a turn of the viewer's head would reveal the correct angle without any distortion. However, the viewer would not be able to move and walk freely around things. That technology would require a 3-D model of the real environment, which could be obtained only by taking thousands of images from several viewpoints. However, a real-time transmission would be possible only with a very fast wireless connection; a jungle environment might become a reality in the future, but not today.

What about saving this 3-D video and then looking at the scene from different perspectives? Would it not be great if a physician trainee could look at an operation from any possible viewpoint? Or if instructions on assembling things could be shown from any perspective you want? Students could actively look at real animals running or giving birth. An educator could insert additional information and annotate the scenes. Or, such a video could be augmented with virtual objects. Imagine walking around in the historic center of Philadelphia and seeing buildings the way they were in 1776 co-existing with pedestrians from today. Techniques of so-called *augmented reality* are already used in Hollywood, but the final result is just a movie in the same format we were watching in the 1950s.

While immersion describes the technology, the term *presence* characterizes the feeling of being in a virtual or remote place. T. B. Sheridan gives three requirements to increase the feeling of presence for an immersive environment:

1. extent of sensory information (surround vision, sound, haptics)
2. control of and matching of sensorimotor cues (head movement changes viewpoint, collision is displayed as bouncing)
3. ability to interact with and modify the environment[3]

The creation of 3-D movies that can be seen from every possible viewpoint is a great advancement with high educational utility and with increased sense of presence. Though many of us in the field of computer vision work on this technology, it is still a passive, one-way medium and does not reflect Sheridan's third requirement. Why not let our imaginations fly and have multiple viewers interact "live," sharing the same physical space and playing with virtual objects within it?

Tele-Immersion

Tele-immersion tries to create the illusion that users at geographically dispersed places share the same physical space, possibly one augmented by virtual components. To provide a comprehensible sketch, we will describe a one-way system between two student peers, a sender and a receiver. (A two-way system is just the symmetric replication.) We will call the sender Alice and the receiver Bob.

At Bob's end, we need a screen, which can be just a part of a wall in front of the desk. A computer sends the 3-D model of Alice and her surroundings to a stereoscopic projector. Bob wears polarizing glasses, like those used in 3-D theaters, as well as a small device to capture the position of his head. Depending on the head's position, the graphics computer renders the remote scene from Bob's viewpoint. (Bob does not wear any head-mounted display.)

Figure 1. A remote scene is projected stereoscopically on the screen at the user's desk. The user wears polarized glasses and a small marker to have his head's position tracked.

One step further into the future, the same display will be used for multiple viewers, showing—with a sophisticated multiplexing—the remote scene from each individual's viewpoint.

In addition, we want Bob to feel as if he were in his natural environment, which is augmented by a "window" view into Alice's room. In the future, autostereoscopic devices will enable the display of depth without the use of glasses. In addition, passive visual devices will be able to capture the head and eye positions so that the user does not wear anything. One step further into the future, the same display will be used for multiple viewers, showing—with a sophisticated multiplexing—the remote scene from each individual's viewpoint.

How can we display the remote scene from every possible viewpoint and render virtual objects at the correct 3-D positions? Let us consider the first part of the question. To show a scene (e.g., a surgical operation) from every possible viewpoint, we could imagine that there would be a very fast camera at the sender's end, which would be moving as fast as the head of the receiver. Such a setup would be very intrusive. Instead, we are creating a real-time 3-D model, a "moving sculpture" as Jaron Lanier calls it, of the world.[4] This can be achieved with an array of cameras (see Figure 2) using a technique called stereo reconstruction from the field of computer vision.[5] The moving person and the scene are described in a single "world" coordinate system. Any additional virtual object—for example, an arm "prosthesis"—can easily be embedded in this description. The result unifies correct perspective and also creates the occlusions that amplify the receiver's depth perception.

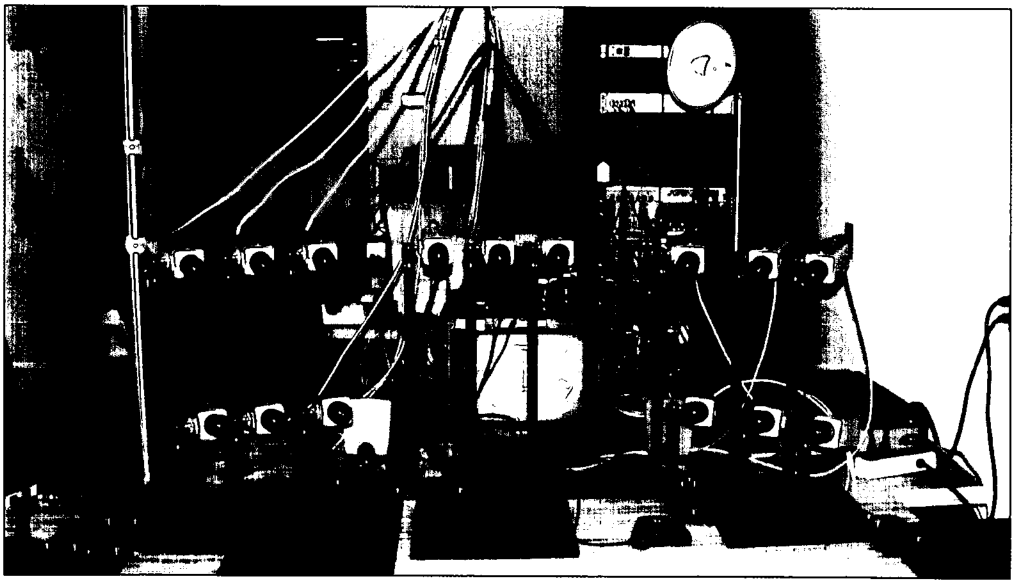

Figure 2. An array of five camera triads captures five depth maps combined onto a 3-D "sculpture" that is transmitted to another place. Cameras will be less intrusive in the future and will be integrated with the display.

By this point, it is more than obvious that we are not talking about big-screen videoconferencing where the view into Alice's room never changes with the motion of the receiver's head. This is called *virtual co-presence* to distinguish it from *virtual collocation* used for NetMeeting applications. It encompasses one of the key presence aspects, which is the ability to interact with and modify the environment. It might be that Alice cannot yet touch Bob, but a 3-D rendering enables the interaction with virtual objects. Using any pointing device, the viewer can insert any computer-generated object into the scene and it will be visible at the same 3-D position in both sites. For example, if the sender holds the real arm of a patient, the receiver can draw or attach a "prosthesis" on the arm, so the combination of virtual and real appears to both users. In addition you can place a teapot at your "neighbor's" desk (see Figure 1); of course, the teapot must be virtual. This is the ultimate natural medium for communication for the purposes of training, collaboration, and even entertainment.

In summary, we want to create the illusion that you open a hole in the wall of your room and look into it. However, what you see is not the room next to you but a room in any other place in the world, connected via the Internet. In the shared place between you and the other user, you can interact with real as well as virtual objects.

To enable a natural interaction, the 3-D acquisition and the immersive display must work in real time. Today we can achieve eight frames per second, but this is not enough for natural communication: What is the mediator between the cameras at one side and the display at the other that slows the process? And though computers will very soon produce the required data in the adequate speed, the network has to have very high bandwidth with minimal delay to prevent interruption of the communication. That's why tele-immersion is called the ultimate application for Internet2, the new high-bandwidth education network. And, though a connection between a central node in Philadelphia and a central node in Berkeley might be 2.4gbps and sufficient for tele-immersion, the connections between these central nodes and any school or other institution goes down to 100 or even 10mbps. It turns out that this "last mile" connection is still the most expensive component and the one that requires collective subsidizing by several agencies. The system for building the sender and receiver suites, which are modular and scalable, starts at $30K for a constrained set of viewpoints and

goes up to $80K for a full-human-motion acquisition. However, these costs are negligible when compared to the travel costs associated with medical or other staff training, not to mention the infinite value of their use in emergencies and crisis management.

Co-Presence for Learning

Gaining expertise appears to require both exposure to some basic facts/instructions/understanding of goals and opportunities for observations. The value of experience and practice in practical settings has been documented. It applies equally to solving geometry problems[6] and to training surgeons.[7] This technology offers an affordable way to assess learner performance. As the recent National Academy of Sciences study of student assessment notes, "New capabilities enabled by technology include directly assessing problem-solving skills, making visible sequences of actions taken by learners in solving problems, and modeling and simulating complex reasoning tasks."[8]

What kind of skills learning cannot be achieved via the Web, Microsoft NetMeeting, or videoconferencing? It is the learning that physically engages the student! Let us mention some examples of what we plan as prototype applications.

Anthropology

Researchers from the Department of Anthropology at the University of Pennsylvania regularly visit our lab to obtain 3-D scans of bones and scalps. The researchers would like to avoid transporting the actual exhibits every time they want to teach about them or conduct research on them. Usually they build replicas that are studied, for example, by combining many bones with mechanical joints or by augmenting them with clay to estimate their proper positions. Tele-immersion can revolutionize such learning and experimentation work. Not only can the exhibits remain safely in Philadelphia if our colleagues want to meet with students in the UK, but no replicas need to be sent to any other place. The instructor in Philadelphia can hold a scalp in the shared space between her and the UK students while the students can look at it from different viewpoints. They might even start building virtual

augmentations of the scalp that would be visually correct from both ends of the transmission. Similarly, a remote laboratory can be held from structures close to a fieldwork site. On-site students can interact visually with their instructors to discuss their findings as often as necessary.

The handles where the physician holds the tool or the endoscope are exactly the same as the handles of the real tools. Such a technique removes the necessity of building or shipping a plastic model of an organ.

Surgery

All surgical operations have to be taught hands-on and a new surgeon can take the lead only after multiple participations as a trainee and/or assistant. A typical example is minimally invasive surgery. Today, patients spend only two or three days instead of 15 in the hospital for operations such as colectomy or gastroplasty. This advance was made gradually because of the time needed by doctors to master such techniques. The continuous training that goes into steadily invented procedures costs both time and money because it necessitates the physical presence of the trainees.

Minimally invasive surgery takes place by inserting an endoscope and one or two tools through very small incisions. The surgeon operates by viewing the endoscope on the monitor. Recently the FDA approved the da Vinci robot, which the surgeon controls with a haptic full-fingered device and visual input from the endoscope. Usually training in such a physically challenging skill starts with watching and practicing on plastic models (e.g., models of the stomach). Instead of an artificial stomach, with tele-immersion we can create a virtual stomach that can be "felt" and seen. Such a 3-D model is not only enriched with color but also with force distributions, which convey how much resistance you feel if you bounce on, pinch, cut, or apply suction to any point. The handles where the physician holds the tool or the endoscope are exactly the same as the handles of the real tools. Such a technique removes the necessity of building or shipping a plastic model of an organ. Instead, a worldwide library contains the 3-D and haptic models, and the trainee can just copy them to use for practice.

If we want the instructing surgeon to lead the hands of the trainee both verbally and physically, they must be next to each other. A tele-immersive surgical training system would employ robots to display force at the trainee's site and at the remote surgical trainer's site. The trainer's replica of the simulator would display both the motion of the trainee and the forces from inside the body. If the trainee moved the

tool or the endoscope in the wrong way, the trainer could press a button and start leading the trainee's hand. Such a system would necessitate a high-bandwidth network with minimal delay in the order of milliseconds. Today, this is difficult to accomplish when the two network places are too distant from each other. Mathematical predicting techniques are used to compensate for the delay in haptic feedback. While this is applicable for training on a virtual model or even an animal, it is not yet FDA-approved for training from a distance on a real patient.

Tele-immersion could further push the envelope by inserting the physician's viewpoint into the area where the endoscope is moving. This would require two tracked endoscopes and a way to control the viewpoint, either with hand or head motions. The advantages would be more visual information and a substantial decrease in the additional time needed for the trainee to adapt to the correspondence between 3-D reality and 2-D endoscopic output.

Tele-immersive surgical training also holds potential to assess trainees. Today, physical skill examinations vary from hospital to hospital and involve traveling and physical meetings. Training and examination with the trainer-trainee model that we propose might provide a unifying standard to judge an experience in minimally invasive surgery at several levels of expertise.

Sports Training

Rehabilitation and sports training concern individuals at the two ends of the spectrum, from those physically impaired to those physically most versed. In both cases, a trainer shows the trainee specific motions. They might be very simple and slow, such as how to move your leg to walk again after a stroke, or very complex and fast, such as the proper way to perform a gymnastics move. Many athletes use an offline video method; after they exercise, they watch themselves on video and then they watch a video of the desired motion as shown by the trainer. Imagine that you are exercising in front of a mirror, and your trainer is just behind you (and thus visible in the mirror) showing the optimal movement. Tele-immersion would replace the mirror with a projection display and use an array of cameras to capture the trainee, enabling the trainee to watch from any possible viewpoint. As with other examples, trainer and

trainee can be in different locations. Tele-immersion projects both persons aligned as if they were reflected on the mirror. In addition, the trainee can record the trainer and replay the 3-D movie to continue to exercise with offline feedback.

In rehabilitation, tele-immersion can be even more effective if coupled with haptic display and interaction with virtual objects. To reintroduce motor skills in hands, the apparent weight of a virtual object can be varied to match the ability level of the impaired person. A simple docking operation, such as putting a handheld into its stand, can be realized with a mock-up handheld mounted at the end of a robot. The docking stand might be virtual, as well as the appearance and weight of the handheld.

Tele-immersion, in combination with virtual interaction, can be modified to the level of the trainee and can be customized to reflect individual differences.

Training Transfer and Evaluation

We presented examples of tele-immersive instruction in anthropology, surgery, and gymnastics. While the anthropology laboratory is a collaborative experiment, the surgery and gymnastic sessions are training experiences where the main question is how well the physical skills are transferred from the training to the working environment. According to Durlach and Mavor, the applying theories are behavioral and quite old.[9] The "theory of identical elements" introduced by Thorndike and Woodworth,[10] as well as Osgood's theory,[11] state that the success of transfer is proportional to the similarity of stimuli-response in the training and the working session. While in the case of virtual reality, the similarity has to be between virtual and real visual stimulus, in tele-immersion the similarity between real and reproduced action has to be measured. This involves, for example, the perception of depth and spatial orientation in tele-immersive environments (see virtual reality results by Loomis, Blascovich, and Beall[12]). Recent theories emphasize the fidelity of the training environment, meaning the accuracy of physical representations. Tele-immersion, in combination with virtual interaction, can be modified to the level of the trainee and can be customized to reflect individual differences. The addition of cues, like graphical overlays or sound effects, can provide reinforcements for learning.

The wide acceptance of this new environment will depend on how well it delivers the learning content—in our case, training certain physical skills. The following considerations can be used to develop evaluation criteria:

1. The time spent exercising before the learner masters the skill.
2. The saved time and cost for meeting in cyberspace instead of real space.
3. The accessibility of learners with many backgrounds to knowledge/skills otherwise not available to them. Consider, for example, people who need more training time but who cannot afford it in real time. With tele-immersion they can go back to cyberspace and replay the exercise with the master as often as needed and as time permits.
4. The value of interactivity and receiving feedback. The real-time connection means the learner can ask questions and try again with different approaches; this has value and needs to be recorded. But the fact that the learner can interact with different students and different teachers also adds to the motivation to learn.

Conclusion

We need to prove that training with tele-immersion, a new technology, is superior, at least for some tasks. Such a comparison to classic on-site training might be difficult and unfair since classic training does not give a learner the opportunity to interact with and be guided by virtual information.

In upcoming research, we plan to compare three training sessions: (1) a session of traditional training, with trainer and trainee both physically present; (2) a session with a remote trainer transmitted via videoconferencing; and (3) a session with tele-immersive sharing of the same space. A fourth option, if applicable, is to extend surgical training with haptic devices. The only comparable experiment, which used avatars and not a tele-immersed trainer, was a collaborative session to solve a 3-D puzzle.[13] We intend to prove that the full augmentation and flexibility of viewing and interaction will not only compensate the traveling cost and time but might actually be even better than having trainer and trainee physically together.

Notes

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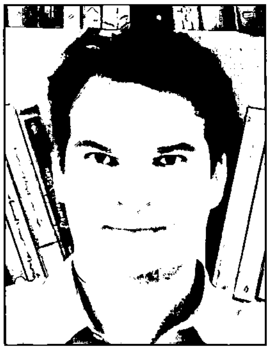
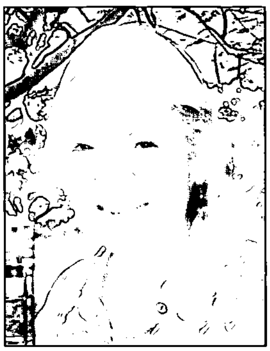
About the Authors



Kostas Daniilidis is assistant professor of computer and information science at the University of Pennsylvania and affiliated with the interdisciplinary GRASP laboratory. His current research centers on omni-directional vision and vision techniques for tele-immersion and augmented reality. Dr. Daniilidis is cochair of the computer vision TC of the Robotics and Automation Society and a reviewer in multiple journals. His research on tele-immersion was featured in *Scientific American* (April 2001). He is a recipient of the Ford Motor Company Award for the Best Penn Engineering Faculty Advisor. He holds a Ph.D. in computer science from the University Karlsruhe and a Master's in electrical engineering from the National Technical University of Athens.



Ruzena Bajcsy is director of CITRIS at the University of California, Berkeley. Prior to the appointment, she was assistant director of the National Science Foundation's Computer Information Science and Engineering Directorate (CISE). She has done seminal research in the areas of human-centered computer control, cognitive science, robotics, computerized radiological/medical image processing, and artificial vision. Dr. Bajcsy has been professor in both the Computer and Information Science Department and the Mechanical Engineering and Applied Mechanics Department at the University of Pennsylvania, where she founded the GRASP Laboratory. She is a recipient of the ACM/Allen Newell Award and a member of the National Academy of Engineering.

V I S I O N

5

MOBILE USABILITY REQUIRES TELEPHONES TO DIE

Jakob Nielsen, Ph.D.

It has been reported that as many as 38 percent of American teenagers have cell phones. Now that vision-enabled mobile devices make it possible to place a phone call; take, send, and receive pictures; check e-mail; play games with full-color graphics and sounds; and browse the Internet wirelessly at speeds comparable to dial-up connections, the utility of such devices in the classroom must be considered. In this article, Jakob Nielsen points out design flaws inherent in today's mobile services that make cell phones an unlikely learning tool at this time. In the Leadership section, Larry Berger and Elizabeth Lynn focus on handheld applications that are proving to be promising in schools.

5 VISION

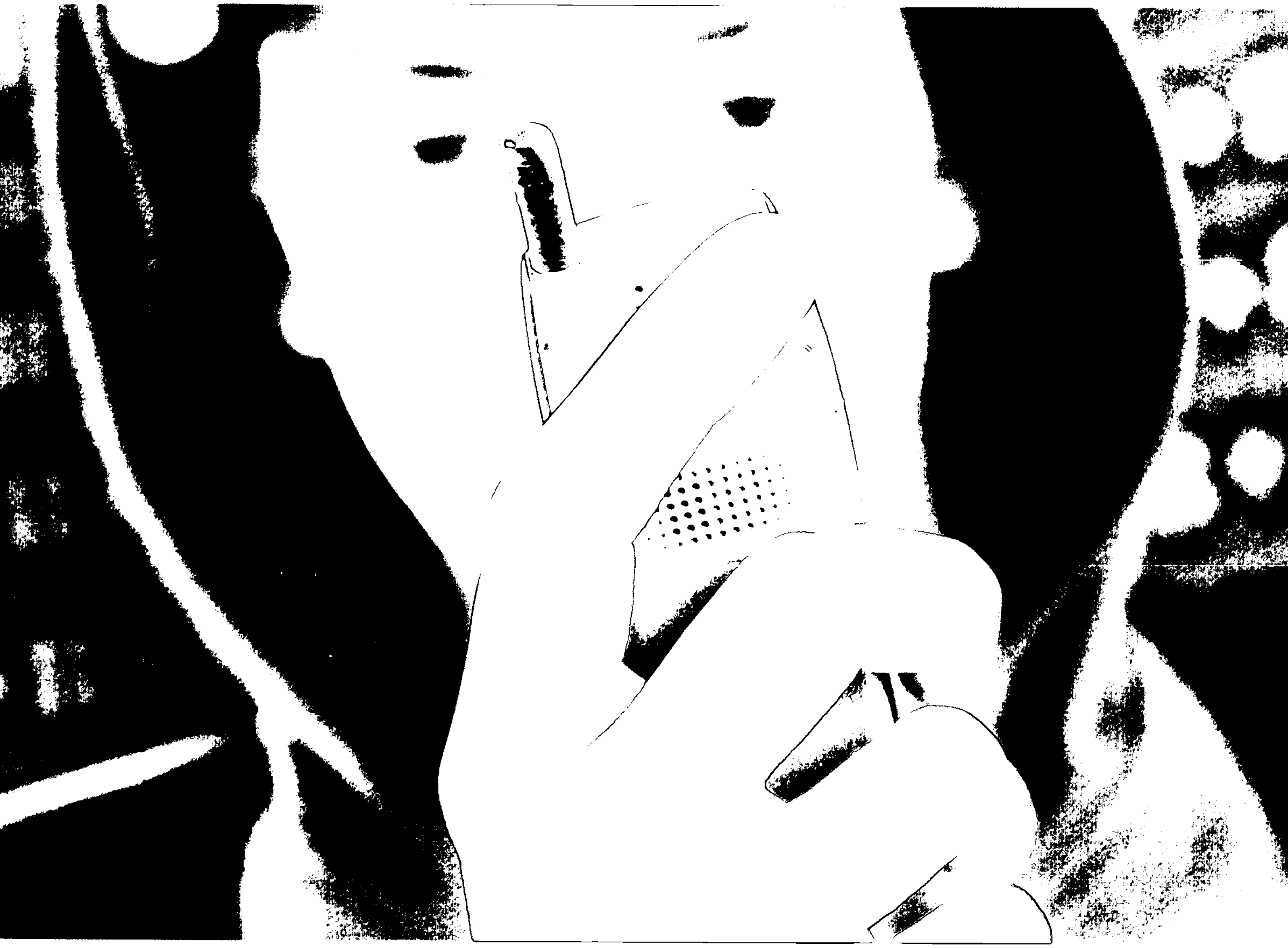
MOBILE USABILITY REQUIRES TELEPHONES TO DIE

Jakob Nielsen, Ph.D.

The initial experience with mobile access to the Internet was miserable, to say the least. Despite billions of dollars, euros, and pounds invested in building and touting early services from 2000 to 2002, nobody used them. In my judgment, this is not because mobile user interfaces have to be bad. It's simply because the first technology chosen by the telephone companies, Wireless Application Protocol (WAP), was a mistake.

WAP continues to offer a substandard user experience that makes it useless for all common applications. In a report on WAP usability based on field studies in London in 2000, I concluded that WAP offered a low-quality user experience and did not work for mainstream applications for average consumers. WAP supporters complained that I was being unfair because the technology would continue to improve, and WAP would, therefore, gain more users. A supplementary study in late 2001 found WAP just as hard to use as it was the year before. It didn't mature at all. Today, it is clear that almost no one uses the WAP features on cell phones.

Even worse, newer mobile services continue to include the design mistakes I documented in 2000. For example, I recently tried to check the stock market on an Internet-enabled cell phone. The service forced me through an awkward set of steps.



1. First, I had to wait through three splash screens:

    a. Microsoft Mobile Explorer (software provider) logo

    b. Vodaphone (cellular carrier) logo

    c. Vizzavi (WAP portal) logo

Considering WAP's slow speed and the minute-by-minute fees, it is unreasonable to force users to download all these logos every time.

2. Select WAP access (Other options included e-mail, which was also an option on the top-level phone menu. Why add an additional step here?)

3. Select financial info

4. Select financial indexes

5. Get a screen that lists several financial indexes:

    a. Dow Jones Industrial Index

    b. FTSE 100 Index

    c. DAX Index

6. Select an index to get the first screen with real content: the current value of the index

Several steps could have been eliminated, but worst of all, why didn't they follow our advice to provide the content (index quotes) on the screen that named the indexes. The word "Index" could have been eliminated from each line, and the space used to provide immediate information. Instead, they forced extra navigation. I had selected financial indexes, so there was no need to explicitly state that each option was an index.

It's striking how closely the usability of current mobile solutions resembles Web usability in 1994 (the age of Mosaic). It's truly *déjà vu*: Many of my current conclusions are the same as those I reached at the dawn of the Web. We can hope mobility's evolution will follow that of the Web. When things improved in subsequent

years (especially around 1997), many more users got onto the Web and commercial use exploded.

The greatest problem test users had with mobile phones was the inability to connect to services due to various failures: networks were down, the phones crashed, or the service itself was down. Users didn't know the problem and couldn't find out how to resolve it. All they got was an incomprehensible error message. This is quite similar to the state of the Web in 1994, when it was extremely common to get disconnected. (It is still common to fail to connect to a Web site, and it is still hard for average users to find out what to do about these failures.) Let's hope that mobile systems do better in the future. Connection failures are particularly annoying to telephone users who are paying for airtime. If you spend two minutes trying to get something that is not there, you will still be charged for those minutes. Paying for something that doesn't work seems unfair and unacceptable to the users.

Users often face unclear labels and menu choices written in special language invented by the telephone industry engineers or designer. Newspeak was rampant in the Web's infancy, and many site creators invented vocabulary for their services in a misguided attempt to brand their sites with proprietary language. This didn't work. Users want no-brainer design with standard terms for standard features. The need for simple language is even stronger in mobile design, where there is no space to explain non-standard terminology with rollover effects, icons, or captions.

Several mobile services I have tested were unnecessarily hard to use because of a mismatch between their information architecture and the users' tasks. For example, a service with British TV listings was organized by television network, making users go to several locations to find out what was on at 8 p.m. (i.e., screen for BBC1, another screen for BBC2, and so on, in an annoyingly slow sequence of screens). Highly detailed and accurate task analysis will be necessary for mobile services to succeed. Unfortunately, task analysis is a black art to most people and the least-appreciated part of usability engineering.

The traditional Web also suffers from poor task analysis, with many sites structured according to how company management thinks rather than how users typically approach their tasks. Although poor task support is a serious usability problem

for a big-screen Web site, it is a usability catastrophe for a small-screen service. With the big screen, users can see many more options, and thus it is less critical that designers pick exactly the right ones at each step. The mobile design rule: Be right or be dead.

One test user expressed the benefits of understanding users' needs as follows, "The [service tested] seems to have no sense of humor. The portal should be like a friend who kind of has an understanding of what you like. So you say to your friend, 'Just tell me something about the sports, about the weather.' So a good portal would be the one that thinks the way that you do to a degree. That's why Yahoo! was best for me because it was less tabloid-orientated, more international, and had a clear way of presenting itself, which was long scrolling menus. A portal, a search engine, or any computer should be as friendly to you as possible. You should feel that it's an ally, that it will help you out. If you find one like that, you will forget all the others."

On several occasions, we have observed users fail at tasks because they did not scroll their mobile screens to see content and menu options that were "below the fold" (i.e., not visible on the first full screen). Again, this exactly duplicates a main finding from our 1994 Web usability studies. Then, very few users scrolled Web pages, so navigation pages failed if important options were invisible. In later Web studies, we observed that users had begun to scroll, and it is no longer a usability disaster to have a home page that scrolls over two or even three full PC screens. Possibly, mobile users will evolve in similar ways. They may start to appreciate the need to scroll and decide to check out multiple screens before making choices. We can only guess, but our assessment is that scrolling will be less common in mobile navigation than in PC-based Web navigation. It is simply less pleasant to scroll through many small mobile screens than to peek at what's "below the fold" in Internet Explorer.

In the Web's infancy, outdated content and incomplete services were major problems. Companies launched sites without committing to necessary maintenance or professional editorial support. Mobile services have hit that same wall. Newspaper sites that displayed the morning headlines late in the afternoon, sports sites that didn't have the scores of recent games, and services that provided sporadic, incomplete information rather than full listings often disappointed test users. The Web still has many unprofessional sites that were apparently launched and forgotten, but most big sites are

Newspaper sites that displayed the morning headlines late in the afternoon, sports sites that didn't have the scores of recent games, and services that provided sporadic, incomplete information rather than full listings often disappointed test users.

now committed to frequent updates and comprehensive content. Let's hope that mobile Internet services reach this point soon.

It's not surprising that mobile users do not want to read a lot of text. After all, the screens have poor typography, and it is painful to scroll through page after page of small snippets of text, trying to piece them together in your mind. In several studies, we have found that Web users don't want to read much on computer screens. Our typical advice is that Web text should contain half as many words as print. On mobile devices, brevity becomes even more important. Cut. The. Words.

Future devices for mobile communication should abandon the telephone handset form. Let's stop wasting more than a third of the limited physical surface on a numeric keypad. Let's get rid of the keys and spend every available square millimeter on pixels.

The telephone user experience was aptly characterized by a test user in one of our studies: "I was a bit miffed because I had been on the phone for about 20 minutes and had not gotten a lot of information out of it all. I thought, maybe it's me; maybe I don't know my way around it. It's actually physically more demanding than the Internet because you are staring at a very small screen, your fingers are quite awkward. It's not designed to sit and browse. I can't imagine sitting and surfing [on this telephone]. So, you are sitting there watching a very small screen. It's very irritating and very uncomfortable."

Some people claim the telephone exemplifies perfect usability and should be emulated by software designers. After all, *it's easy*:

1. you pick up the handset
2. punch in the number
3. you are connected

If only it were that easy in the mobile world. Of the three steps, only picking up the handset is truly easy. Turning on the device and logging in to your account are both accomplished by the simple action of picking up the handset. There is no boot

time, and the dial tone is always there. Computers (and in particular the Web) can definitely learn something from the uptime requirements of the phone system.

It is possible to build mobile devices that support voice communication without being bastardized telephones.

Let me debunk the myth that punching in a number is an easy-to-use interface. First, these numbers are actually hard to learn and remember. Quick, what's the number of your dentist? Second, they are hard to type, and there is no forgiveness if you mistype, nothing to do but hang up and start over. To make a long-distance call from a typical office in the United States, the user types in 12 digits, which is quite cumbersome and time consuming. International calls are even harder.

The real usability problems of the telephone appear in a task analysis. What does the user really want to accomplish? In most cases, this is to talk to a specific person. Doing so means finding that person in the telephone directory (or another list of phone numbers) and then dialing the number. Who wants to talk to a number?

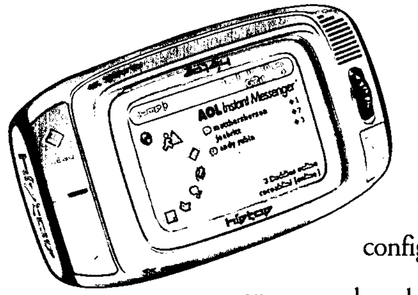
Most numbers come from one of these sources:

- a personal address book
- an e-mail message (or equivalent such as SMS or paging messages)
- online lookup in yellow pages, telephone directories, or corporate Web sites

Instead of keying in a huge string of digits, it is easier to use the screen by simply tapping the name of the person or company.

It is possible to build mobile devices that support voice communication without being bastardized telephones. One great design that combines mobile voice and data communication is Danger's mobile device, the Hiptop, which will probably be shipping by the time you read this article.

The Danger device is a two-in-one design in two different ways. First, it's both a personal digital assistant and a cellular phone (through a headset). No more cell phone to carry in addition to your data device. Voice is data. Second, the form has two different configurations. Initially, you see only the screen and the device is the size of a fat deck of cards. As I have often requested, the entire surface area is devoted to screen space, with the exception of a few thumb-operated buttons. This base form works fine



The Hiptop device (Photo courtesy of Danger)

for checking appointments or incoming e-mail. If you want to respond to e-mail or interact with a data service, the device twists open like a Russian snuffbox to reveal a keyboard under the screen. In this configuration, the device is obviously twice as big and doesn't fit in a pocket any more, but that's okay: You twist it back to its compact size when you're done typing.

Danger has done many things right. Although the keyboard is small, it works fine for two-thumb typing. It is also slightly bigger than the Blackberry keyboard, and, based on a short trial, I think Danger may support slightly faster typing. I reserve my final judgment on this until I've run a controlled typing study. (At the time of writing, the Hiptop was still in the pre-release stage.)

Although I like having an A-Z keyboard on my mobile device, I am not convinced that micro-keyboards are the best long-term solution. Better handwriting recognition is coming, and Microsoft's Pocket PC 2002 already has reasonably good recognition that doesn't require users to learn a new alphabet. Also, Danger, Blackberry, and most data phones use a track wheel to move around the screen. This feels very unnatural and constraining compared to a direct manipulation device such as a pen or a mouse, or simply poking your finger at the screen.

Traditional handsets are the wrong form for mobile user interfaces. You can put prettier lipstick on it, but it remains a pig. Whether the winner will be Danger, Palm, or something from Microsoft is hard to say. For mobile user interfaces to succeed, they will need improvements in usability that can only come from better graphical user interfaces than those on current telephones.

Promising mobile Internet services seem to take two dramatically contrasting approaches that both work well with users:

- Highly goal-driven services aimed at providing fast answers to specific problems. Examples include: "My flight was canceled; get me a new airline reservation" and "What's the weather?"
- Entertainment-focused services whose sole purpose is killing time. Examples include gossip, games, and sports services. Gossip is particularly suited for mobile devices because the content can be very brief and still be satisfying.

Mobile services must target users with immediate, context-directed content. General services such as shopping are less likely to succeed in the mobile environment. Indeed, among mobile service users in a study we conducted in London, shopping hardly figured at all; sports and entertainment were the two big categories. During the soccer World Cup, getting beeped when England scored a goal was a big hit with users.

Killing time is a perfect application for mobile devices because they are readily available when users are waiting for something to happen. At the bus stop? Play a short game. In line for something? Read a paragraph of gossip. Stuck in traffic that doesn't move? Check the scores of your favorite teams.

Success for mobile devices and services depends on abandoning both of the old metaphors: It's neither a telephone nor a Web browser. We need simpler services than Web sites and more focus on users' needs in the moment and in the context of their current location. We do not need telephones with features that are inelegantly grafted on as an afterthought.

I am convinced we will see new devices that emphasize usability. In fact, some good designs are already available, though it will take a few years for them to penetrate the mass market.

I am less optimistic about the potential for highly usable services in the near future. Experience from previous technologies has shown that a technological imperative and a low understanding of users' needs drive the first several generations of design. We are probably doomed to a few years of miserable user interfaces on our shiny new mobile devices. Gradually, we will establish usability guidelines through testing and failure of these initial designs. Finally, it will become blatantly obvious to all product managers that they can't ship stuff just because people on the project teams think their own designs are easy enough to use. Then we will get good usability for mobile services. It will be pleasant to use mobile data services. Just wait a few years.

About the Author

Jakob Nielsen is principal of Nielsen Norman Group, a think tank focused on making technology more suited for humans. He is the founder of the "discount usability engineering" movement, which emphasizes fast and efficient methods for improving the quality of user interfaces. Dr. Nielsen, noted as "The world's leading expert on Web usability" by *U.S. News and World Report,* is the author of the best-selling book *Designing Web Usability: The Practice of Simplicity* and the new *Homepage Usability: 50 Websites Deconstructed.* He holds a Ph.D. and has been awarded 66 U.S. patents, mainly for ways to make the Internet easier to use. His Web site is www.useit.com.

VISION

FACE TO FACE: AN INTERVIEW WITH SENATOR JAY ROCKEFELLER

Jay Rockefeller is a United States Senator representing West Virginia.

Janet Copenhaver, director of technology at Henry County Public Schools in Virginia, addresses the same questions in the Leadership section.

FACE TO FACE:

VISION

AN INTERVIEW WITH SENATOR JAY ROCKEFELLER

Many people consider the E-rate program to be enormously successful in connecting America's classrooms to the Internet. What potential did you foresee for the E-rate, and has it lived up to or exceeded your expectations? What challenges remain, and how do you envision the E-rate program evolving over the next 10 years?

JR: The E-rate program has been enormously successful, and I am very proud of the accomplishment to date. In 1994, only 3 percent of classrooms were connected to the Internet. Now, thanks to E-rate and other initiatives, 87 percent of classrooms are connected. This is real, meaningful progress. And it has been recognized by many who were skeptical at first of the E-rate program—including companies who have seen how the E-rate helps build their markets.

It is interesting and rewarding to see how quickly the E-rate has developed. In 1997, a Congressional Budget Office report suggested that it would take as long as six or seven years before schools and libraries requested discounts up to the cap of $2.25 billion. In reality, it took just a few years, and now the demand for E-rate discounts is almost double the available funding. The enormous demand is creating new challenges for the E-rate program, but I believe we can continue to improve and streamline the program.

As for the future, none of us can predict the incredible advances that new technologies are likely to bring over the next decade. But the E-rate program will be ready. The E-rate, and indeed the entire universal service program, was designed to be flexible and responsive to changes in the telecommunications market. The *1996 Telecommunications Act*, which created the universal service program and the E-rate, says that "universal service is an *evolving level* of telecommunications services...taking into account advances in telecommunications and information technologies and services." As technologies evolve, so too will the E-rate.

▶▶: ***E-rate funds have been capped at $2.25 billion since 1997, yet demand keeps growing. What steps should be taken to ensure that funding is available to meet schools' needs? Because the bulk of E-rate funds now supports recurring charges for connectivity, little remains for new connections or inside wiring. However, many classrooms in rural and disadvantaged schools still lack basic access to the Internet. What can be done to ensure equitable access to technology so that no schools are left behind?***

JR: We are beginning to bridge the digital divide, but unfortunately, this takes time, and there are still significant differences between wealthy schools and poor schools. The latest data from the National Center for Education Statistics indicated that Internet access in poor schools is about 60 percent, while that for wealthier schools is higher—between 77 percent and 80 percent. This gap is real, but poor schools are getting help, thanks to E-rate, and we are bridging the gap. Indeed, the E-rate gives the highest discounts to the poorest schools. It is important to remember, however, that the E-rate is a voluntary program. Not every school must participate, and not every school does. I can understand why some of the poorest schools may have other, higher priorities, like safety, maintenance, and other critical needs.

E-rate is only part of the education technology puzzle. Other programs should support technology as well. In July, the Senate Appropriations Committee recommended $792 million for education technology investments, which was almost $70 million more than the president's budget request. We need to invest in education,

including teacher training and development, in order to take full advantage of the potential of technology.

Finally, we need to look beyond the schools themselves. We should support Community Technology Centers and other investments to help connect all communities to the technology that will be crucial for jobs and continuing education.

▷▷: *In a report just released by the Pew Internet & American Life Project, called* **The Digital Disconnect: The Widening Gap Between Internet-Savvy Students and Their Schools,** *students argue that the multibillion-dollar investment to connect schools to the Internet is in danger of being wasted because they are not realizing the benefits of Internet connections in their schools. The report suggests that teachers and principals are lagging behind students in tapping the Internet's vast resources. How do you suggest this concern be addressed?*

JR: Again, quality education improvements take time. The first step was to connect classrooms to the Internet, and we've made real progress. Since the majority of classrooms are connected to the Internet, the next logical step is to focus on teacher training to ensure that we can gain the full advantage of education technology.

Now is the time to invest in training teachers currently in the classroom and to improve how we educate and prepare college students to teach in ways that integrate technology. The Senate Appropriations Committee recommends $67.5 million for the Preparing Tomorrow's Teachers to Use Technology Program (PT3), while the administration's budget eliminates the program. I believe we must invest in teachers, and I will be working hard for this program and others. When reauthorization of the Higher Education Act is debated in the next Congress, I will fight to ensure that professional development for teachers will be a real priority.

New teachers, who are in school now preparing to teach, use more technology and, I believe, are more comfortable with technology.

▶▶: *The lack of technical support and adequate staff to maintain the technology infrastructure can be a significant barrier to effectively integrating technology in education. In business, the ratio of computer support personnel to users is approximately one to 50, while in education, the ratio is one support person to every 500 students. The nation's schools now benefit from an enormous infrastructure as a result of the federal investment in educational technology. What steps must be taken to ensure the maintenance and expansion of this infrastructure?*

JR: Maintenance and computer ratios will always be a challenge. To be honest, I doubt that schools will ever be able to afford the same maintenance and computer support as business. But I also believe that there are creative ways to bridge the gaps and provide critical infrastructure support, including training students to do computer support in their own schools and classrooms.

▶▶: *West Virginia is emerging as a national leader in the field of biometrics. For example, West Virginia is home to the FBI's fingerprint database, the largest biometrics depository in the world, and West Virginia University now offers a unique biometrics degree program. Although much has been reported about biometrics since September 11, most of this attention has focused on airport security. Some schools are considering biometrics to authenticate personal identity in a variety of educational applications. One such application might be finger-scan technology in the school lunch line. Biometric systems are designed to preserve the privacy of students who participate in the free and reduced-price meal program, and they have been shown to increase participation in that program. However, some parents have concerns about the potential for misuse of biometric databases and feel discomfort with the notion of a government institution teaching children to use biometric identification. How should these issues be addressed?*

JR: I've long thought that technology is our biggest advantage in the fight for homeland and airport security, and biometrics is one of our most promising technologies in this regard. I think we can use biometric technologies in homeland security applications without creating security loopholes or violating privacy. Biometrics also has great potential apart from homeland security—in schools, for example. As

commercial and educational applications are developed for biometric technologies, we will, of course, need to address questions of privacy and database protection. But I'm convinced we will be able to do so. I'm a principal cosponsor of a bill that would require Internet Web sites to obtain users' permission before collecting or distributing sensitive personal information—perhaps a similar approach might be appropriate for civilian or educational biometrics. This issue will require a great deal of thought over the coming years.

Senator Jay Rockefeller has represented West Virginia in the U.S. Senate since 1984. He is a member of the Senate Commerce Subcommittee on Science, Technology, and Space and coauthor of the E-rate program, which provides discounts on telecommunication services, Internet access, and internal connections to public and private schools and libraries.

HINDSIGHT

Much has happened since we first launched IN⏩SIGHT a year ago. It seems appropriate to look back at last year's Vision topics and the people who presented them and to report on how they have changed since they were first described in IN⏩SIGHT.

Customizable Content

Last year, Walter Koetke shared his vision about the ability to customize content to meet the individual needs of learners. At that time, he was vice president of K12, Inc., an e-learning provider led by former secretary of education William Bennett. Koetke now spends his time addressing what he sees as the biggest hurdle to the effective use of technology: Teachers need good materials with which to work. He is developing a series of three supplementary mathematics books for students in grades 6 to 14 and for in-service and preservice use by all mathematics teachers. Students and teachers using the books will understand the appropriate role of technology in problem solving—sometimes a source of the whole solution, sometimes a tool to help find a solution, and sometimes of no use. His goal is to provide material that helps to improve mathematics instruction while increasing the effective use of technology in the classroom.

Evidence-Based Education

In the last issue of IN⏩SIGHT, John Willinsky offered a compelling case for evidence-based education. Recently, Willinsky told IAETE staff that the Public Knowledge Project continues to develop publishing and indexing systems designed to make open access to education research possible for journals and conferences. By publishing research in this free-to-read way, journals and conferences will help educators, parents, policymakers, and the media readily and accurately find the education research that bears on the immediate questions they are facing. These easily installed and operated systems are available to journals and conferences at no charge from the Public Knowledge Project as its contribution to forming educational decisions by a full range of the best available evidence. For more information, visit http://pkp.ubc.ca.

Internet2

Last year, Louis Fox and Ron Johnson presented an overview of Internet2 and highlighted some of the innovative applications under way at that time. Today, Louis Fox, director of the Internet2 K20 Initiative, reports that in the past year the interest in Internet2 among K20 institutions soared beyond expectations. As of September 2002, 25 states were connected to Abilene, the Internet2 backbone network. Within those states, 7,200 K-12 schools; 500 community colleges; 550 four-year colleges and universities; 1,200 public libraries; and 100 museums, science centers, zoos, and aquariums are connected. For more information, visit www.internet2.edu/k20.

THE BEGINNER'S GUIDE TO RADIO

PRACTICAL WIRELESS

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MARCH 1955

EDITOR: F.J. CAMM

PRACTICAL WIRELESS? NOT YET - SEE PAGE 87.

Building an 8-Valve Super-Het Radiogram

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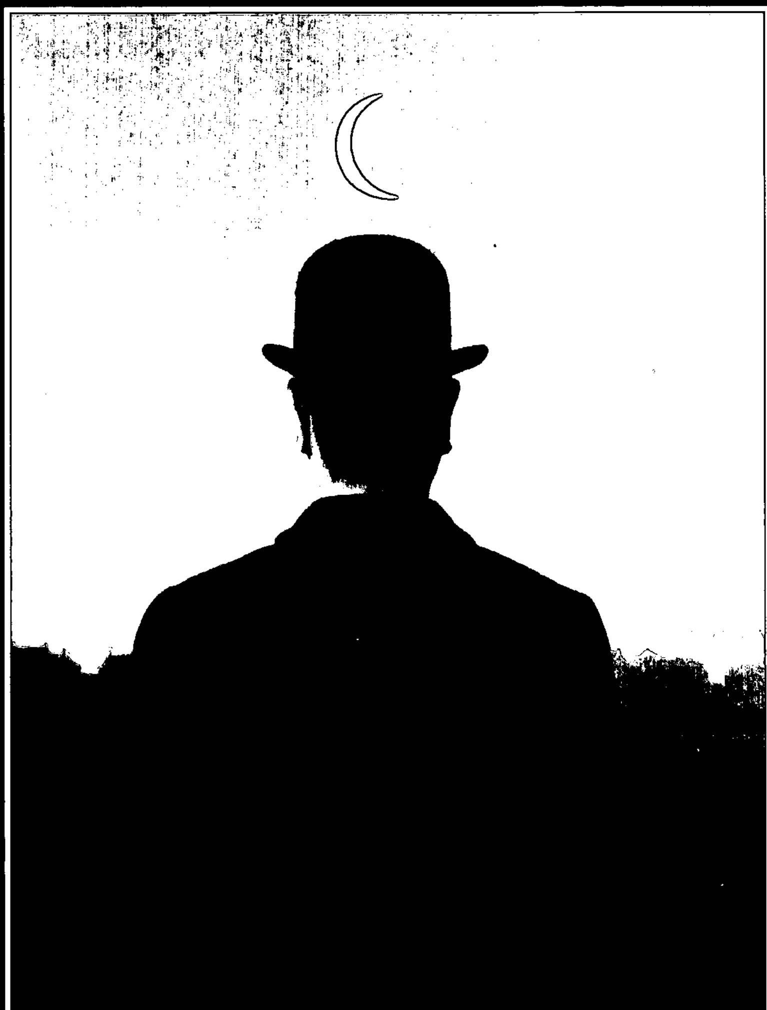

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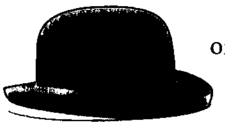
IAETE

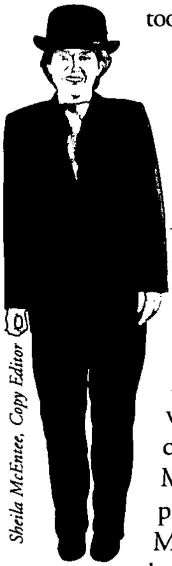
OUR MISSION: TO SUPPORT THE PURPOSEFUL USE OF NEW AND EMERGING TECHNOLOGIES TO IMPROVE TEACHING, LEARNING, AND SCHOOL MANAGEMENT

On the cover: René Magritte's *Le Maitre d'ecole (The School Headmaster)*



John Ross, Web Producer

Technology is empowering students to think and act creatively in ways that we are only beginning to understand. Recently I had the opportunity to talk with a 17-year-old entrepreneur about her Web site development business. She told me that she learned HTML when she was 10 years old, and that since then, it has become a "second language" to her. She has used this second language in recent years to earn a five-figure income annually—not bad for a part-time high school job. This student impressed me when she said, "I can accomplish anything with PhotoShop." Her words reminded me that digital tools and media offer unprecedented opportunities for student expression.



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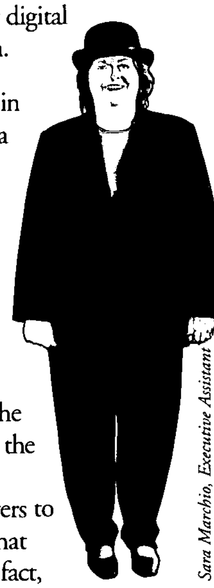
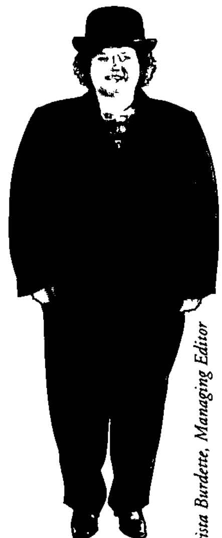


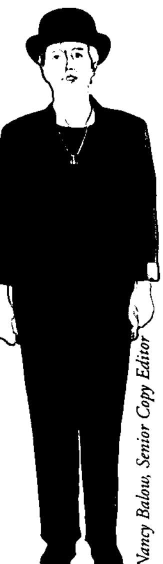
Sara Marchio, Executive Assistant

Nicholas Negroponte talked about the new "E-xpressionists" in his 1995 book *Being Digital*. He suggested that we are entering an era when expression can be much more participatory in nature, allowing the viewer or listener to transform the work of art to meet his or her personal needs or preferences. Digital manipulation is beginning to empower students to participate fully in the creative process, instead of just assuming the role of consumer.

So how do "peer-to-peer" file sharing and other Napster-type issues affect this new era of creative possibility? It is difficult to know, but there are early instances that might inform our thinking. The work of René Magritte, whose painting *Le Maitre d'ecole* is featured on the covers of this issue of IN▶▶SIGHT, might be the perfect example. Magritte's art has been widely reproduced on everything from book covers to product packages, posters, and television advertisements. It is reported that Magritte was never angry about this blatant copyright infringement. In fact, he encouraged reproduction of his paintings in any form and viewed it as a surrealistic way to display his work. Only after his death in 1967 were copyright infringement penalties enforced. I believe Magritte would have greeted the idea of sharing his work over the Internet with great enthusiasm.



Krista Burdette, Managing Editor



Nancy Balow, Senior Copy Editor

We, too, are enthusiastic about sharing our work over the Internet and invite you to visit www.iaete.org/insight to participate fully in the exchange of information inspired by IN▶▶SIGHT. The articles presented here represent a starting point for what we hope will be a rich and productive discussion about these topics. We believe vision and leadership must be viewed in tandem. Vision is important for illuminating possibilities while leadership helps us explore areas where more rigorous work is needed. It is important to view these papers in this context and to remember they represent the authors' perspectives at a given point in time.

Tammy McGraw

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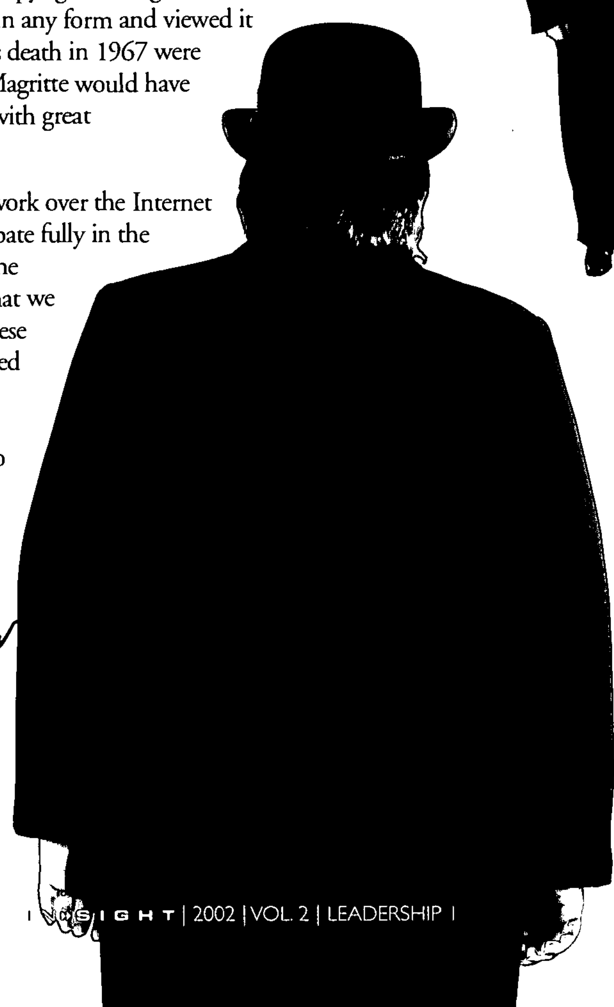

Tammy McGraw, Editor in Chief

LEADERSHIP

"Leaders are visionaries with a poorly developed sense of fear and no concept of the odds against them."

—*Robert Jarvik*
Inventor of the Jarvik-7 artificial heart

LEADERSHIP

1

THE EFFECTS OF PERVASIVE, CONSUMER-BASED, INTERACTIVE MULTIMEDIA GAMES ON THE READING DISORDERS OF ADHD CHILDREN

Tammy McGraw, Ed.D.; Krista Burdette, M.A.; Virginia Seale, M.A.; and Soleil Gregg, M.A.

IAETE staff present the results of an exploratory study employing a recreational interactive multimedia game, Dance Dance Revolution, *to tackle neural impairments likely associated with reading and attention disorders. In the Vision section, Michael Kamil presents his view of how technology can support reading.*

THE EFFECTS OF PERVASIVE, CONSUMER-BASED, INTERACTIVE MULTIMEDIA GAMES ON THE READING DISORDERS OF ADHD CHILDREN

Tammy McGraw, Ed.D; Krista Burdette, M.A.; Virginia Seale, M.A.; and Soleil Gregg, M.A.

Two highly prevalent disorders affecting school-aged children—dyslexia and Attention-Deficit/Hyperactivity Disorder (ADHD)—have been found to increase children's risk for underachievement, school failure, delinquency, and dropping out.[1] And while more and more children with learning deficits are being educated in regular classrooms, many teachers lack sufficient training to help them succeed.[2] Moreover, the pressures of high-stakes testing and accountability on schools make imperative interventions that address learning deficits and maximize academic achievement.[3]

Certain interventions that ameliorate impairments in reading and attention disorders work on the physiological level and, therefore, might lend themselves to technology-based applications. This article describes the methods and results of an exploratory study conducted to determine if regular play of a popular, interactive multimedia game entitled *Dance Dance Revolution*, commonly called *DDR*, improved individual performance on reading and writing assessments of students with demonstrated reading impairment. Because *DDR* requires participants to match movement to visual and rhythmic auditory cues in a natural way, within the play of the game, the authors hypothesized that *DDR* may strengthen neural networks shown to be involved in reading and attention and thereby improve student outcomes. Though the number of subjects in the study receiving full intervention was limited, results showed

Further research may support the use of recreational games such as DDR to supplement traditional classroom interventions for addressing these disorders, offering educators and families alike a child-focused option that is neither pedagogical nor pharmacological.

improvement by the treatment group in three subtests, indicating that the intervention may have targeted the neural impairments associated with dyslexia and ADHD. It is important to remember that this work represents an exploratory study and generalization is not possible at this time. Further research may support the use of recreational games such as *DDR* to supplement traditional classroom interventions for addressing these disorders, offering educators and families alike a child-focused option that is neither pedagogical nor pharmacological. A subsequent study is under development.

Background

Dyslexia and Attention-Deficit/Hyperactivity Disorder (ADHD) are two disorders likely to tax the abilities of teachers of all grades and content areas because of their prevalence and potential for negative education outcomes. Dyslexia is a partly heritable, neurobiological, language-based disorder that obstructs the development of linguistic skills—reading, writing, spelling, and speaking.[4] ADHD is a mainly heritable disorder of inhibition, self-control, and executive function, affecting a child's ability to sit still, pay attention, follow rules, and complete cognitive tasks crucial to school success (e.g., organizing, prioritizing, sequencing, planning, problem solving, concentrating, self-motivating, inhibiting impulses, memorizing verbal information, and working toward future goals).[5]

Because of their potentially devastating effects on learning and behavior, dyslexia and ADHD pose a particular challenge to educators who must help struggling students meet performance goals. Dyslexia is "the most prevalent . . . learning disorder in childhood," affecting up to one in five students.[6] Similarly, ADHD is the "most common neurobehavioral disorder" and "one of the most prevalent chronic health conditions affecting school-aged children"—as many as 10 percent.[7] Both disorders have been found to increase children's risk for underachievement, school failure, dropping out, suspension, expulsion, and delinquency.[8]

Despite high prevalence of both disorders, many teachers lack the necessary training to help students with special needs succeed.[9] In response, states and districts are providing professional development opportunities to help teachers acquire the knowledge, skills, and repertoire of interventions and strategies needed to assist students

with dyslexia, ADHD, and other disorders. Yet training large numbers of teachers at sufficient depth and intensity to affect pedagogy can be costly, time consuming, and slow to show results in improved student performance.

Dyslexia

According to the *MEDLINEplus Medical Encyclopedia*, dyslexia, also known as developmental reading disorder, is "a reading disability resulting from a defect in the ability to process graphic symbols."[10] Impairments associated with dyslexia diminish children's ability to distinguish the sounds in words, link letters and sounds, retrieve and name words, and become automatic, fluent readers.[11] Because reading skills are prerequisite to learning in all academic areas and to participation in large-scale assessments, poor readers are likely to underachieve in all subjects and perform poorly on assessments unless they are provided testing accommodations or modifications.

Dyslexia has been linked to impairments of phonological, motor, and sensory processing systems.[12] Brain-imaging and neuroanatomical studies have revealed structural and functional differences in the brains of dyslexic individuals as compared to nondyslexic controls, including the volume and activation of certain brain regions and the size, number, and distribution of particular neurons—especially in the brain's left hemisphere.[13] For example, researchers have found atypical activation of brain regions—specifically the angular gyrus—during phonological tasks.[14] This area is thought to assist in the integration of orthographic and phonological information such as is necessary to connect the letters in words to their corresponding sounds. Others have found functional deficits and cellular abnormalities in sensory processing systems, particularly in those pathways central to rapid auditory and visual processing, which could affect entry-level tasks critical to reading, such as discriminating the individual sounds that comprise words.[15]

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Dyslexic individuals may also exhibit developmental writing disorder and/or developmental arithmetic disorder, since "all these processes involve the manipulation of symbols and the conveyance of information by their manipulation."[16]

ADHD

Brain-imaging studies have also revealed structural and functional differences in subjects with ADHD, particularly in the right hemisphere, supporting a neurobiological basis for the disorder.[17] For example, in two seminal studies, Zametkin et al. found reduced metabolic activity in regions linked to motor control and attention, while Castellanos et al. found decreased cerebral volume in regions associated with inhibition and executive function.[18] Schweitzer et al. noted underactivation of an area thought to be involved in working memory—an area also impaired in ADHD—during cognitive tasks.[19] Other research has focused on the function and genetics of neurotransmitter systems that modulate the activity of these same circuits.[20]

Similarities, Comorbidity, and Brain Research

Dyslexia and ADHD frequently coexist.[21] Studies have found that from 25 to 40 percent of children with ADHD have a reading disorder; likewise, 15 to 26 percent of those with reading disorders and 30 to 50 percent of those with learning disabilities meet criteria for ADHD.[22] Based on parent and teacher ratings, one study found that 60 percent of reading-disabled boys met criteria for ADHD, Inattentive Type.[23]

Both disorders can impair higher order cognition and memory, possibly because language plays a key role in the development of executive functions and working memory.[24] In addition, both are characterized by social skills deficits, coexisting psychiatric disorders, and motor difficulties.[25]

Clumsiness and motor skills deficits have long been observed in children with ADHD, learning disabilities, and dyslexia.[26] Likewise, children with developmental coordination disorder have been found to have an increased incidence of nonmotor impairment, especially language disorders.[27]

Some researchers propose that underperformance on tests of rapid naming—associated with both dyslexia and ADHD—may be indicative of global motor and temporal processing deficits as well as impairment of executive functions.[28] In dyslexic children, specific deficits in motor timing have been found,[29] while studies of children with ADHD have shown deficits of motor timing and time perception.[30]

New thinking about the role of the cerebellum may help to explain the apparent connection between cognitive and motor impairment in dyslexia and ADHD. At one time thought to be limited to functions of motor control and coordination, the cerebellum is increasingly believed to play an important role in perception, cognition, and behavior as well.[31]

New thinking about the role of the cerebellum may help to explain the apparent connection between cognitive and motor impairment in dyslexia and ADHD. At one time thought to be limited to functions of motor control and coordination, the cerebellum is increasingly believed to play an important role in perception, cognition, and behavior as well.[31]

Patients with cerebellar disease have been found to have associated deficits in executive functioning (e.g., planning, verbal fluency, working memory, and reasoning); language; and emotional and behavioral control—impairments also characteristic of reading and attention disorders.[32] Studies have also suggested the cerebellum's contribution to linguistic skills and to sensory discrimination and processing—functions known to be impaired in dyslexia.[33] In fact, brain-imaging studies have found structural abnormalities in the cerebella of dyslexic subjects and less activation during speech and learning tasks.[34]

Cerebellar dysfunction may also contribute to the core symptoms of ADHD. Research suggests that the cerebellum plays a role in motor control, behavioral inhibition, and attention.[35] In addition, brain-imaging studies have found structural and functional differences in the cerebella of subjects with ADHD as compared to controls.[36]

Research Implications for Interventions

Knowledge of the brain's plasticity, or its ability to adapt to the environment,[37] has raised the possibility that interventions can directly target neural impairments underlying certain disorders.[38] Studies show certain interventions based on this principle to be promising for ameliorating the impairment in reading and attention disorders. Because these interventions are intended to work on a physiological level, they lend themselves to technology-based applications.

Dance Dance Revolution (DDR) is a pervasive, interactive multimedia game designed solely for entertainment. As such, it has massive appeal to young people.

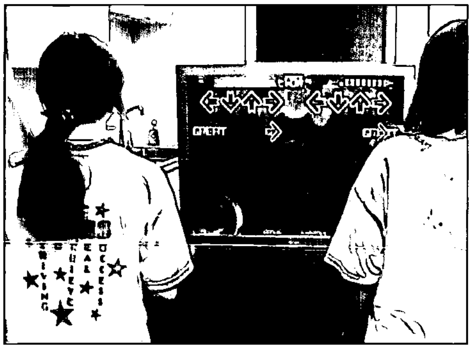
Technology-Based Games and Applications

Fast Forward, an interactive computer game developed by neuroscientists Merzenich and Tallal, was designed to remedy rapid temporal processing deficits by artificially stretching or slowing the sounds in speech.[39] It has been shown to improve the reading achievement of language-impaired and dyslexic children by promoting the development of auditory discrimination and phonological awareness.[40]

Similarly, dyslexic students who received audiovisual training with a computer game developed by Kujala et al. improved their reading skills, even though the game was nonlinguistic.[41] By matching sound patterns to graphic representations, the children improved auditory perception—a finding confirmed by electroencephalogram readings.

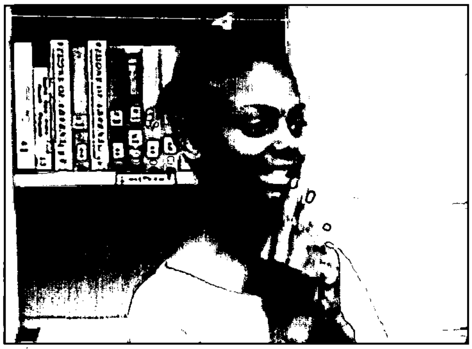
Attention Trainer and *Interactive Metronome* are computer programs that aim to improve the symptoms of ADHD by strengthening pathways involved in attention, motor planning, and sequencing. *Attention Trainer* uses neurofeedback to evoke and reinforce a type of brainwave purportedly linked to attention, although rigorous research as to the program's effectiveness is lacking. Preliminary studies of *Interactive Metronome*, on the other hand, found that the program significantly improved attention and motor control, as well as language and reading skills.[42]

The previous examples are indicative of efforts to develop specialized, interactive, multimedia computer games to address disorders such as ADHD and dyslexia. *Dance Dance Revolution (DDR)*, on the other hand, is a pervasive, interactive multimedia game designed solely for entertainment. As such, it has massive appeal to young people. Described as a high-tech combination of the children's games Twister and Simon Says, *DDR* made its first appearance in Japanese arcades in 1998 and quickly became enormously popular. It appeared in the United States in March 1999 in California and exceeded initial projections for play. For example, owners of a San Francisco-based arcade expected 30 to 35 plays a day but reported 4,000 plays in the first 30 days.[43] Tournaments are routinely held in major cities throughout the United States. The popularity of the arcade game quickly led to the release of a home version.

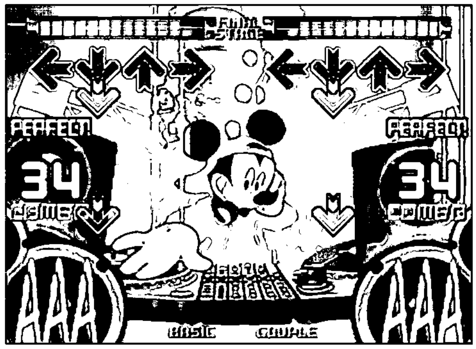


Two students follow visual cues on the screen.

Students use Konami external game pads.



A student is ready for the game to begin.



A screen shot from the DDR Disney Mix *shows the full background image.*

Konami and Sony PlayStation introduced the home version of *DDR* in March 2001. The popularity of the original game led to the production of *DDR Disney Mix* (released in September 2001) and *DDR Konamix* (released in April 2002). All of the versions hold an "E" rating (suitable for everyone) by the Entertainment Software Rating Board (ESRB). The PlayStation One console sells for approximately $50, the games sell for $30 (*DDR and DDR Konamix*) to $40 (*DDR Disney Mix*), and the peripheral dance pads range in price from $20 to $50, making the game relatively inexpensive and widely available. The games are also compatible with the PlayStation 2 (PS2) console, which sells for approximately $200. This study used the *DDR Disney Mix*, which uses popular Disney songs with "kid-friendly" lyrics and visual imagery, on the PS2 console.

This study used the *DDR Disney Mix*, which uses popular Disney songs with "kid-friendly" lyrics and visual imagery, on the PS2 console.

Research Rationale

By matching movements to visual and rhythmic auditory cues, *DDR Disney Mix* may strengthen neural networks shown to be involved in reading and attention, thereby improving student outcomes. Like the game developed by Kujala et al., *DDR*

Disney Mix uses audiovisual matching and may improve entry-level sensory processing systems involved in reading.[44] In addition, its use of rhythm to evoke a synchronized motor response may assist in the development of motor timing and processing. As previously discussed, research has associated dyslexia with deficits in rapid processing of both auditory and visual stimuli, as well as in motor timing and response.[45]

Research has associated dyslexia with deficits in rapid processing of both auditory and visual stimuli, as well as in motor timing and response.[45]

Methodology

Participants

The sample was selected from a middle school in rural southwest Virginia. The school was chosen for two primary reasons: (1) logistics (i.e., availability of research staff in the area) and (2) the willingness expressed by the school to participate in the study. The school is located in a small town and serves students in grades 6 to 8 who are predominantly White (85%). There were approximately 575 students in grade 6, the focus of this study, and more than 90 percent of those students (547) qualified for free or reduced-price meals.[46]

Access to students' permanent and medical records was limited, so diagnoses of dyslexia and ADHD were impossible to confirm. Furthermore, dyslexia and ADHD are not always included in the permanent and/or medical records unless a parent or guardian voluntarily submits the information to the school or unless, in the case of ADHD, medication during school hours is required. To identify potential participants with a diagnosis of ADHD that was confirmed by a parent or guardian, a letter explaining the study, along with informed consent forms, were distributed to every student in grade 6. For the purposes of the study, the presence of reading impairment in potential participants was determined by a pretest.

The pool of potential participants included 51 students who were identified by their parent or guardian as having been diagnosed with ADHD by a medical or psychological professional. This number is consistent with the national prevalence rate. (For gender, racial, and socioeconomic differences among the potential participants, see Tables 1, 2, and 3.)

Table 1

Gender of Potential Participants

	Frequency	Percent
Female	21	41
Male	30	59
Total	51	100

Table 2

Race of Potential Participants

	Frequency	Percent
White	39	76
Black	11	22
Total	50	98
Missing Data	1	2
Total	51	100

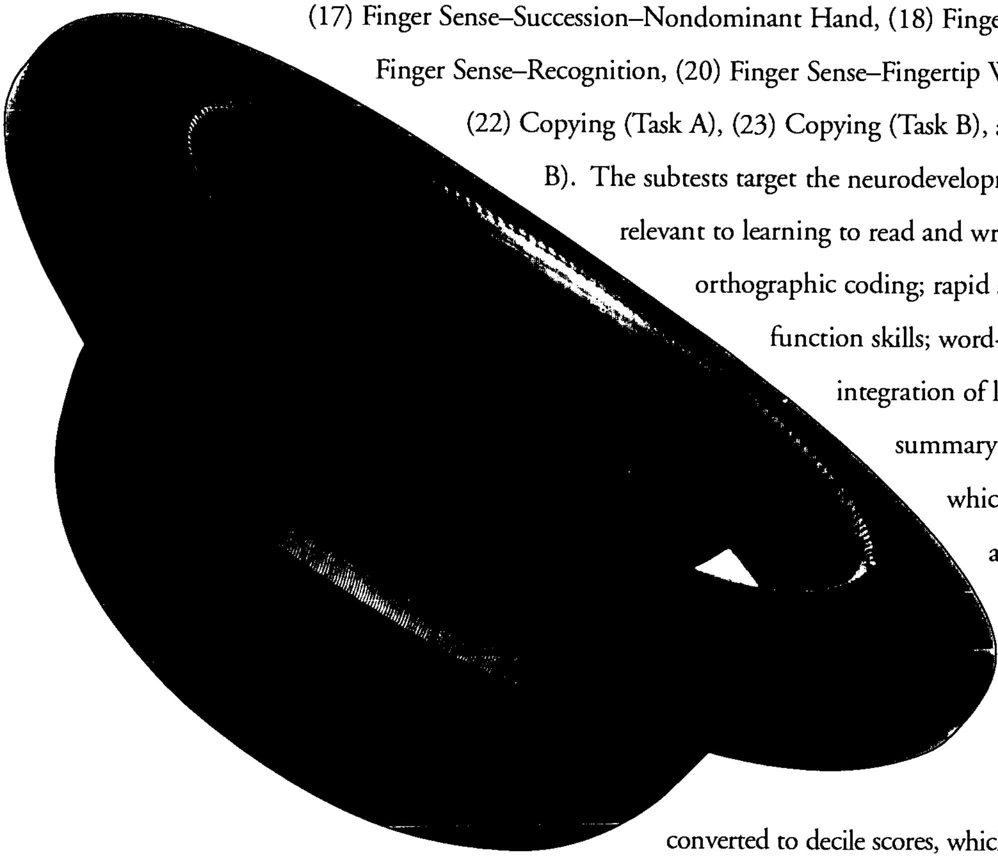
Table 3

Eligibility of Potential Participants for Free or Reduced-Price Meals

	Frequency	Percent
Yes	30	59
No	20	39
Total	50	98
Missing Data	1	2
Total	51	100

Assessment Instrument

The Process Assessment of the Learner: Test Battery for Reading and Writing (PAL–RW) is used to identify students at risk for reading/writing problems, monitor students' progress as they participate in intervention programs, and aid in diagnosis by evaluating the nature of reading/writing-related problems. It is designed to provide individual assessment of reading and writing component skills of students from kindergarten through grade 6. The test contains 24 subtests relevant for students in grade 6: (1) Alphabet Writing, (2) Receptive Coding, (3) Expressive Coding, (4) Rapid Automatized Naming–Letters, (5) Rapid Automatized Naming–Words, (6) Rapid Automatized Naming–Digits, (7) Rapid Automatized Naming–Words and Digits, (8) Note-Taking (Task A), (9) Syllables, (10) Phonemes, (11) Rimes, (12) Word Choice, (13) Pseudoword Decoding, (14) Finger Sense–Repetition– Dominant Hand, (15) Finger Sense–Repetition–Nondominant Hand, (16) Finger Sense–Succession–Dominant Hand, (17) Finger Sense–Succession–Nondominant Hand, (18) Finger Sense–Localization, (19) Finger Sense–Recognition, (20) Finger Sense–Fingertip Writing, (21) Sentence Sense, (22) Copying (Task A), (23) Copying (Task B), and (24) Note-Taking (Task B). The subtests target the neurodevelopmental processes most relevant to learning to read and write: phonological processing; orthographic coding; rapid automatized naming; finger-function skills; word-specific representations; and integration of listening, note taking, and summary writing skills[47]—processes in which students with ADHD and/or dyslexia are believed to exhibit deficits, as supported by a literature review.



Subtest raw scores are converted to decile scores, which describes the tenth of the distribution in which the child's performance is scored. The test manual divides the decile scores into five classifications (see Table 4).

Table 4

Classification by Decile Score According to the PAL-RW Manual

DECILE SCORE	CLASSIFICATION
10 & 20	Deficient
30 & 40	At-Risk
50	Emerging Adequate
60, 70, & 80	Adequate
90 & 100	Proficient

The test was standardized according to 1998 U.S. census data for grade level, sex, race/ethnicity, geographic region, and parent/guardian education. Test-retest reliability coefficients were calculated using a combined sample, drawn from Grades 1, 3, and 5 in the standardization sample. Therefore, only subtests with common items across all grades were reported (see Table 5).

Table 5

Test-Retest Stability Coefficients by Subtest

SUBTEST	CORRECTED r*
Alphabet Writing	.61
RAN-Letters	.92
RAN-Words	.70
RAN-Digits	.84
RAN-Words & Digits	.92
Finger Sense: Repetition Item 1	.68
Finger Sense: Repetition Item 2	.79
Finger Sense: Succession Item 1	.89
Finger Sense: Succession Item 2	.87
Finger Sense: Localization	.66
Finger Sense: Recognition	.68
Copying Task A (20-Second Score)	.82
Copying Task B (90-Second Score)	.76
Sentence Sense	.64

* *Correlations were corrected for the variability of the standardization sample*

Materials

In addition to the PAL-RW test, this study used *DDR Disney Mix*, one Sony PlayStation 2, two Konami external dance pads, and one 50-inch Magnavox rear-projection television.

Procedure

Subsequent to acquiring parental approval, each of the 51 children identified as potential participants was individually tested using the PAL-RW to reveal the presence of reading impairment and to provide baseline data. For the purpose of this study, reading impairment was defined by the percentage of subtest scores in the Deficient and At-Risk categories compared to the percentage of subtest scores in the Proficient category. That is, students with greater than or equal to 40 percent of subtests scored in the Deficient (10 & 20 decile scores) and At-Risk (30 & 40 decile scores) categories AND less than or equal to 40 percent of subtests scored in the Proficient (90 & 100 decile scores) range were considered eligible for the study.

According to the pretest results, 41 students were eligible to participate in the study; however, the school limited student participation in the treatment group to elective class periods only. Given that a maximum of eight students per class period could be included in the treatment group (i.e., 2 students x 2 sessions per class period x 2 days per week), the sample size was negatively impacted. (Table 6 shows the number of eligible students by elective class period.)

Table 6

Number of Eligible Students by Elective Class Period

ELECTIVE CLASS PERIOD	NUMBER OF ELIGIBLE STUDENTS
1	6
2	2
3	24
4	4
5	5

Eligible subjects were randomly selected by class period availability using a table of random numbers. Nine eligible students were excluded from the study due to the scheduling limitation. The remaining eligible students (32) were randomly assigned to either the treatment group or control group. After assignment, one student in each group withdrew from the study, leaving 15 in the treatment group and 15 in the control group. Ineligible students were used as fillers to ensure pairs during each treatment session, but no additional data were collected about them or their performance. Students assigned to the control group did not participate in the intervention activity. They attended elective courses as normal and completed the posttest at the end of the four-week treatment period.

Although gender, racial, and socioeconomic differences were not variables in the study, analysis of the treatment and control groups revealed nearly equal representation between the two groups (see Table 7).

Table 7

Gender, Racial, and Socioeconomic Representation

GROUP	GENDER		RACE		FREE OR REDUCED-PRICE MEAL PROGRAM	
	Female	Male	Black	White	Eligible	Not Eligible
Treatment	6	9	3	12	11	4
Control	5	10	3	12	10	5

DDR Disney Mix was the intervention used with the treatment group. Game settings were adjusted to minimize background audio and visual stimuli. Participants followed onscreen cues to match rhythm and choreography. They stepped on arrows on the dance pad when corresponding arrows on the television screen moved up, down, left, and right. Students participated in pairs (matched randomly within their available class period), attending two 25-minute sessions each week for a period of four weeks to accommodate the maximum number of students in the treatment group. The length of treatment in the original study design was seven weeks, to parallel procedures used by Kujala et al.; however, due to challenges associated with conducting an experimental design in a public school (i.e., confidentiality issues, scheduling problems, etc.), the intervention

period was shortened to four weeks.[48] Sessions were monitored by a trained researcher and periodically observed by and recorded for primary investigators.

Due to scheduling conflicts (e.g., class trips and school assemblies) and student absences, the number of completed treatment sessions varied by participant within the treatment group (see Table 8). At the conclusion of the study, only five students had attended eight sessions, the maximum number of sessions provided. Only students receiving all eight treatment sessions were included in the experimental group analyses.

Table 8

Number of Treatment Sessions Completed by Number of Participants

Number of Participants	Number of Completed Treatment Sessions
5	8
7	7
1	6
2	5

Following the treatment period, the PAL-RW was readministered. Posttest subtest scores were compared to pretest subtest scores.

Results

The experiment was designed to test a hypothesis regarding improved reading performance by ADHD students on the PAL-RW test following a four-week intervention period. Pretest and posttest scores were used for comparison. A repeated-measures general linear model was employed to examine performance data for each subtest within subjects (pretest and posttest) and between groups (treatment and control).

Given that only five subjects received the full intervention (eight complete sessions), the treatment group (n=5) was low compared to the control group (n=15). Because the purpose of the experiment was exploratory and the treatment group was low, a 90 percent confidence interval was used.

Differences of p < .1 or greater were found *within* subjects (pretest to posttest) without regard to group in 11 of 24 subtests, indicating that improvement occurred across both treatment and control groups in nearly half (46 percent) of the subtests (see Table 9).

Table 9

Subtests Showing Differences (p < .1) Within Subjects (Pretest to Posttest)

Subtest	Significance Level
Expressive Coding	.012
RAN–Letters	.003
RAN–Words	.083
RAN–Digits	.015
RAN–Words & Digits	.002
Note-Taking (Task A)	.047
Phonemes	.097
Sentence Sense	.004
Copying (Task A)	.001
Copying (Task B)	.000
Note-Taking (Task B)	.000

Three subtests revealed differences of p < .1 or greater between groups, indicating that subjects in the treatment group improved more than those in the control group on those subtests (see Table 10).

Table 10

Subtests Showing Differences (p < .1) Between Groups (Treatment and Control)

Subtest	Significance Level
Finger Sense–Succession–Dominant Hand	.089
Finger Sense–Succession–Nondominant Hand	.012
Finger Sense–Fingertip Writing	.069

There have been few studies devoted to the epidemiology of written language expression, but historically, writing has been associated with both attention difficulties and reading development and/or similar metacognitive processes.[53]

Discussion

Limitations. Both sample size and intervention period were considered to be limitations of the study. Time constraints, in particular, severely limited the sample size. Because students were available for treatment only during elective class periods and a single class period could provide time for only two full sessions, some eligible students were not included in the study. For example, a large number of students were scheduled for their elective class during third period, but the maximum number of students that could be included in the treatment group per class period was eight (2 students x 2 sessions per class period x 2 days per week). Consequently, although more than eight students in the third-period elective class were eligible, some were excluded through random selection.

Scheduling conflicts dictated the shortened treatment period and caused students in the treatment group to miss sessions. For example, class trips, team activities, and school assemblies interfered with scheduled sessions a number of times.

Also of concern was the identification of participants. It was impossible to confirm diagnoses of ADHD or dyslexia in the school setting. As a result, the study became reliant on parent- or guardian-supplied information to identify potential participants.

Although the school in which the study was conducted was hospitable and as flexible as possible, these limitations simply could not be addressed in the school setting.

Findings. Results indicated improvement across both treatment and control groups in nearly half of the subtests. Possible causes for this finding include posttest familiarity (especially Copying and Note-Taking subtests) and external interference (e.g., intensified instruction and remediation for students required to retake Virginia's Standards of Learning test and regular progress that occurs during four weeks of schooling).

Compared to controls, subjects in the treatment group improved ($p < .1$ or greater) on three of the Finger Sense subtests. The Finger Sense subtests measure finger-function skills that research has shown are related to written production of letters and numbers. The Succession subtest measures the child's ability to plan and execute sequential finger-tapping movements by imitating a sequence demonstrated by the examiner.[49] The task is performed with both hands—dominant and nondominant. Given that ADHD and dyslexia are known to affect a child's executive function and motor timing, improvement by the treatment group

on these tasks suggests that the intervention may have targeted the neural impairments associated with both disorders.

Having found improvement by the treatment group in three subtests, the need for additional research is supported.

The Fingertip Writing subtest measures the child's ability to recognize symbols written on the fingertips by touch and with no visual input.[50] Shurtleff, Fay, Abbott, and Berninger found a connection between fingertip writing and learning-disabled students' ability to perform calculations.[51] Berninger and Colwell reported an association to written expression.[52] There have been few studies devoted to the epidemiology of written language expression, but historically, writing has been associated with both attention difficulties and reading development and/or similar metacognitive processes.[53] Improvement on this subtest, then, suggests a link between the intervention and the underlying neural impairments associated with ADHD and dyslexia.

Conclusion

The appeal of interactive multimedia games is unmistakable. Hu reported that 2001 retail sales in the U.S. video game industry increased by 43 percent to $9.4 billion from $6.6 billion in 2000, and PC game sales reached nearly $6 billion, increasing from $5.4 billion in 2000.[54] It is not uncommon for popular games to top $100 million in sales.[55] Educational software titles, on the other hand, are far less profitable, resulting in fewer appropriate titles. Identifying the educational applications of pervasive and engaging games such as *DDR* could provide tremendous benefits to children who struggle with specific learning problems. The wide availability of these applications and their intrinsic appeal to young people suggest that they warrant further consideration as intervention for certain disorders.

Having found improvement by the treatment group in three subtests, the need for additional research is supported. The exploratory nature of the study enabled staff to develop procedures and refine methodologies necessary for a larger, more comprehensive study.

As a result, several changes to the design are being considered. For example, the expanded study will include a larger sample and multiple sites. It is also likely that clinical settings will replace the school setting, enabling researchers to confirm diagnoses of ADHD or dyslexia and to avoid time constraints inherent to academic schedules. Assessment instruments with better reliability will be explored, and the length of the treatment period will be reconsidered to address potential novelty effect.[56]

The gaming industry has long driven technical advancements in software, from photorealistic imagery to "what you see is what you feel" (haptic) experiences. Educators have a tremendous opportunity to maximize these advancements in pursuit of valid learning goals and to use the installed base of Sony Playstations, Microsoft Xboxes, Nintendo GameCubes, and other gaming devices to provide widespread and affordable access to effective technology-based interventions. This study using *DDR Disney Mix* is a first step in harnessing these potentially valuable resources.

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About the Authors

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L E A D E R S H I P

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BIOMETRIC TECHNOLOGY GOES TO SCHOOL

Mary Axelson, B.A.

Mary Axelson explores the benefits and limitations of applying biometrics in educational settings. In the Vision section, Anil Jain and Salil Prabhakar explain biometric authentication and the human characteristics used in biometric systems.

2 LEADERSHIP

BIOMETRIC TECHNOLOGY GOES TO SCHOOL

Mary Axelson, B.A.

Three decades ago, the question "Who are you?" rang out in The Who's refrain and reflected issues of adolescent angst. For some students today, the question points to the issues of the power and potential of technology. As biometric technologies increasingly become the method of choice to authenticate personal identity, educators, students, and parents must grapple with the pros and cons of submitting iris, fingerprint, or hand geometry scans to a school database.

A biometric system uses dedicated hardware and software to interpret images and manage the database and middleware that send data to other software programs. That dedicated package remains at a price point that requires a compelling need, not curiosity. Or, to continue the song, do you "really wanna know"?

Just a short time ago, only high-security government installations or sensitive corporate information justified an investment in biometric authentication. Costs, however, are now approaching the reach of school budgets as the technology improves. Damon Wright of Identix, a biometric company in Los Gatos, CA, says finger-scan readers the size of credit cards are now available in bulk for as little as $10 each. Three years ago, says Wright, they cost $400 to $500 and were the size of a brick. Five years ago, they were the size of two phone books and priced in the $800 to $900 range.

But hardware devices are only a part of the equation. Gabriel Waters, director of security strategy for Novell, dates the ability to deploy a biometric solution in a large-

scale environment from mid to late 2001. Single workstations could handle localized tasks before then, but only last year, he says, could the software components and recognition devices finally work together on a network.

Out of the Starting Gate in 2001

That timeline reflects the experience of San Diego Jewish Academy, which installed finger-scan devices on 400 computers in their 500-computer network. The new school of 600 students was in the planning stage in 1999, says director of operations Doug Reiss, when they decided they wanted network access that did not rely on passwords. By the summer of 2000, they had identified the vendors they would use for finger-scan access—Compaq for the readers and client software, Identix for the server software. The school opened that fall, but the biometric solution wasn't ready to go for another year. Figuring out how to overlay biometrics on a Citrix system caused the biggest delay. The Academy tested with staff, then phased in deployment of the system and teacher training throughout the school. The technology was introduced in a computer lab, then moved into classrooms, from high school down to kindergarten. Math and science teachers enrolled students into the system.

Reiss, who admits to having been skeptical, is pleasantly surprised that they now have a smoothly running system with finger log-on.

Reiss, who admits to having been skeptical, is pleasantly surprised that they now have a smoothly running system with finger log-on. That means no forgotten passwords, no stolen or shared passwords, and no more wondering which student visited an inappropriate Web page.

Still Waiting

The recent arrival of compatible software and lower price points doesn't mean biometrics are off-the-shelf solutions just yet. In Eagan (MN) High School, Laura Nagel, library information specialist, wanted to provide a self-checkout station that did not require cards or passwords both to reduce the labor needs of the library and allow students to enjoy greater confidentiality in their selections. "By high school," says Nagel, "students are beginning to check things out for personal reasons; there is still some hesitation about what they will bring to a librarian."

Bob Engen, president of Educational Biometric Technology (EBT) in Caledonia, MN, introduced his finger-scanning system to the school, which started using it in April 2000. Winnebago Spectrum, a division of Sagebrush Corporation, then upgraded the library's circulation software. Although Engen says his system could have managed the upgrade (or indeed any Windows-based software), Nagel could not easily use the new version with EBT's finger-scan system and decided to beta test Winnebago Spectrum's new in-house biometric solution. The company, which already had a self-checkout station that required students to scan cards or enter passwords, decided to try finger scans. Unfortunately, a student's finger scan brought up the wrong account about 30 percent of the time, says Nagel, who received a letter in the summer of 2002 announcing the end of the beta. Nagel understands that such is the risk of a beta, but she is still disappointed. With all the students registered, she says, the principal had hoped to expand finger scans to the lunch line and attendance. They may return to EBT products.

EBT, started by Engen in 1997, may be the lone biometric company focused on schools. A brochure for the company's Bio Connect finger identification system recommends "a few ways our ID accessory can be used with other systems." It lists food service applications, attendance applications, medication distribution, resource room attendance, front door tracking, library circulation, staff time and attendance, door entry systems, special event attendance, bus loading, and portable ID needs.

Most of these uses are still being refined in partnership with a few customers. Six school nurses, for example, are working with the company's developers on medication distribution. Using this application, the school can comply with required state documentation of dates, times, medication, students, and verifying adults. EBT's system identifies a student by finger scan and displays the medication dosage. The nurse types in what is actually given and verifies with his/her own finger scan. A second person can verify with a scan if needed.

In practice, with EBT or other biometric companies, such deployments are only occasionally working systems. More often, they are pilots, betas, or plans. The following case studies show some benefits and challenges of biometric implementations in schools. Aside from technical difficulties of premature projects, early adopters are

pleased. However, plans for biometric-based schools are premature. A few notes on market development and hot spots of controversy merit consideration.

The Lunch Line

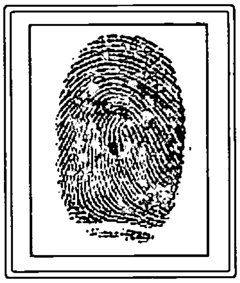
Supervision of the school lunch line requires more than moving hungry kids through before the next class begins. The accounting here determines the school's poverty rating for access to E-rate funds, interpretations of test scores, and qualifications for grants. Simple lunch tickets, which largely disappeared some time ago, were replaced by accounts accessed by PINs (personal identification numbers) and bar code identification cards. Food Service Solutions, Inc. (FSS), of Altoona, TN, is among the companies offering such tools. Three years ago, it began offering a finger-scan solution that doesn't rely on children to keep track of a card or remember a PIN.

Biometrics, says Mitch Johns, president and CEO of FSS, provide the speed and accuracy needed in the lunch line. The company's POSitive ID System relies on the MorphoTouch, a biometric scanner from Sagem-Morpho of Paris, France. After a child's finger is scanned at the point of sale, the image is standardized and resized before processing. The software develops a grid of the scan with about 26 intersection points for the swirls and arcs. The image is then discarded from the record, leaving a template of the intersection points that is stored as a series of numbers. The FSS product, which typically costs $5,000 to $7,000 per lunch line, operates over the school network with a TCP/IP connection.

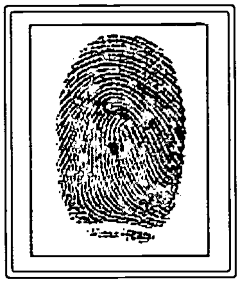
The SAGEM MORPHO, Inc. Biometric Process

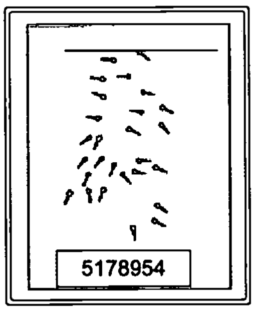
Step 1: Finger is scanned and viewed by the MorphoTouch access unit at the point of entry.

Step 2: In applications for children (under the age of 18) the image is standardized and resized before processing.



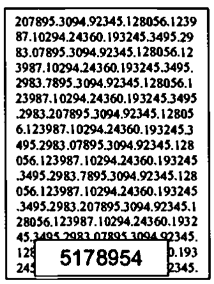
Step 3: System develops a grid of intersection points from the swirls and arcs of the scanned finger.





Step 4: The image is discarded from the record and is no longer available to the system or any operator. Only a "Template" remains that indicates the intersection points.

Step 5: In fact, all that the MorphoTouch stores and recognizes for each individual is a set of numbers that can only be interpreted as a template.



The system only remembers and processes numbers for each individual, just like a social security number. The advantages with a biometric approach is that the number cannot be duplicated, lost or stolen, and uniqueness is defined by the individual.

Used with permission from Sagem-Morpho

One FSS customer, the Penn Cambria (PA) School District, expanded its use of finger scans across the district during the 2001-2002 school year. The 2,100-student district, which has been implementing the system in stages for the past three years, now has all five schools using the system.

Miller says that some very skeptical parents were brought around to being strong advocates for the system.

When the high school started using the system three years ago, about 32 percent of its students registered for the free and reduced-price meal program. Milt Miller, Penn Cambria food service director, always suspected this figure was too low. Last year, that number rose to about 38 percent. Districtwide, the figure has risen from about 38 percent to a little more than 44 percent. Miller attributes the increase to students' trust of the system to guard the anonymity of their status from other students and from cafeteria workers. Miller says kids could be deterred from taking advantage of the program by simply knowing that "somewhere in the cafeteria was a list of low-income students." Miller adds, "It begins to bother them in fifth or sixth grade. By high school they would rather just not eat."

Miller found the system was initially easiest to use with young children, largely because they want to do things right. He found that older children, curious to see if they could beat the system, would clown around. The lunch line now runs smoothly after students became confident of the system. Indeed, one of the greatest challenges now might be finding an appropriate cleanser for the pad as kids go through the line.

Informing parents is a crucial step in Miller's mind. "The more communication we had with parents, the less resistance, the less skepticism we encountered." The machines were available at every registration, and the fact that no images were on file was underscored. Miller says that some very skeptical parents were brought around to being strong advocates for the system. Parents do benefit from some features. Money they place in the account can only be spent on food, children don't loan cards to their friends, and parents receive a monthly report of all items purchased. Miller adds that it is a good way to introduce kids to managing a debit card.

Penn Cambria is now considering expanding the system. Over the next three to five years, Miller can see the system moving to the library, attendance office, and eventually to buses.

Biometric analysts, individuals who previously paid little attention to K-12 schools, are closely watching Stockholm.

Preserving Instructional Time and Protecting the Network to Boot

The vulnerability of passwords is likely to drive corporate use of biometric authentication for logging on to computer networks. School officials in Stockholm also sought an alternative to passwords when they began a finger-scan pilot.

In the corporate world, Novell estimates that each forgotten password costs a company $340 or an average of $450 per user per year. Accounting for a lost password in school is a trickier issue than combining fractions of employees' salaries with those of the network administrators. Stockholm's schools, however, did determine that forgotten passwords required four to five minutes of a teacher's time for every 45-minute computer class. (Every student in Sweden is required to take a computer literacy class.)

In addition to lost instructional time, a password system resulted in stolen passwords that were used for inappropriate Web activities. Sometimes, students would simply write their passwords on notebooks. Sometimes, says Jeppe Gadd, product manager with vendor Data Construction, older kids would bully younger kids to get their passwords. Sometimes, kids shared.

Biometric analysts, individuals who previously paid little attention to K-12 schools, are closely watching Stockholm. Right now, the use of biometrics is limited to the pilot site, Kvarnbyskolan, a primary school for children aged 6 to 12. Kvarnbyskolan, located in Rinkeby, one of Stockholm's 18 boroughs, has had 450 students accessing its computer network via finger-scan authentication since February 2001.

The success of the pilot site has the experiment poised to expand to the largest biometrically authenticated network in the world, explains Michael Thieme, an analyst with International Biometrics Group. Stockholm schools, which have approved biometric network access for all schools, is upgrading the city network to handle it. If all schools decide to fund it, that would create a biometrically protected network of more than 120,000 users.

Data Construction, the vendor behind the pilot, is the Nordic distributor for SAFLINK. SAFLINK provides biometric authentication for workstations and computer networks—the client and server components that manage and store biometric information. This includes an enrollment program, a practice tutorial, and the interface to the various biometric devices. The enrollment program used at Kvarnbyskolan was designed specifically for the school by SAFLINK.

SAFLINK also distributes various biometric devices, including several finger-scan devices. Kvarnbyskolan evaluated four devices supported by SAFLINK: devices from Lifeview, Inc., Precise Biometrics, SecuGen Corp., and Veridicom. Of these, Kvarnbyskolan found two were best suited to children's fingers and selected Lifeview, Inc., for the pilot.

Since that time, says Gadd, vendors of the devices that required adult fingers, Veridicom and Precise Biometrics, have rewritten their algorithms to accommodate children's fingers. As the system moves forward, Stockholm's approval of vendors includes devices from both Lifeview and SecuGen.

The system also relies on the Novell Modular Authentication Service (NMAS), which allows organizations that run eDirectory to use any authentication method they choose, including smart cards, tokens, or biometrics. NMAS also offers the flexibility to change biometric methods. A school could change finger-scan vendors midstream or switch to, say, iris recognition. An upgraded version that Stockholm will eventually use allows for levels of authentication, meaning some log-ins could require a *series* of authentication methods: fingerprint plus a token, fingerprint plus iris recognition, and other combinations. NMAS coupled with a Novell product called SecureLogin, says Gabriel Waters, director of security strategy for Novell, "insulates the biometric vendors from having to integrate with every application."

Typical commercial pricing for the SAFLINK solution, says Walter Hamilton, vice president of business development, is a one-time, per-user license fee of $49.99. That price goes down with volume (more than 10,000 users) to as low as $16.02. Educational institutions receive an additional 10 percent discount. The Lifeview devices cost $123 each for up to 100 units; with a volume above 2,000, the unit price is $99 or less. The company also offers a 10 percent education discount.

A school district already running Novell needs only to add NMAS. Although suggested retail is $49 per user, Novell's education customers pay less than $1.50 per user, says Waters.

Authenticating Custodial Parents

It is rare to see a biometric method other than finger scans in schools, but the Albuquerque (NM) School District ran a pilot using hand geometry with the help of nearby Sandia National Laboratories, a U.S. Department of Energy facility with 30 years experience in using technology to solve physical security problems. The goal was to identify custodial parents using hand geometry. The pilot study, which took place in 1994, ended with software problems, as might be expected for that time. A brief run in two schools, however, confirmed the potential value of the application.

Recognition Systems of Campbell, CA, donated two hand geometry units, and Sandia Laboratories developed custom software. Dr. Patricia Wagner, who was principal of Lavaland Elementary at the time, describes it as a low-income school in a district with a transient population where children's caretakers change frequently. A population of migrant workers made it especially difficult for office workers to know parents. At the beginning of the year, the school asked families to register every person authorized to pick up a student during school hours with the hand geometry system. Sandia supplied personnel for registration at the beginning of the school year. Mary Green, who headed the program for Sandia, was impressed with people's willingness to stand in long lines. Wagner explains that at the time of this trial it would have been very unusual for a family in the district to own a computer. Although unfamiliar with technology, they were very accepting of tighter security measures.

Wagner says the biggest plus of the system was relieving front office personnel from being security officers. She sought out the system because having staff look up index cards and check photo identification when parents came to pick up children was extremely time consuming. It was also unpleasant when it was determined that someone did not have custodial rights. Wagner says that simply having the system deterred unauthorized pick-ups. It also identified an unauthorized parent, triggered

office personnel to call the custodial grandparents, and verified when a child should not be released.

The most common problem was computer breakdown. Then parents who expected to need only their hands for identification had to return to the parking lot for additional identification. Registering adults also required more person-power than the school could spare. Although Sandia Labs supplied people to help with registration, when funding for the pilot ran out, Lavaland was not able to handle the task.

When Wagner left Lavaland Elementary for Double Eagle Elementary (also in Albuquerque), she brought a machine with her. The move provided a study in contrasts. Double Eagle is a high-income school with many tech-savvy parents. Again, knowing the families was difficult for office personnel because it was a new school. Here, Wagner took the system a step further by using the comments feature to enter custody schedules. Again, the front office staff appreciated relief from the security officer role. However, Wagner says these parents were more confrontational when the system was down and alternative identification was required. As enrollment at the school outgrew the number that Sandia's original software could handle, the experiment was discontinued. Sandia continues to work with the New Mexico Child Care Association to identify custodial parents with hand geometry.

Sandia is obligated by Congress to share its technologies with other places of need, and, for the past eight years, the departments of Energy and Justice have funded the School Safety Technology and Research Center.

School Security

Sandia is obligated by Congress to share its technologies with other places of need, and, for the past eight years, the departments of Energy and Justice have funded the School Safety Technology and Research Center. Mary Green, who led the Lavaland pilot study, carries out this work in a place that looks like Hollywood's version of biometrics. Security, after all, is critical at a nuclear research lab. The twofold mission, says Green, is to "show how technologies can be effective and how they can be a tragic waste of schools' hard-earned money."

Her conclusion thus far is that biometrics are a small component of a school's overall security needs. "Biometric technologies are mature," says Green, "but schools are not yet meeting other basic security needs." Having more adults in the school, for example, means fewer problems, especially if the school can create an environment

where kids will talk to them. She would like to see one uniformed, armed security resource officer for every 1,000 kids and additional unarmed security aides. Their number would vary from two to seven per 1,000 students depending on the layout of the school. Cameras are next on the wish list, followed closely by entry control. Lighting and fencing are other basic needs that Green thinks merit attention before biometrics.[1]

That said, she anticipates a place for biometrics in school security down the road. Facial recognition software, for example, could identify when an expelled student, known drug dealer, or registered pedophile enters the school or nearby areas on camera. This software could compare images with a database of people to watch for, but it could not identify an unknown person in the school. In addition to technical difficulties, legal issues could slow the implementation of such a system. Access to the school or areas within it could also have better security control by biometrics than by keys or codes. Schools would not, for example, have the expense of rekeying the entire building because of a lost key. "I think those sorts of things will be successful in the future, but we are not going to see it this decade," Green says.

Background Checks in Florida

Security can be enhanced by efficient background checks, and the Florida Department of Education is screening job applicants quickly these days. Gone are paper prints, lost records, and the era of waiting up to six months for a criminal background check. Today, responses from the Federal Bureau of Investigation can come in a couple of hours. Applicants end up with clean fingers, and they don't have to go to the police station.

In May 2002, Orange County Public Schools became the first school system to install an electronic fingerprinting system developed by Lockheed Martin Information Systems of Orlando, FL. As of June 28, 2002, they have at least one Electronic Fingerprint Capture Station in each district.

Lockheed Martin, which has extensive experience in this area, developed the electronic fingerprint database for the FBI. In 2001, Lockheed Martin set up the U.S. Military Entrance Processing Command (MEPCOM) to enable rapid processing of

electronic fingerprints by the FBI. The system now processes all military applicants in the nation.

In Florida, school personnel applicants have all ten fingerprints taken. These are traditional "rolled" fingerprints, not the templates used by other school implementations. The system immediately determines if all are of good quality. Prints are sent to local law enforcement and forwarded to the FBI. The images, which are not retained after confirmation of receipt, are encoded, compressed, and transmitted over a secure line. When they reach their destination, images are decoded and decompressed for a gray-scale image. The FBI then runs algorithms to characterize the biometric data and compare them against mathematical representations in the database.

Jim Carlson, manager of business development for Lockheed Martin Information Systems, says the Automated Fingerprint Identification System is ready to run in any state. Florida pays nothing for the system, but Lockheed Martin receives $8 from each applicant's $52 processing fee.

A Boost to Online Testing and Learning?

Organizations that provide test-taking centers are well aware of the potential of biometrics to securely identify test-takers. Educational Testing Services (ETS)—the venerable Princeton-based administrator of the TOEFL, SAT, GRE, and GMAT—ran a pilot of iris scans at one center from the summer of 2000 to 2001. "Occasionally, we do have impersonators," says Ray Nicosia, director of security. Iris scans would give registrants only one shot at a test. Installing iris scan devices at every test center would also be expensive.

Identifying test-takers with certainty could help expand testing centers to high schools, thus meeting needs for technical certification or more frequent college entrance exams. Having that degree of certainty might support replacement of a state's annual assessment of students with intermittent assessments that aid diagnostics and measure performance against standards.

If biometric devices can move to the home, they have potential for use with distance learning, particularly testing. Charlie Silverstein, president and founder of

Sue Collins, president of Apex Learning, cautions biometrics could be overkill for K-12 online learning. Online courses, like classroom-based courses, she says, should rely on a relationship with the teacher, and that teacher should be able to see if something is out of line.

Photoscope Authentication Solutions, expects to sell many iris recognition systems to universities for authenticating test takers and ensuring that online learners are really who they claim to be. "The government wants to know if they are reimbursing them and providing financial aid." While he expects legislation requiring proof of identify for online learning at the college level, he does not yet see a compelling need for iris scans of K-12 students.

Likewise, Sue Collins, president of Apex Learning, cautions biometrics could be overkill for K-12 online learning. Online courses, like classroom-based courses, she says, should rely on a relationship with the teacher, and that teacher should be able to see if something is out of line.

Where Are You? The Risk of Vendor Abandonment

The biometric industry is a volatile landscape of undercapitalized companies. Mergers and acquisitions are rapid, as are shifts in business priorities. Michael Thieme, an analyst with International Biometrics Group, calls it "a highly unstable and generally unprofitable industry." Thieme adds, "There are a lot of startups always working on their next round of funding, chasing the recent, hottest market." Those alluring markets would be healthcare, finance, and government—not schools. He estimates K-12 education comprises less than a tenth of one percent of the roughly $730 million biometrics industry. So, even if a company offers education solutions, the next merger could shift that marketing focus elsewhere.

On the upside, Thieme notes that "a running successful deployment means a lot." He thinks any company is likely to continue to support an operational program.

Not every vendor banks exclusively on biometrics. Vendors, like Novell which offers products to assist bringing biometrics to a computer network, offer reliability to school customers. The market will be ripe for schools when many of their known vendors begin to offer biometric components. Food Service Solutions is one example. Down the road, vendors of highly personalized curriculum software, for example, may encourage biometric extensions of their products to give greater confidence in the data amassed. Library automation software packages and other administrative software could

well offer biometric solutions. Many curricular, administrative, and network software developers could come out with biometric components.

Still, it's early in the game. Jumping on new technologies too fast is a huge financial risk for vendors and schools. A toe in the water may not be the best solution either. MobilTec, which offers GPS tracking for vehicles, has a Web site showing a finger-scan system combined with the GPS tracking. While the diagram online shows a complete solution, it has never actually been implemented.

"I would be concerned that it would grow into a larger, super-efficient surveillance system for my child that would follow him through the rest of his life," says Jay Stanley, privacy coordinator, ACLU.

Privacy: Or Why Biometrics Are Not Everywhere Now

The American Civil Liberties Union is attentively and quietly wary of biometrics. Jay Stanley, privacy coordinator, won't speak out against lunch programs or other school biometrics. "We are concerned about American freedom turning into a field of weeds, and this is the one dandelion. So you look silly when you complain about the one dandelion." Stanley sees these school applications of finger scans as part of a larger trend in which more and more of what we do is recorded by computers so that we leave data trails. It's called *function creep*, and listening to civil libertarians describe the increasing potential uses for a database of fingerprints does indeed give one the creeps.

Asked how he would react if his child's school were to implement, say, a lunch program, Stanley says, "I would first wonder if it is really necessary or a gimmick. Personally, we find so many of these technologies are gimmicky. Assuming it's worth the cost, I would be very concerned." One of his key concerns is that proper protections would not be put in place. "I would be concerned that it would grow into a larger, super-efficient surveillance system for my child that would follow him through the rest of his life."

Stanley recommends abiding by the right to notice and the right to consent; limiting secondary usage (meaning, don't move it from lunch to the library without another round of notice and consent); giving people access to databases with information about them and giving them the right to correct errors; and maintaining a high level of security. He adds that biometric devices are not foolproof. A Japanese

"...The stigma of being fingerprinted is slowly being worn away," cautions Kshirsagar.

scientist recently fooled a finger scan with fake fingerprints molded from the same substance used to make Gummy Bears.

Sticky Fingerprint Questions

Talk about using fingerprints especially raises red flags in some circles and political contexts, and those concerns are heightened when the prints are combined with an electronic database. Mahir Kshirsagar, policy analyst for the Electronic Privacy Information Center (EPIC) of Washington, DC, advises schools to develop a privacy policy before implementing systems that collect fingerprints and behavioral information about individuals. Schools should clearly define how the information will be used and who has access to it. Such a policy is tricky in a school setting, where administrators must balance a student's privacy against a parent's right to know what a minor child is doing.

For example, if the lunch line finger-scan system is expanded for use in the library, can parents get a monthly report of the books their child checked out along with an accounting of the food that was bought? Kshirsagar, and probably most librarians, would hope not. Kshirsagar even questions sending the lunch information to parents of high school students. Can the principal use the lunch information to ascertain the whereabouts of a student, or is that information strictly for federal accounting? Can the school sell marketers aggregated data on high school students' food preferences? Can law enforcement have access to the database? Despite explanations that a database contains only series of numbers and not actual images, Kshirsagar says it would be a simple thing to compare a fingerprint with a school's database if a vendor chooses to share algorithms with law enforcement. Who decides the circumstances that could call for that extreme measure?

While Kshirsagar favors encouraging children to eat lunch and check out library books, he is not ready to celebrate wide-scale fingerprinting. "It is clearly getting kids used to being fingerprinted," says the privacy advocate, "or being required to share some biometric information to get access to certain things—and this is mirroring how these companies are wanting adults to use these things. The stigma of being fingerprinted is slowly being worn away."

Asked if these encrypted definitions of intersections aren't different from a fingerprint, Kshirsagar asks, "What is a fingerprint? If it is a stored impression of your finger that is unique to you and used for matching purposes, I would call that a fingerprint."

Finger Scans Illegal for Students in Michigan

Michigan's attorney general agrees with Kshirsagar. That state's Child Identification and Protection Act of 1985 prohibits a governmental unit, such as a school, from fingerprinting a child. The law applies to children under 17 years of age, with some exceptions that are unlikely to fit a school scenario. Senator Ken Sikkema asked Michigan Attorney General Jennifer Granholm to determine whether the finger-imaging process used by biometric devices was legal. Granholm determined that a district implementing a finger-scanning program would be violating the Act on multiple occasions: "First, [a violation occurs] when the child's fingerprint is initially taken for storage in the system and, thereafter, each time a child places his or her finger on the electronic image pad to compare it with the stored print."[2]

Brad Banasik, Michigan Association of School Board's legal counsel, sees no movement to amend the law to allow for finger scanning in schools. "We haven't received any complaints from our members, so it's definitely not on our legislative agenda."[3]

No Guarantees for an Agreeable Public

Where finger scans are legal, schools have found that communications with parents have generally quelled fears, but occasionally a parent opts out. Sometimes this happens for religious reasons; some parents have even identified the finger scan as the "mark of the beast." Some parents prefer lunch money for the same reasons they prefer not to pass around their social security numbers. But objections remain minimal. The entire district of Penn Cambria had only three families who chose not to participate.

A recent survey by SAFLINK also shows a public willing to trade convenience and privacy for security. The survey found that 94 percent of respondents supported the use of biometric devices to improve airline security; 84 percent backed the use of biometric systems to check their identities against a database of criminals and terrorists at the entrances of stadiums and public events. A similar number (86 percent) would agree to incorporate biometric technology in driver's licenses and passports. While 46 percent of those surveyed preferred using PINs with their ATM cards, 36 percent favored biometric authentication. Similarly, while 42 percent of respondents preferred the use of signatures with banking and credit card transactions, 32 percent would prefer a biometric method. Overall, 90 percent said they would not be opposed to the use of some biometric device for verification purposes with any of these transactions.

However, that sentiment could be as volatile as the emerging business environment. One misused database, for example, could topple consumer confidence. Combine the words *database, fingerprint,* and *children,* and there will be voices of opposition more strongly worded than those of the ACLU or EPIC.

The Libertarian Party issued a February 2001 press release titled "Should your children be required to submit 'fingerprints for food' at school?" In it, the party's national director, Steve Dasbach, is quoted as asking, "Should children in grammar school be treated like criminals for the convenience of public school bureaucrats? Or has schoolyard surveillance finally gone too far?" Dasbach also states, "Perhaps the most ominous thing about fingerprinting schoolchildren is that it conditions them to surrender biometric data whenever the government demands it."

Or consider the award given to Tussey Mountain, Penn Cambria, and Lower Merion school districts in Pennsylvania by Privacy International. That organization named the districts as runners-up for their 2001 Big Brother Awards in the category of "Worst Public Official" for "using fingerprints on children for school lunches." First place went to the "City of Tampa for spying on all of the Superbowl attendees."

Happily Ever After Behind the Curve

Today's kindergartners may well enter college with handheld PCs sporting iris recognition. In a few short years, kids may interpret Rumpelstiltskin as a fable about the fallibility of passwords. They may note that Prince Charming identified Cinderella with crude foot geometry. Biometric use will increase in offices, personal financial transactions, and even cars. Schools are likely to benefit eventually, but this may be a case when schools can be satisfied to lag a bit in technology adoption. Any perception of being a large-scale marketing arm for the biometrics industry by teaching children to accept the practice is high risk, especially for public schools. If schools really want those lunch line benefits, perhaps it's a teachable moment for civil liberties and the policies that go with the technology.

Notes

[1] For more information, see Sandia's school security handbook at www.ncjrs.org/school/home.html

[2] See the opinion at www.ag.state.mi.us/opinion/datafiles/2000s/op10144.htm

[3] Banasik summarized the situation on the MASB Web site: www.masb.org/page.cfm/29/?po=152&id=104

About the Author

Mary Axelson has two decades of experience as a journalist, primarily focused on educational technology. She edited *Internet Strategies for Education Markets*, a trade publication from The Heller Reports, and has authored numerous articles and reports for the Heller Reports, *Electronic School*, Find/SVP, Jupiter Communications, *New Media Magazine*, Quality Education Data, The Software Publishers Association, and other organizations. Ms. Axelson graduated *summa cum laude* from the University of Colorado at Boulder with a degree in English and was certified to teach. She currently moderates a series of online panels for IAETE at AEL.

L E A D E R S H I P

3

AN AMERICAN SIGN LANGUAGE FINGER-SPELLING TRANSLATOR

Ryan Patterson

Ryan Patterson describes the fascinating series of events surrounding the development of his American Sign Language Finger-Spelling Translator. What began as an entry for his high school science fair brought notoriety and experiences he never imagined. In the Vision section, Terence Rogers draws on his experiences with ThinkQuest to explore the creative potential of children and how children can channel that creativity to enhance their education.

AN AMERICAN SIGN LANGUAGE FINGER-SPELLING TRANSLATOR

Ryan Patterson

I was in a fast food restaurant when the idea hit me. I had participated in regional, state, and international science fairs for four years and planned to enter again. However, as in previous years, I was totally stumped about what to do as a project for the coming year. While sitting in this restaurant, I recalled that a few months earlier, I had seen a small group of people come in who obviously could not speak. They had a human interpreter with them, reading the group's hand signs and verbally relating them to the person taking the group's food orders. Looking back at that incident, I realized that my goal for that year's science project should be to build a device to electronically translate the American Sign Language (ASL) hand signals into written text. This would enable people who don't know ASL to understand what people who use ASL are saying, without the need for a human interpreter or paper and pencil.

I quickly did some research to make sure that such a device wasn't already in existence and also to find out more information about American Sign Language. I found that there were many attempts to make such a device. None had yet succeeded, and they all took a different approach than I had in mind.

I also found a great need for such an invention. Communication skills are vital for success in today's labor market, yet about 7.5 million Americans have communications disabilities. Life for these people can be very difficult, since the simple acts of speaking, listening, or making their wants and needs understood are so hard. Every year, about 1 in every 1,000 infants born is deaf, and another 1 in every 1,000 infants has a hearing impairment significant enough to make speaking difficult. Speech


LINX
RF MODULE
TXM-315-LC-R
LT# 1004
Ryan Patterson

loss also occurs in millions of adults, from causes such as stroke or other brain injury, head and neck cancer treatments that damage organs critical for speech, communications difficulties that arise from stuttering, and vocal cord paralysis.[1]

American Sign Language is a complete, complex language that employs signs made with the hands and other movements. ASL is said to be the fourth most commonly used language in the United States. In spoken language, the different sounds created by words and tones of voice (intonation) are the most important devices used to communicate. In sign language, however, the devices used are hand shape, position, and movement along with body movements, gestures, facial expressions, and other visual cues.

Even though ASL is used in North America, it is a language completely separate from English. It contains all the fundamental features a language needs to function on its own. It has its own rules for grammar, punctuation, and sentence order. Every language expresses its features differently; ASL is no exception. Whereas English speakers often signal a question by using a particular tone of voice, ASL users do so by raising the eyebrows and widening the eyes. Sometimes, ASL users may ask a question by tilting their bodies forward while signaling with their eyes and eyebrows.

Just like any other language, specific ways of expressing ideas in ASL vary as much as ASL users themselves do. ASL users may choose from synonyms to express common words. ASL also varies regionally, just as certain English words are spoken with different accents in different parts of the country. Ethnicity, age, and gender are a few more factors that affect ASL usage and contribute to its variety.

I had not realized that ASL was so complicated until I did this research, so I decided that my first attempt at a translator would be simply to translate the American Sign Language alphabet to English text. This would require the user to wear a glove with sensors that detect finger and hand movement rather than the massive amount of hardware that would be needed to detect hand, arm, and body movement along with facial gestures. It would also be much more realistic to translate just the alphabet, because it would take a great amount of computing power and code to accomplish translating the full language (if this type of translation is even possible with our current technology).

I had not realized that ASL was so complicated until I did this research, so I decided that my first attempt at a translator would be simply to translate the American Sign Language alphabet to English text.

Building Blocks over the Years

Designing the ASL Finger-Spelling Translator required extensive knowledge of digital electronic design and an understanding of today's newest components and programming languages. A person can't sit down and start designing an electronic device such as this with no background in the field. I've had a passion for electronics all my life, and as a toddler, I carried an extension cord with me everywhere I went and took apart household appliances. By age seven, I had read all the electronic resources I could get my hands on and built many simple devices.

During third grade, my teachers and parents could no longer answer my questions, so one of my teachers introduced me to John McConnell, a retired physicist from Los Alamos who had a strong background in electronics. He immediately became my mentor. For the next eight years, I went to Mr. and Mrs. McConnell's house every Saturday for about eight hours. They had a shop where I could work on electronic projects. This is where I learned about semiconductors, integrated circuits, and analog and digital circuitry to the point that I could design and build almost any type of circuit. During this time, I also learned how to lay out circuit boards on a computer and then chemically etch them.

This mentor-protégé relationship has had a bigger impact on me than anything else in my life. It has enabled me at the age of 16 to design circuitry that is comparable to that of a graduate student. I've gained a great amount of wisdom from my mentor. This type of relationship is very powerful; when a young person looks up to somebody skilled in the art in which they are interested, the other person has the power to pass an incredible amount of knowledge down to the youngster. I've been very fortunate to have a mentor; without the knowledge he has given me, there is no way I could have successfully created the translator.

Developing the ASL Finger-Spelling Translator

Before starting to design the translator, I first chose a number of goals to accomplish in the completed design.

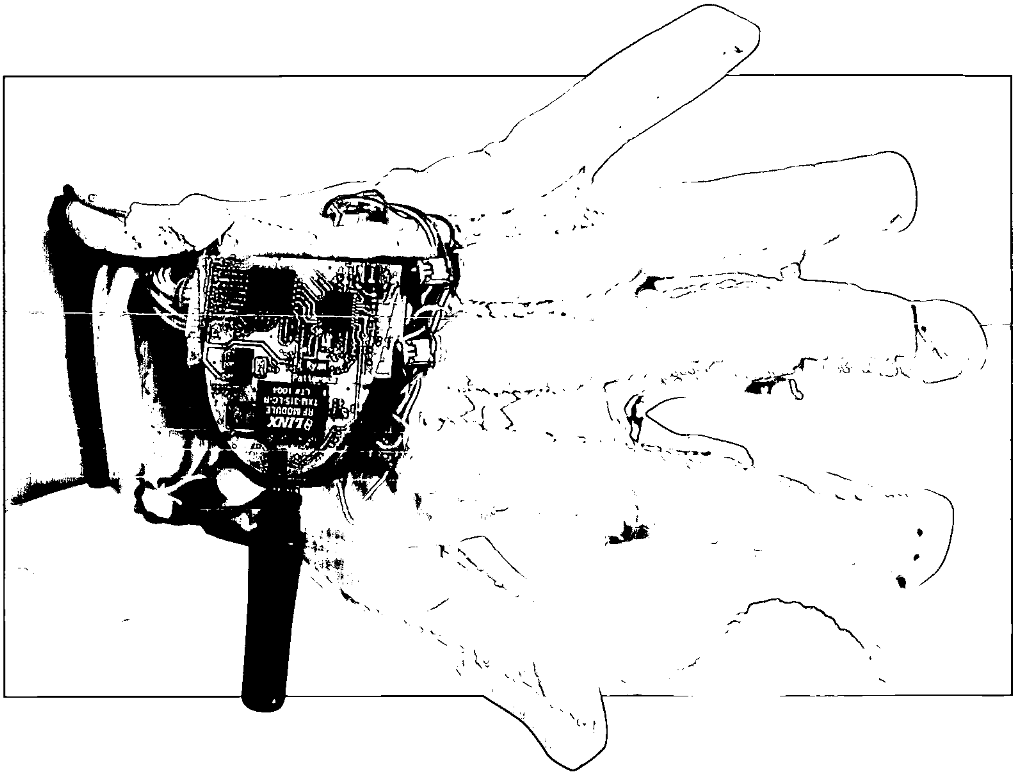


Figure 1. The prototype ASL Finger-Spelling Translator Glove. This device transmits data from the user's finger and hand movements to the PC or portable display/translator device via radio frequencies.

- The glove needs to be very rugged, yet comfortable.
- The translator needs to be very accurate, because low accuracy can be very aggravating for the user.
- The system needs to be low in cost so all people who need such a tool can afford it.
- The circuitry needs to be very power efficient so the device has a long battery life.

Once the background research on ASL was complete and the goals were set, design was initiated by first drawing schematics and prototyping circuitry. The first part of the system to be completed was the data acquisition glove, a glove with multiple sensors attached to detect finger and hand movements. A circuit board on the glove would read the sensors and continuously transmit the sensor readings to a receiver by means of a radio frequency link. A leather golf glove was used in the prototype translator. Ten sensors were sewed onto the glove and wired to a small circuit board on

If the translator system is passed between signers, it will translate for all of them, but the translations are much less accurate for the other users than for the original user.

the top of the glove. Two circuit boards were used on the prototype version of the translator. They had identical outlines but only one board had components on it. The boards were designed to have the same outline as the Velcro tab on the glove, so the board with no components could be sewed directly to the glove. The other board would plug into the one sewed to the glove, so it could be easily removed if changes were needed (see Figure 1).

Each of the 10 sensors on the glove emits an analog voltage that represents the current finger and hand position, relative to the user's arm. The electronics on the circuit board convert these 10 analog voltages to digital values so the computers in the system can process the data. A small microcontroller on the circuit board quickly reads the 10 sensors and the battery level via an 11-channel Texas Instruments analog-to-digital converter. It then transmits these data over the wireless radio frequency link and the receiver does all the processing. The original system simply used a small radio receiver connected to a laptop computer, which handled the data processing. As stated earlier, everybody who uses ASL signs differently because of where they learned, their dialect, and the like. Even with the ASL alphabet, people have different hand and finger sizes, they sign at different speeds, and, when compared to another person signing the same letter, the finger position can vary significantly. If the translator system is passed between signers, it will translate for all of them, but the translations are much less accurate for the other users than for the original user. This is because, to insure the most accurate translations, the translation system is trained by its user, much as voice recognition and handwriting recognition software are trained by the primary users.

Training the glove is a very simple process. The software was written so that the user simply selects a training option on the receiving computer and then follows the directions. The software will display a character, such as *A*, and the user signs that letter. The computer will do this repeatedly, with different combinations, until it has "learned" how the user signs. This usually takes new users 3 to 5 minutes. Current users who want to improve their accuracy can do it in less than a minute. The computer stores everything it learns from the user in a database, where it can access the information during future translations.

Once the system has been trained, the user is free to do translations. To do a translation, the user simply makes the hand gesture, such as a fist for *A*. The user then must hold his hand motionless for a preset amount of time (usually about 20 to 100 milliseconds) so the receiver knows to do a translation. Once this time has passed, the receiver (in this case the laptop computer) compares the current sensor readings and the stored readings in the database to prepare a translation. Once the proper character has been found, it is printed to the display, so the person trying to understand the user can read it. Because nobody can hold his or her hand completely motionless for any amount of time, during the training process, the microcontroller on the glove adjusts its definition of motionless by measuring how much motion is in the user's hand while he or she attempts to hold it still. This allows the system to accommodate people who have unsteady hands or fingers.

Once I got to this stage, I found myself traveling with the glove and my laptop computer, giving demonstrations and asking people who have used American Sign Language for many years to try out the translation system.

Once I got to this stage, I found myself traveling with the glove and my laptop computer, giving demonstrations and asking people who have used American Sign Language for many years to try out the translation system. During this time, I found out firsthand how inconvenient it was to have a laptop computer as part of the system. A pencil and pad would be an easier translation system than an electronic system attached to a laptop.

The Next Step

It was obvious that I needed a more portable translation system, so I sat down at my computer and workbench to begin with redesigning the system. My plan was to build a device about the size of a candy bar, with a screen that could display the translation. For the display, I chose a 20-character liquid crystal display (LCD) with half-inch-tall characters that could be easily read by another person. I also made sure it had a backlight so it could be read in low-light conditions. I then started to design a circuit board that would attach directly to the back of the LCD. The board needed a radio frequency receiver to receive data directly from the glove. It also needed enough processing power to receive the data packets from the glove via the radio frequency link, decode the packets into usable information, detect pauses in the hand movement, do a translation, and then print it to the LCD. I ended up using two microcontrollers, each

running at 20 million instructions per second (MIPS). When running, this module can do a translation in approximately 150 microseconds, making it possible to do more than 6,000 translations per second. Most ASL users sign no more than five characters per second, so the translator had no problem keeping up with even the fastest signers.

To keep both the glove and the portable display/translator's circuitry small, most of the components are the smallest available in the industry: the ICs (integrated circuits) are SSOP (small shrink outline packages), the resistors and capacitors are 0402 packages, and all transistors are in SOT-23 packages. This is necessary because the system uses 96 components across the three circuit boards. Very power efficient components also had to be used, because the glove runs off a 9-volt battery, and the PC receiver is powered by the PC's RS-232 serial port, which can only source about 10-18 milliamps (see Figure 2). On the portable display/translation device, the backlight consumes approximately 300 milliamps, so its pulse width is modulated by one of the microcontrollers on the module to reduce current consumption. It's very important to take these power measures so that the device is battery efficient.

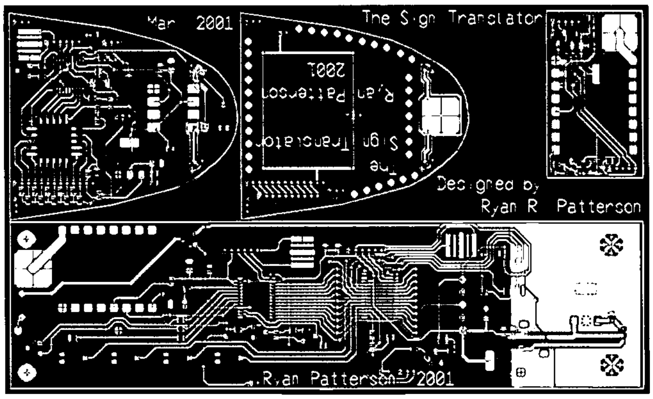


Figure 2. The completed circuit board design for the translation system. On the upper left are the two circuit boards used on the data acquisition glove. On the upper right is the radio frequencies receiver used when interfacing the translation system with a PC. Along the bottom lies the circuit board used by the portable display/translator device.

As with the original system, the user employs a PC to train the portable display/translation device in his or her style of signing. Rather than using the PC for translations, the user then plugs the portable translation/display device into the PC and downloads the database created by the training into an electrically erasable and programmable read-only memory (EEPROM) module. When users have done this, they can simply take the glove and portable translation/display device with them for use (see Figures 3a and 3b).

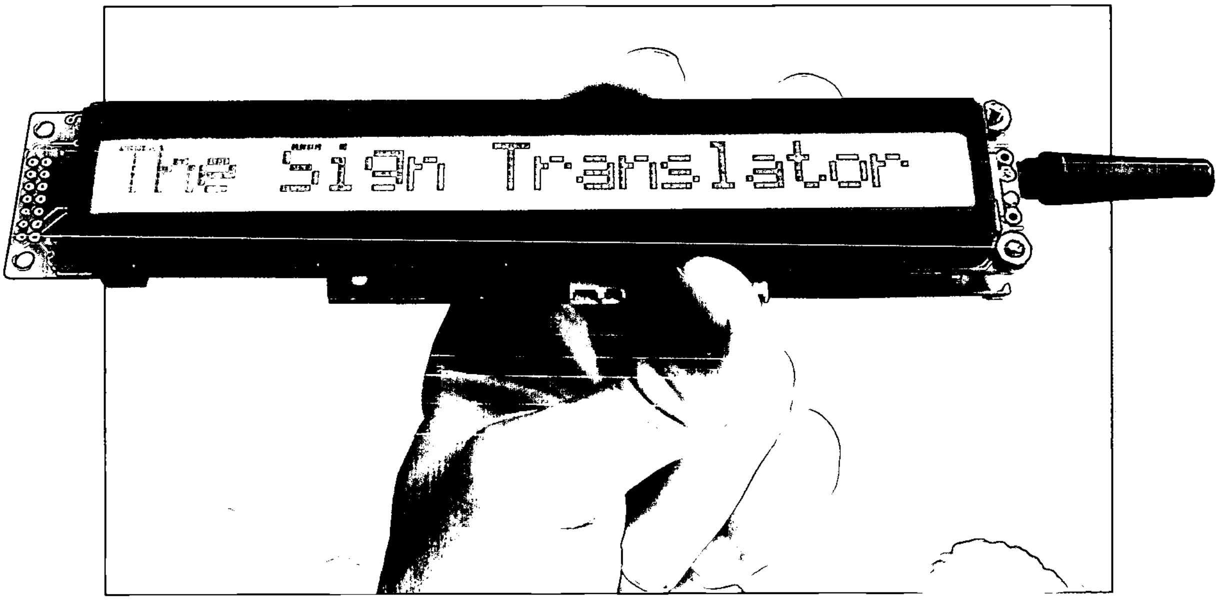


Figure 3a. The front of the portable display/translator module, which can be used with the glove to do translations independent of a PC.

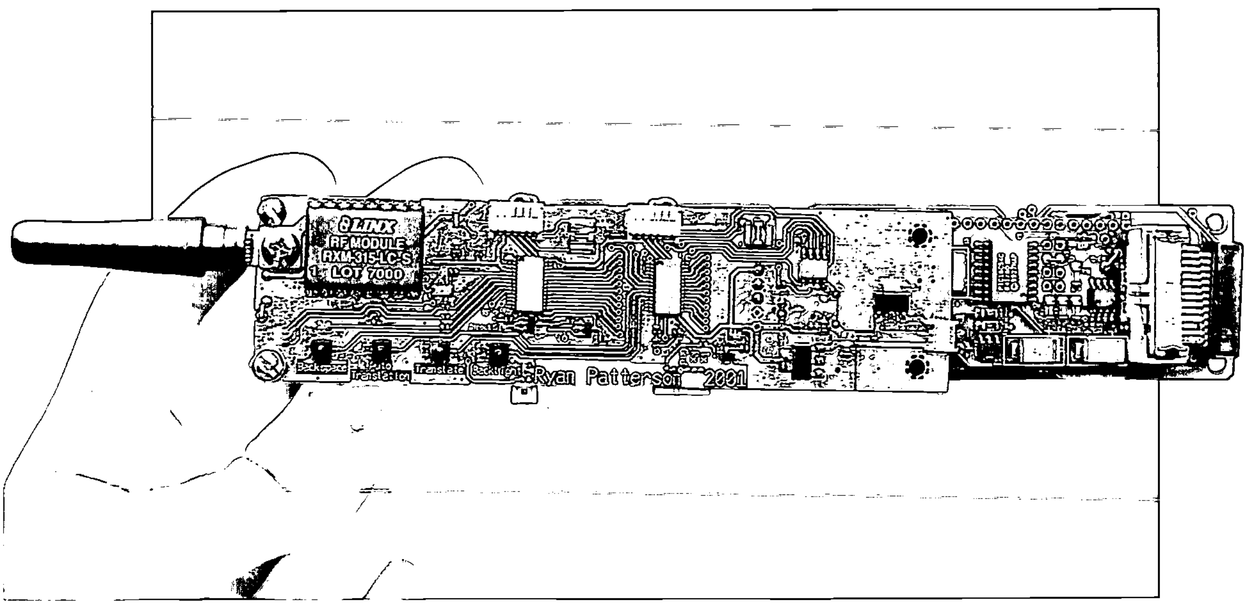


Figure 3b. The back of the portable display/translator module. The circuitry shown here receives data from the glove, translates it to text characters, then prints it to the liquid crystal display.

The glove-based translator is still in its early stages, but, like speech recognition systems just four to five years ago, it shows that communication can be achieved via a person's native language without the assistance of a keyboard or pencil and paper.

Using the ASL Finger-Spelling Translator

The American Sign Language Finger-Spelling Translator Glove was designed to be used by persons who can't speak so that they can wear the glove and spell out what they would like to say. The person who doesn't know ASL can then read the display to understand what the nonspeaking person is trying to say. A number of speaking people have argued that there is no real advantage to this system and that it has very limited uses. However, nonspeaking people see it in a different light.

The glove-based translation system is an aid comparable to speech recognition for speaking people. When it first came out, speech recognition software was very cumbersome to use: Users had to pronounce words very carefully and speak slowly. However, it was a huge innovation when compared to using a keyboard to communicate with a computer, since the spoken word is the native language of a person with speech abilities. The ASL Finger-Spelling Translator is similarly useful to people who use ASL as their native language. True, they don't use finger spelling all the time, but they use it frequently enough to be very good at it, and they are accustomed to using it. The glove-based translator is still in its early stages, but, like speech recognition systems just four to five years ago, it shows that communication can be achieved via a person's native language without the assistance of a keyboard or pencil and paper. It is hoped that, in the future, the ASL translation system will become as versatile as speech recognition is becoming, and an aphonic person will be able to communicate easily and quickly with others who don't know sign language.

Another use many people have suggested for the translation system is teaching ASL finger spelling. Young children learning the language can train the glove in the presence of a supervisor to be sure they do it correctly. Then, without a supervisor present, they can practice the finger-spelling alphabet on their own. During practice, the software running with the glove displays the speed and signing accuracy of the user, much like a typing-tutor program for a PC. In the future, if the glove is expanded to translate the full American Sign Language, rather than just letters, the unit could also be used as a practice tool for the entire language, not just the alphabet.

At this stage of development, there is no way the electronic American Sign Language Finger-Spelling Translator can totally replace the human sign language interpreter. However, it is considered an aid for aphonic people. It helps them to be more independent while running errands or engaging in short bits of communication, and it can be more convenient than a pencil and paper. It's obvious that it's useful only for one-way communication—from the signer to the person who doesn't know sign language. However, some people who can't speak can still hear, and people who can't hear can sometimes read lips. Finally, there are already portable speech recognition systems available to consumers on portable digital assistants (PDAs), so the glove-based translation system enables communication in the other direction.

When I began work on the device 22 months ago, I never imagined the places the translation system would take me.

The Science Fair and Beyond

When I first designed the ASL Finger-Spelling Translation System, I had two things in mind: to build a device that could help people and to compete at the science fair. When I began work on the device 22 months ago, I never imagined the places the translation system would take me.

My first competition was in March 2001, at the Western Colorado Regional Science & Engineering Fair. Two days before this fair, I finished all the hardware and firmware and started writing the software that would run on the PC. Luckily, I was able to complete this task, along with teaching myself the ASL Finger-Spelling Alphabet, within the two days. I competed with my project that weekend and won first place, which enabled me to go on to the Colorado State Science & Engineering Fair (CSEF) and the Intel International Science & Engineering Fair (ISEF).[2]

Before continuing to compete, I decided that the portable translator/display device should be developed, so I designed and built two versions of this device within four weeks, along with a spare glove. I then traveled to Fort Collins, CO, where I competed in the senior division of the CSEF and won first place. This funded my travels for the Intel ISEF, which was held in San Jose, CA. A month later, in May, I flew to San Jose to compete for this weeklong science fair, which included more than 1,000 competitors about my age from all around the world. I won the grand prize and eight special awards. The grand prize included the Glenn T. Seaborg Nobel Prize visit

award, a $50,000 scholarship to be used at any college or university, the Best of Engineering category award, and two computers. This is also where I first started getting media coverage on the translation system, beginning with CNN. This interview made me very nervous because it was my first live interview and it was broadcast internationally. When I got home, a friend from South Africa e-mailed my mentor, telling him that he had seen me on the news! At this point, it also became apparent to me that the media weren't interested only in the translation system. They were most interested in the fact that a 17-year-old had created such a device by himself and that he was so concerned about what people with disabilities needed to make their lives easier.

I then spent the summer at a company where I wrote computer code for automated robots used in laboratories. During this time, I also made some improvements on the glove, such as replacing the wires that had been soldered to the sensors with strain-relieved connectors so the wires would no longer break. I was then invited to present my translator system at the 2001 Intel Technology Summit in Colorado Springs. There I demonstrated my device with Dr. Craig Barrett (Intel CEO) and my mentor, John McConnell, to an audience of about 2,000 people. It was a showcase for what teens can do with technology, if they've had the technology in their education. In my case, that education came from Mr. McConnell.

In my next competition in November, I participated in the western region Siemens Westinghouse Science & Technology Competition in Berkeley, CA.[3] I won first place, which allowed me to continue to the national competition in Washington, DC. One month later, I headed for the national competition and gave a 12-minute presentation to a large audience. I won first place at this competition, which consisted of a $103,000 scholarship to be used at any university.

The day after the Siemens Westinghouse Science & Technology Competition, I jumped on an airplane and headed for Stockholm, Sweden, to attend the 2001 Nobel Prize Ceremonies. This was the result of the Glenn T. Seaborg prize I won the previous May at the Intel ISEF. I stayed in Stockholm for one week, touring and demonstrating the glove. On the second-to-last day, I had the opportunity to attend the Nobel Prize Ceremonies, which was definitely the most exciting event of my life—all due to the successful development of the ASL Finger-Spelling Translator!

The next few months were spent catching up with school and adding one more feature to the glove: voice dictation capabilities. I incorporated the Microsoft Voice Dictation direct-link library control to my software so that the computer can "speak" what the user is saying when he or she is translating with a PC or laptop. In late January, I also had the opportunity to demonstrate my translation system on the CBS *Early Show*. This made me very nervous because the program was live. The translation system was still a prototype, so it didn't work 100 percent of the time. However, the system translated perfectly, so the interview went very well. I next traveled to Houston, TX, to demonstrate my translation system at the Schlumberger Scientist campus in Sugarland, because they had sponsored a special award I won at the Intel ISEF the previous May. John McConnell and I then headed to Bethesda, MD, where I demonstrated my translation system to the National Institute on Deafness and Other Communication Disorders (NIDCD) at the National Institutes of Health. We spoke with many knowledgeable people on matters such as deafness and aphonia, and several deaf people tried the translation system.

I found this competition a lot of fun, because I didn't go there just to compete: I went there to find people who were interested in the translator system and to find other people my age who had the same scientific interests.

Shortly after returning home from NIDCD, I learned that I was one of the 40 finalists for the 2002 Intel Science Talent Search (STS),[4] which was held in March 2002. This was also a weeklong competition, held in Washington, DC. However, rather than give a full presentation, each finalist was asked to present to small groups of people and judges from their projects. Finalists were interviewed privately four times by three different sets of judges, who asked rigorous questions outside the finalist's field of expertise. I found this competition a lot of fun, because I didn't go there just to compete: I went there to find people who were interested in the translator system and to find other people my age who had the same scientific interests. It was great to spend a week with the 40 finalists, and I made a lot of new friends. At the end, I won first place, which was a $100,000 scholarship and a new computer. Overnight, I traveled to New York City, where I did an interview with *Good Morning America* and demonstrated the translation system.

After this competition, things were finally able to slow down a bit so I could get caught up in my studies at school, since graduation was coming soon. I continued to do interviews (about one per day) for radio stations, newspapers, and magazines such

Today, I prefer to do interviews for child- and teen-related publications, because it's important to show people my age what they can do if they put their minds to it.

as *People Magazine*. I applied for three other scientific events during this time. I applied to be inducted into the National Gallery for America's Young Inventors, to become a delegate for a Korea-U.S. Science and Engineering Summer Camp, and to join the Lucent Global Science Scholars Program, which is administered by the Institute of International Education (IIE). Within the next few months, I was chosen to be inducted into the National Gallery for America's Young Inventors and also as a delegate for the Korea-U.S. Science and Engineering Summer Camp, which takes place every year in Seoul, South Korea.[5] This camp is sponsored by the American Association for the Advancement of Science (AAAS). After interviewing with the Lucent Global Science Scholars Program judges, I was chosen as one of the award winners and received a $5,000 award, the opportunity to attend the Lucent Global Summit, and internship offers. However, it turned out that the Lucent Global Summit was scheduled at the same time as the Korea-U.S. Science and Engineering Summer Camp. It wasn't possible for them to work out a schedule for me to attend, so the award was rescinded by IIE.

In June 2002, I was asked to attend the National Medal of Science and Technology awards presented by President Bush at the White House. The Siemens Foundation flew me and two of the team winners from the Siemens Westinghouse Science & Technology Competition to Washington for two days, so I could meet the president and attend the awards ceremony. As I reflect, it's hard to believe that all of these honors have come from a simple idea that I was determined to carry out. Today, I prefer to do interviews for child- and teen-related publications, because it's important to show people my age what they can do if they put their minds to it.

Future Plans for the ASL Finger-Spelling Translator

A U.S. patent has been filed for the ASL Finger-Spelling Translator, and the product should be available on the market in the near future. I get many e-mails from people needing such a device who inquire about purchasing one. Seeing these messages makes me hope that progress toward translator production can continue rapidly. In the meantime, I'm working on improvements to make it more efficient, less expensive, and easier to manufacture.

For example, I have selected a new microcontroller that reduces the number of components in the translation system and increases the battery life. The number of components on the glove will be greatly reduced because the new microcontroller also does many of the operations that the other components currently do; for instance, it has an analog-to-digital converter built into it. The current glove will operate for approximately 50 hours on a 9-volt battery, while the new revision, powered by a 3-volt watch battery, will have an operating life of at least twice as long. The processor in the latest microcontroller has much greater arithmetic capabilities, allowing more complex translation algorithms than the ones currently used on the portable display/translator device. The microcontroller also has enough memory and speed to conduct translations onboard the glove, rather than in the receiver module. This greatly simplifies the system and allows the revised system to be much more flexible than the original one.

Because the chosen microcontroller has a large amount of built-in flash memory, the glove module will be able to store the database created when training the glove. The translating algorithms will vary from the current design by allowing a translation to occur whenever hand movement approaches a sign, and then backs away from it. This will allow a person to sign much more quickly, since he or she won't have to pause hand movement. There are many more benefits possible from doing translations onboard the glove. Rather than constantly sending data to a receiver via the radio frequency link, a small packet will be sent each time a translation is completed. This will reduce the radio frequency bandwidth to about 3 percent of its size on the current version of the translator. It also allows other devices to be used to display translated characters, such as a PDA or any PC, rather than only the current portable display/translation module. This also makes training the device much easier, because the electronics on the glove itself will always be learning and adapting to the user, rather than the portable display/translator module. This will make the system much simpler, requiring only a glove component, rather than the glove, a PC, and the portable translator/receiver device.

Many people have suggested that the system should have the ability to verbally speak; in other words, it should be able to synthesize human voice. Currently, the PC verbally speaks what the user types by utilizing a library file available in all Windows

operating systems. I plan for the future portable display/translator also to have the ability to speak. This won't be too difficult, because many such systems already exist. It will simply require merging an existing voice dictation system with the current translation system.

All the improvements described above should happen in the near future. Many more improvements can be made in the long run. The biggest step to eventually complete will be to translate the full American Sign Language, rather than the alphabet alone. I see the current finger-spelling translator as igniting progress toward the ideal translator. The current translator will help trigger the research needed for the complete system. We must still wait for certain technology to become available, such as ways to accurately detect full finger, hand, arm motion, and facial gestures, without the cumbersome sensors currently required. Very powerful processors and huge amounts of computer code will also be required for such a system.

I plan to continue this research as a freshman attending the University of Colorado at Boulder, where I'm studying electrical and computer engineering. I hope to develop this product until it's the ideal ASL translator, making communications easier and more natural for people using American Sign Language.

Notes

[1] Statistics found at National Institute on Deafness and Other Communication Disorders (NIDCD) Web site, www.nidcd.nih.gov/ and American Speech-Language-Hearing Association (ASHA) Web site, www.asha.org/hearing/disorders/children.cfm

[2] For more information, see the Science Service Web site on the Intel International Science & Engineering Fair, www.sciserv.org/isef/

[3] For more information, see the Siemens Foundation Web site, www.siemens-foundation.org/

[4] For more information, see the Science Service Web site on the Intel Science Talent Search, www.sciserv.org/sts/

[5] For more information, see the Korea-USA Science and Engineering Summer Camp Web site, http://camp.scienceall.com/

About the Author

Ryan Patterson is from Grand Junction, Colorado, and has always had a strong passion for electrical and computer engineering. To help answer his engineering questions, John McConnell became his mentor during Ryan's third-grade year. He and John worked together on electronic projects on a weekly basis to develop his skills in electrical engineering. Ryan is currently a freshman attending the University of Colorado at Boulder and has one patent pending.

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FROM CONFERENCE ROOM TO CLASSROOM: THE "MAGIC" OF TELEPORTATION

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

In this article, IAETE staff share how digital teleportation is currently being used to address distance education needs in Texas. In the Leadership section, Kostas Daniilidis and Ruzena Bajcsy explore the many applications of tele-immersion in education.

4

LEADERSHIP

FROM CONFERENCE ROOM TO CLASSROOM: THE "MAGIC" OF TELEPORTATION

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

In the summer of 2001, film megastar Tom Hanks and director James Cameron of *Titanic* fame approached officials at Teleportec, Inc., a company based in Dallas, TX, and asked them to do the seemingly impossible: teleport Sir Arthur C. Clarke from his office in Sri Lanka to the Arthur C. Clarke 2001 Gala that was to be held November 15, 2001, in Los Angeles, CA. Teleportec isn't a special-effects shop, but a distance communication company and manufacturer of conferencing systems.[1] Yet, using technology once reserved for Captain James T. Kirk and other fictional characters of the future, Teleportec digitally transported Clarke, a renowned scientist and author of *2001, A Space Odyssey*, halfway around the globe to "virtually" attend the event. While not technically a hologram, Clarke appeared at the gala named in his honor in three-dimensional splendor, much to the delight of attendees.[2]

The Technology

The technology that made this exciting experience possible is based on digital teleportation, which creates *telepresence*, that is, it allows people in different locations to interact as if they occupy the same physical space. A life-sized image of a presenter is captured and transmitted to an audience as a digital signal.

The Teleportec lectern system typically provides a presenter with a workspace that is 40 inches wide and 30 inches high—large enough to display the upper body

with arm movements. The technology can also support larger workspaces. The Teleportec conference system, for example, can project three to five people around a conference table. In these standard configurations, the teleported person may appear seated or standing (see Figures 1a and 1b).

Figure 1a. Teleportec lectern system (Photo courtesy of Teleportec, Inc.)

Figure 1b. Teleportec conference system (Photo courtesy of Teleportec, Inc.)

Using a reverse chroma key, the background is removed and the presenter appears to be in the room. This adds to the feeling of actual presence and reduces the processing load on the codec, enabling a quicker refresh rate. The result is a real-time conferencing experience without the jerkiness or latency of many videoconferencing technologies. Digital teleportation provides a more lifelike interaction with participants, unlike the typical videoconferencing experience, which more closely resembles watching a person on TV.

The presenter sees a large video display of the audience. The view has the same aspect ratio and the same line of sight that the presenter would have if he or she were actually in the same room with the audience. This enables the presenter to communicate directly with a particular audience member and gesture in his or her direction. In addition, two computer monitors that control transmission operations and access to digital resource material are at the presenter's fingertips. One monitor might be used for information reserved for the speaker, while the second monitor displays the visual material that is shared with the audience.

On the receiving end, the teleported image appears on a monitor that lies at the base of a podium. A transparent projection surface, which reflects the monitor's image,

extends from the top of the podium at a 45-degree angle. The surface doesn't distract from the telepresence experience because it closely resembles the familiar teleprompter display surfaces. The position of the display surface makes the presenter appear to be standing just behind the podium. Cameras hidden in the curtains behind the podium allow an eye-level view of the audience to be transmitted to the presenter.

In the locations between which images will be transmitted, the network for teleportation uses an ISDN or T1 line and codec. Teleportec systems operate on either H.320 or H.323 videoconference standards for transmission of life-sized images. Users can select from a wide range of videoconference codecs to connect to Teleportec products, making possible the addition of Teleportec products to existing videoconferencing networks. Bandwidth requirements for optimal videoconferencing experiences are 768 kilobits per second, or approximately half of a T1 line, for H.323 and 384 kbps for ISDN H.320.

Connecting Students on South Padre Island

Teleportec technology had an unusual but very successful introduction to the field of education in the fall of 2001, when Texas Governor Rick Perry made a plea to executives at the company to provide students and teachers on South Padre Island, TX, with digital teleportation capability. After the collapse of the Queen Isabella Causeway, which connects the island to the mainland, students faced a four-hour daily commute to school. Teleportec units enabled teachers to reach nearly 150 students living on the island until the causeway could be rebuilt.

Figure 2. Texas Governor Rick Perry appears in a South Padre Island school with a teacher who is digitally teleported from the mainland.

(Photo courtesy of Teleportec, Inc.)

"Just magical," is how Judy Stricklin described her digital teleportation experience. A history teacher at Richland High School[3] in North Richland Hills, TX, Stricklin and her students participated in four distance-based sessions with students and teachers from Moorside School in Salford, Manchester, in the United Kingdom.

The Richland High School Project

Around the same time that digital teleportation was connecting South Padre Island students to their teachers, high school students in another part of Texas were conversing with students across the Atlantic Ocean via this amazing new technology. "Just magical," is how Judy Stricklin described her digital teleportation experience. A history teacher at Richland High School[3] in North Richland Hills, TX, Stricklin and her students participated in four distance-based sessions with students and teachers from Moorside School in Salford, Manchester, in the United Kingdom.

The first session was held in October 2001. Stricklin said the first moments were spent sharing information about both schools and getting acquainted. She noted that beyond curricular and academic goals, students were affected socially and emotionally by the sessions. For example, in the first session, the students discussed the terrorist attacks of September 11, 2001. Stricklin recalled, "That was one of the most poignant moments. One of the students from England asked how our students felt about 9-11. You could have heard a pin drop. My kids said they were very sad, and the English student said, 'We're very sad, too.' Cultural and social experiences became as important as academic success."

Teachers also collaborated to deliver instructional units. Stricklin taught a unit on the Harlem Renaissance, as the English students were especially interested in American Indian and African American cultures. The classes also discussed the American Revolution and the different portrayals of Benedict Arnold in the two countries.

Rachel Toombs, another Richland High School teacher, used the Teleportec technology to teach Languages Other Than English (LOTE) classes. She taught three classes and a total of 22 students from five small schools in her region. None of the schools could have provided the instruction independently. One of the advantages of this technology, as noted by Richland High principal Randy Cobb, is the ability to share instructors across schools, and thereby expand curricular offerings in a cost-effective way. "Students received credit for the class through their school," Cobb explained. "The $200 per year fee was paid by the schools through the Region 11

Education Service Center, which played an instrumental role in the organization [i.e., payment and scheduling] of the project."

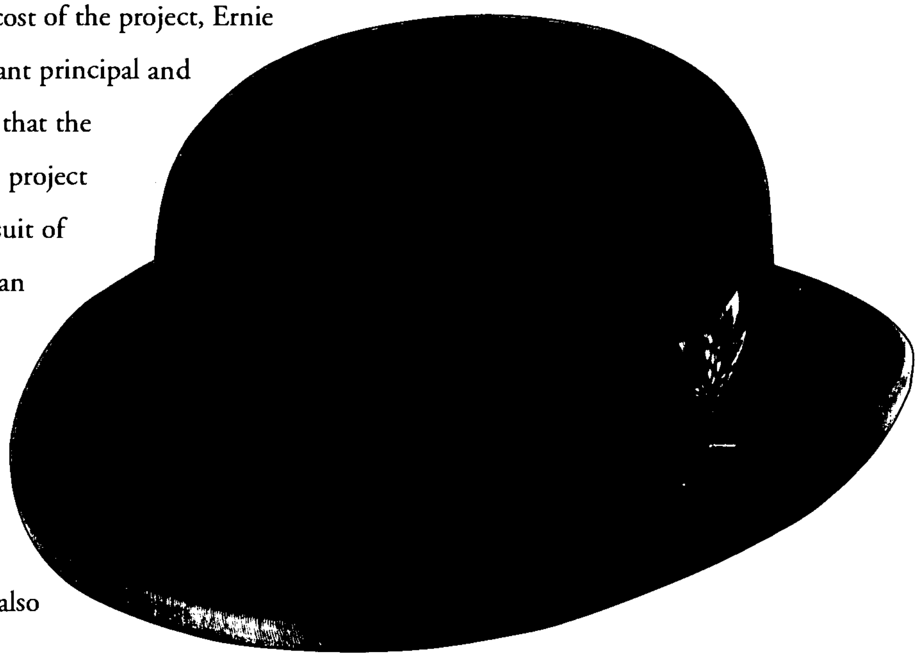
According to the teachers, one change in teaching strategy took some getting used to: remaining stationary.

Cobb also stressed five instructor qualities he believes are required for successful implementation of distance-based education concepts. They include (1) content knowledge, (2) flexibility, (3) patience, (4) communication skills, and (5) collaborative philosophy. He and his staff agree that teachers must make a tremendous commitment to make this type of learning environment succeed. They note that a great deal of e-mailing, faxing, telephoning, synchronization, and prompt grading are required to provide a smooth experience.

Stricklin and Toombs reported that teachers received tremendous support from school administrators, the Region 11 Education Service Center, and Teleportec. Teachers' previous training came in handy, they said, when using distance-based learning tools like document cameras, PowerPoint, and teleconferencing technologies. They added that extra training is planned for instructors who will use the teleportation technology in the future.

According to the teachers, one change in teaching strategy took some getting used to: remaining stationary. This was difficult for teachers used to moving about the room, and they had to force themselves to stay in the work area. But, Stricklin said, "What a small price to pay for such an extraordinary experience."

When asked about the cost of the project, Ernie Valamides, Richland High assistant principal and liaison for the project, indicated that the central office staff, who manages project funding, is aggressive in the pursuit of grants. Stricklin added, "How can you put a dollar value on being able to understand people from another culture? The use of this technology gives my students a realistic view of people from other countries. It also



gives them an appreciation for, rather than a fear of, other people. And vice versa. I think Americans are inaccurately portrayed at times, and this gives the rest of the world a chance to see Americans without the filter of propaganda or media bias."

Valamides happily reported a 100 percent completion rate by students enrolled in the distance-based courses. He stressed that guidelines for enrollment are necessary—both the number of receiving sites (determined to some degree by network connectivity) and the number of students (determined in large part by the teacher).

The Birdville Independent School District, of which Richland High is a part, is a progressive school system consisting of 20 elementary, 7 middle, and 4 high schools. Their distance-based education project originated before the 2001-2002 school year. Then-superintendent Bob Griggs became aware of the digital teleportation system developed by Teleportec and asked the company to demonstrate the product at the April 2001 school board meeting. Board members were impressed with the system—especially the feeling that the presenter was right in the room with them. They did not feel like they were simply interacting with a flat-screen TV. Following the demonstration, the board decided to pursue the project. Because Richland High School had already been approved for a second distance-learning laboratory, the board decided to upgrade Richland's lab to incorporate the Teleportec system. Consequently, the school became the first public school in the United States to have this innovative technology.

According to Cobb, current superintendent Stephen Waddell is very supportive of the distance-based learning and digital teleportation technology and continues to advance the project at Richland High. Future plans include a French/Latin language exchange with a school in Brussels, Belgium.

Beyond Conferencing

Digital teleportation technology can bridge the distance between people in new and dramatic ways, and the usefulness of this technology in distance-based education is apparent. However, the potential value of this technology is not limited to connecting *people* across distance. For example, historical artifacts and relics from distant lands could easily be teleported and archived in school media centers for use as needed. Precious objects from the world's greatest museums could be teleported and recorded so

that students could interact in real time or in the future with life-sized, three-dimensional representations of the objects. Students and teachers could use the digital artifacts as a basis for research or as visual aids in presentations.

The value of capturing lifelike representations for later use is enormous. Imagine a classroom where Martin Luther King, Jr. delivers his "I Have a Dream" speech, where a Greek vase dating back to 550 BC is brought just within reach of students, or where J. K. Rowling reads favorite excerpts from her books or shares the story of how she created Harry Potter. Digital teleportation technology makes it possible and clearly has the potential to change how students experience instructional media.

Notes

[1] For more information about Teleportec, Inc., visit www.teleportec.com or contact James Stephens at 214-615-6434.

[2] For a glimpse of Clarke's appearance, visit www.space-frontier.org/Events/clarkegala2001.html

[3] For more information about the Richland High School (TX) project, contact principal Randy Cobb at 817-547-7000.

About the Authors

Tammy McGraw is executive director of The Institute for the Advancement of Emerging Technologies in Education (IAETE) at AEL. Prior to receiving the appointment, Dr. McGraw served as director of technology and innovation at AEL, 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.

Krista Burdette is research associate with The Institute for the Advancement of Emerging Technologies in Education (IAETE) at AEL. She holds a B.A. in multi-subject education (K-8) from the University of Charleston and an M.A. in psychology from Marshall University. Previous research activities include assessing the use of a computerized test of attention in the diagnosis of ADHD and using discrete trial training with an autistic child. Ms. Burdette currently comanages various IAETE projects and serves as managing editor for IN ⏩SIGHT.

L E A D E R S H I P

5

FORMATIVE VISIONS: USING HANDHELD COMPUTERS TO SUPPORT DIAGNOSTIC INSTRUCTION

Larry Berger, B.A. and Elizabeth Lynn, Ed.M.

Handheld computers are becoming basic tools in the workplace from restaurants to hospitals. In this article, Larry Berger and Elizabeth Lynn describe Wireless Generation's mCLASS and discuss how handheld computers are currently being used for diagnostic assessments of reading. In the Vision section, Jakob Nielsen targets the limitations of the current generation of mobile devices, particularly those related to accessing the Internet.

FORMATIVE VISIONS: USING HANDHELD COMPUTERS TO SUPPORT DIAGNOSTIC INSTRUCTION

Larry Berger, B.A. and Elizabeth Lynn, Ed.M.

Following is a description of Wireless Generation's research, design, and development of a new type of tool for teachers: diagnostic assessment software for handheld computers. Known as mCLASS, it enables teachers to collect sophisticated information about their students' skills and learning needs; to generate easy to use Web-based reports for themselves, parents, and administrators; and to use this information to enhance teaching. The software places the teacher and student at the center of instruction and helps teachers use the information they collect to enhance instructional goals.

Diagnostic Software in Action

In a Texas elementary school, a first-grade teacher analyzes how her incoming students react to reading unfamiliar words and passages. One of her main tasks for the year is to turn her students into fluent readers, and she wants to see a total picture of each student's ability so that she can plan accordingly.[1] Using her handheld computer, she administers a battery of screening and diagnostic assessments, designed to diagnose precisely where each child is succeeding and where reading skills are breaking down.[2] The teacher then uploads the data to the Internet and receives a report showing how each child is performing on each of 17 dimensions of reading proficiency. She knows exactly what to teach each student next and has a good idea of what plan to follow with every member of her class until she assesses her students again.

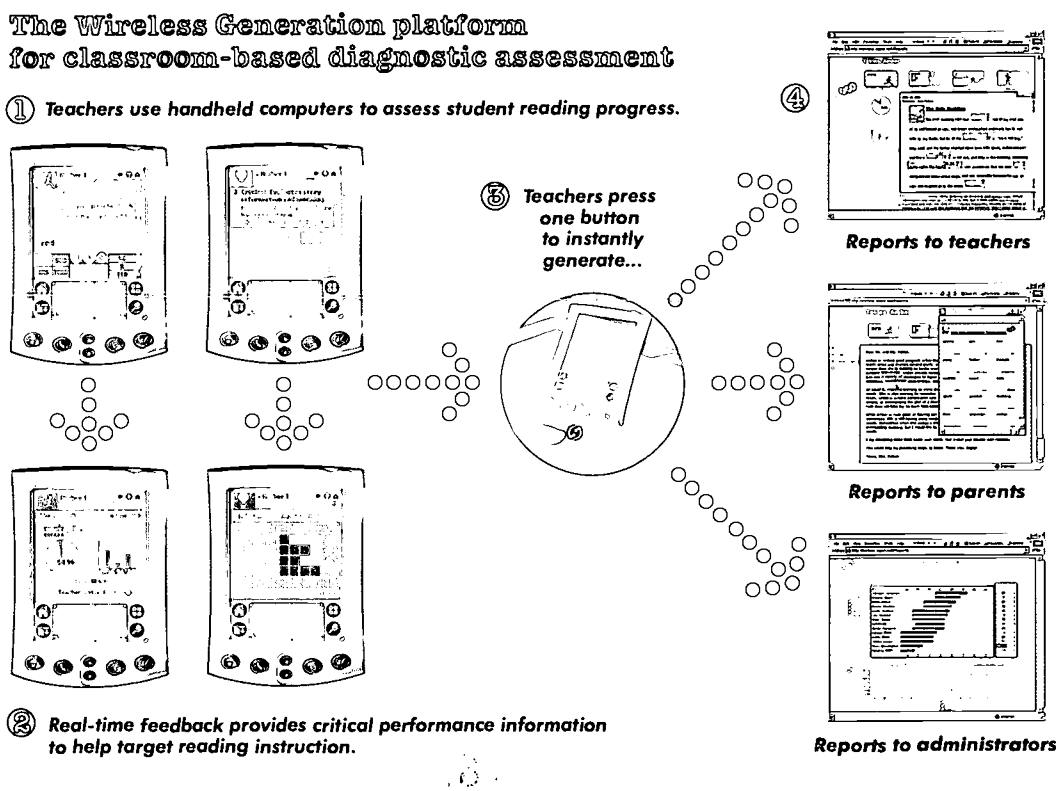
Meanwhile, in Michigan, a second-grade teacher reviews an mCLASS Web report about a student. The teacher collected the information in the report while listening to a child read aloud.[3] The report shows every correct and incorrect word that the child reads, in the context of the book read. The teacher uses this report to look for reading patterns—for example, whether the child seems to sound out words at the expense of comprehension or to guess at the passage's meaning without reading the words. After conducting additional assessments that provide more information, she downloads specific instructional activities that address the student's needs.

The technology-based assessment system provides these teachers with detailed information on how their students learn. The assessments are based on scientific paradigms that describe the stages of development of reading and math skills that enable teachers to gain insight into each student's abilities at any given time.[4] Because they obtain results quickly, teachers can share feedback with their students and help them learn from mistakes. Because the results are stored on a computer, teachers can generate reports to check longitudinal progress or the effects of new instruction.

Software Description

mCLASS is grounded solidly in teachers' needs for classroom management and instructional support. Designed to map onto teachers' daily life in the classroom, mCLASS provides them with new information that enhances and illuminates their interactions with students. Classroom-based diagnostic assessments of literacy and math skills are administered on handheld computers, which have the advantages of being easy to use, portable, and unobtrusive. Teachers upload their information from the handhelds to a Web-based reporting system where they obtain richer details about each student. They can measure each student's progress, identify when extra support may be necessary, and compare each student's performance to that of the entire class. They can download ideas for instructional activities based on each student's profile.

Because every assessment tool is developed in partnership with at least one and often several leading education experts,[5] teachers who use mCLASS begin to understand the scientific research on how children learn. As they reflect on the material they collect, teachers can learn to use a different kind of data about their students—and to understand how their own intuitive judgments relate to hard information about each child's skills.[6]



Context: The Shift Toward Data-Driven Instruction

Increased accountability pressures on schools have encouraged administrators and teachers to examine their students' academic progress with greater scrutiny and more frequency throughout the year. These pressures are briefly summarized here to illustrate the context for data-driven assessment technology.

- *High-stakes tests:* Over the past decade, most states have developed academic standards, designed standardized tests to measure student achievement against these standards, and established punitive measures for schools whose students do not meet specific benchmarks. To better prepare students for these tests, many schools have sought new methods of analyzing and supporting student progress throughout the year.
- *No Child Left Behind legislation:* In January 2002, Congress passed President Bush's education reform initiative. Among other measures, this legislation requires schools to teach reading using "scientifically-based research," and to adopt screening, diagnostic, progress-monitoring, and outcome assessments to measure student progress toward specific benchmarks.

These state and federal policies place pressures on schools to revamp how they teach and evaluate their students. The mCLASS system makes it easier for schools to do this by making sure that the information teachers collect is comprehensive, valid, and reliable and by clarifying how specific instructional activities link to assessment results.

Company History

Like all projects that impact the classroom, technology is accepted more easily by teachers when it is in line with their instructional philosophies and helps them meet instructional goals.[7] With this in mind, Wireless Generation was founded in 2000 by Larry Berger and Greg Gunn. Both were former educators who had seen numerous technology projects fail because teachers could not take the time to reorient their instruction to satisfy the requirements imposed by the new technology. They brought to their work a series of insights about teachers' needs and a desire to develop software that was tailored to the environment of schools.

Berger and Gunn were encouraged in this work by researchers at the Education Development Center's Center for Children and Technology (CCT) who felt that handheld technologies were a promising area to explore for use in the classroom. In CCT's experience, educational technology projects were less likely to succeed when they were too comprehensive in scope. They felt that the small, highly portable nature of handhelds meant that the devices could potentially address targeted areas of classroom need. They were also keenly aware of the accountability pressures teachers and school administrators face, and they encouraged formative research in the classroom to identify ways that teachers were already constructively addressing performance pressures. They sought to develop a handheld platform that would leverage these solutions and scale them widely. Through this additional exploration, Berger and Gunn expanded their initial insights into teachers' needs.

Knowing that the computer is at heart an information processing and communication tool, the team sat with teachers to observe how the teachers collected information about their students and to determine what type of information teachers needed to share within their community and with parents.

Insight #1: Teachers Rarely Sit Down

Berger and Gunn began with the idea that handheld computers could be an effective match for teachers because teachers, particularly elementary school teachers, rarely sit down to use a desktop computer during class. The duo reasoned that with the added dimension of *mobility*, they could create software that would fruitfully support teachers in their daily work with students. They began to visit classrooms to explore where these computers could intersect with and enhance the daily flow of teaching.

Insight #2: Many Teachers Collect Important Information They Never Use

The user-centered vision of Wireless Generation matured as Berger, Gunn, and director of school consulting Elizabeth Lynn began conducting formative research in classrooms. Knowing that the computer is at heart an information processing and communication tool, the team sat with teachers to observe how the teachers collected information about their students and to determine what type of information teachers needed to share within their community and with parents. They found that many teachers used a series of paper diagnostic assessments to track their students' progress at established times during the year. While some teachers thought these assessments were

useful for identifying where students needed extra support, others administered them in response to district mandates but did not use the results to guide instruction. Many teachers complained that the demands of record keeping took time away from teaching and interfered with instructional goals.

Berger, Gunn, and Lynn realized that these assessments would be more useful to teachers if they received guidance in how to analyze the assessments to learn more about their students and to individualize their teaching. Experienced teachers had already taken this step, but many teachers did not know how to interpret the data they were collecting. The Wireless Generation team envisioned a platform that would directly address teacher needs. It would

1. *Save time.* Many paper-based assessment kits come with complicated sets of calculations—how many words the child read correctly per minute or what percentage of mistakes the child caught. The Wireless Generation assessments would conduct these calculations, freeing the teacher to use the analyses instead of creating them.

2. *Organize information.* Some teachers complained that they would conduct assessments, put them in a file, and never look at them again. The Wireless Generation system would extract the important details about students and put them into a format teachers could use immediately and refer to as often as needed.

3. *Meet accountability pressures.* Many teachers and administrators were concerned about being taken by surprise by the results of high-stakes tests; no matter how much time they spent in preparation, they did not know how some students would perform. The Wireless Generation system would provide additional information so they could provide students with the support they needed.

4. *Help teachers and administrators learn how to use the information they collect.* The assessment platform would include a professional development system to help teachers understand what their information meant and how to use it in the classroom. Because each assessment would be based on a research paradigm,[8] teachers would learn to apply scientifically-based practices in the classroom.

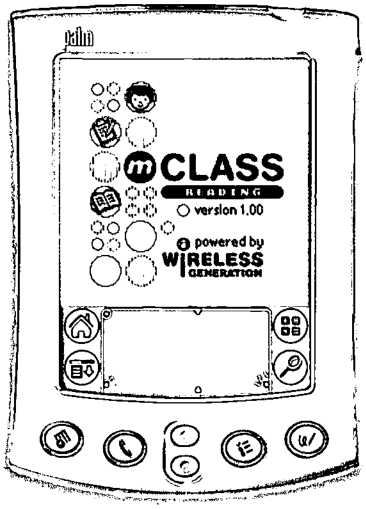
Wireless Generation named this platform *mCLASS*, for mobile Classroom Assessment. Overall, the goal was to create a thorough, easy-to-use system with which teachers could gain tremendous insight into their students' instructional needs.

With advice from CCT, the team began an intensive formative research process to identify the principles they would need to design their software. Their research protocol included

- literature reviews on the development of reading skills
- classroom observations of K-3 literacy teachers
- interviews with teachers about the data they track
- paper prototyping of assessments in the classroom
- usability testing
- classroom piloting

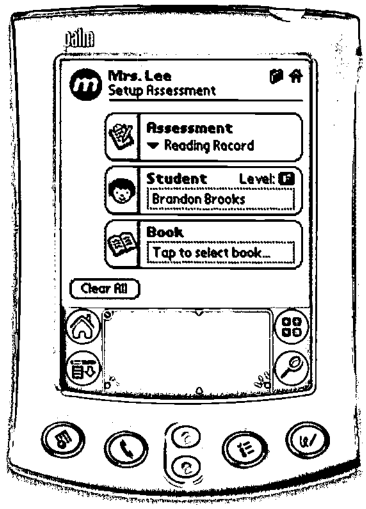
Using this methodology, Wireless Generation developed additional insights about teachers' use of technology and assessments. They adopted a "user-centered" design process[9] to translate these insights into handheld-based assessments.

The following screen shots provide some illustrations of this process.



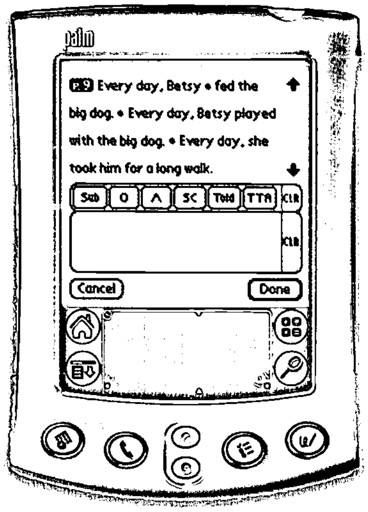
Insight #3: Teachers Don't Have Time to Wait

Unlike desktop computers, which take time to start up, teachers can use handheld computers as soon as they turn them on. Wireless Generation made sure its software loads quickly so teachers can begin an assessment as soon as the child is ready.



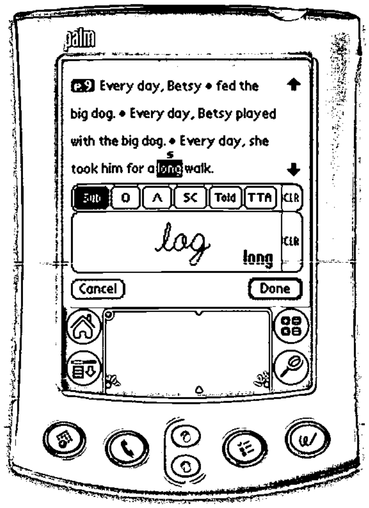
Insight #4: Software Should Accommodate the Way Teachers Work with Students

The design team learned that teachers usually choose a student with whom to work before selecting the assessment materials. On the handheld, the teacher selects a student first and then selects the book the child will read—just like in the classroom.



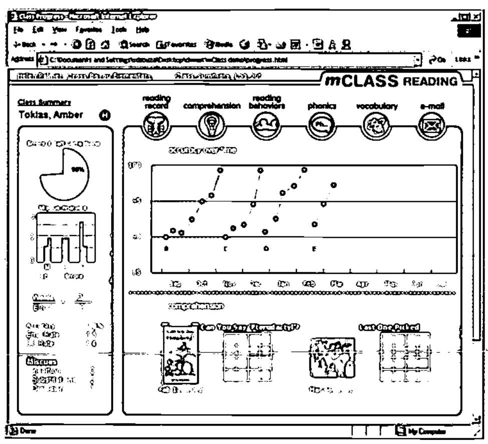
Insight #5: Teachers Want to Watch Their Students, Not Their Handhelds

Wireless Generation made the assessment screens intuitive and clear so that teachers could locate material on the screen at a glance.



Insight #6: Teachers Like to Record Notes about Their Students

The team provided a space for teachers to write on the screen in their own handwriting with a stylus, which they found to be more comfortable than a keyboard or Palm's Graffiti alphabet.



Insight #7: Teachers Value Seeing Their Students' Progress but Don't Always Have Time to Track It Themselves

The system is designed to generate detailed reports on each student's progress. Teachers can obtain snapshots of each student's strengths and needs. Such a report might take a teacher several hours to create on paper.

Project Evaluation

Research and evaluation are ongoing. An exploratory study by CCT found that assessment software on handheld computers can help teachers do the following:

- standardize how teachers collect and use information with formal assessments
- keep formal notes on their students, recording impressions that illuminate the data
- share information with other teachers easily by showing a record that describes how students progress

- reflect, either individually or together, on student and class progress and on factors that might affect performance.[10]

Researchers at the University of Michigan are evaluating an implementation of a handheld version of the Qualitative Reading Inventory-3, a reading assessment, with Michigan teachers.[11] The researchers are examining the inter-rater reliability of the handheld version and the teacher response to using the tool. Preliminary results show that the software

- was equal in reliability to the paper version of the assessment
- required only one training session to learn
- saved teachers time that had previously been spent on recording and calculating data by hand
- provided rich information for documenting children's annual progress

The University of Texas–Houston and the University of Houston are collaborating, under the Interagency Education Research Initiative, to formally evaluate a broad implementation of the Texas Primary Reading Inventory.[12] The five-year study will compare classroom results using the paper and handheld versions of the assessment and the effectiveness of in-person and online staff development for a range of school conditions.

All research results are incorporated into product development in a continuous improvement process.

Beyond Reading: mCLASS Math

Wireless Generation is working with researchers at Columbia University Teachers College and CCT to develop math assessments for elementary school and preschool.

For elementary school students, the team has received NSF funding to develop a tool with which teachers can diagnose children's arithmetic abilities. The tool will be based on a well-researched assessment kit, the Diagnostic Test of Arithmetic Skills

(DTAS).[13] Like the DTAS, the assessment will be based on the principle that children who make mistakes in solving arithmetic problems may have misconceptions that are not immediately obvious; for example, a child may believe it is always appropriate to subtract a smaller digit from a larger, independent of position (e.g., 73-36=43). The tool will help teachers to uncover the arithmetic rules that children are using and provide teachers with strategies to correct them.

For preschool and kindergarten children, the team is also creating an instructional assessment system designed to help teachers examine and respond to young children's skills in number, operation, geometry, measurement, spatial relations, patterns, and logic. The tool is based on research demonstrating that preschool children are surprisingly competent in these areas of mathematics.[14] For example, children playing with blocks show strong informal understanding of shapes, counting, addition, measurement, and spatial relations. The assessment kit will guide teachers through an individualized diagnostic path for each child. It will provide instructional recommendations that encourage teachers to expand children's informal abilities and link them to the formal arithmetic skills they will learn in elementary school.

Conclusion

Teaching is about helping students process information and use it in their daily lives. In the elementary grades, teaching is also about helping students develop the skills they need to process information. Wireless Generation's mCLASS offers teachers a way to build on what they already know about their students and use this information more effectively.

The mCLASS handheld assessment software is grounded in careful observation of how teachers teach. Ultimately, it has the potential to transform instruction by giving teachers new ways to collect and use information about how students learn.

Notes

[1] C. E. Snow, S. M. Burns, and P. Griffin, eds., *Preventing Reading Difficulties in Young Children* (Washington, DC: National Academy Press, 1998).

[2] Texas Education Agency and University of Texas System, *Texas Primary Reading Inventory* (TPRI) (Austin, TX: Texas Education Agency, 2002).

[3] L. Leslie and J. Caldwell, *Qualitative Reading Inventory-3* (Boston: Allyn & Bacon, 2001).

[4] For example, the *Texas Primary Reading Inventory* enables teachers to evaluate students' skills in phonemic awareness, phonics, oral reading fluency, and comprehension—all identified by the National Research Council as foundational elements of reading. The *Qualitative Reading Inventory-3* is derived from an interactive model of reading, which examines the way in which students obtain information from text. See D. Rumelhart, "Toward an Interactive Model of Reading" in *Attention and Performance VI,* edited by S. Dornic (Hillsdale, NJ: Erlbaum, 1977) and K. E. Stanovich, "Toward an Interactive Compensatory Model of Individual Differences in the Development of Reading Fluency," *Reading Research Quarterly* 16 (1980): 32-71.

[5] Partners on the mCLASS:TPRI project included Barbara Foorman (from the Center for Academic and Reading Skills, University of Texas-Houston Health Science Center). Scott Paris (from the University of Michigan) partnered on the mCLASS:QRI project.

[6] C. Brunner and M. Honey, *Exploring the Potential of Handheld Technology for Preservice Education* (New York: EDC Center for Children and Technology, 2001).

[7] R. F. Elmore, "Getting to Scale with Good Educational Practices," *Harvard Educational Review* 66 (1996): 1-25.

[8] See note 4 above.

[9] S. Draper and D.A. Norman, *User Centered System Design: New Perspectives on Human-Computer Interaction* (New Jersey: Lawrence Erlbaum Associates, 1986).

[10] See note 6 above.

[11] See note 3 above.

[12] For more information, see www.tpri.org/

[13] H. P. Ginsburg and S. C. Mathews, *Diagnostic Test of Arithmetic Strategies* (Austin, TX: Pro-Ed, 1984).

[14] H. P. Ginsburg, A. Klein, and P. Starkey, "The Development of Children's Mathematical Thinking: Connecting Research With Practice," in vol. 4 of *Handbook of Child Psychology,* 5th ed. (New York: John Wiley & Sons, 1998), 401-476.

About the Authors

Larry Berger is chief executive officer of Wireless Generation. He was formerly the president of InterDimensions, a Web solutions company. He has developed technology playgrounds in Harlem, created science curricula for NASA as a White House Fellow, and coauthored two books: *I Will Sing Life* and the best-selling *Up Your Score: The Underground Guide to the SAT.* With Greg Gunn, he developed The Hole in The Web, an online extension of Paul Newman's "Hole In The Wall Gang" Camp for children with cancer and blood diseases. Mr. Berger holds a B.A. *summa cum laude* from Yale and was a Rhodes Scholar at Oxford University.

Elizabeth Lynn is director of school consulting with Wireless Generation. She is an educational researcher, writer, and doctoral candidate. In addition to conducting formative research for Wireless Generation, Ms. Lynn has conducted research in children's emotional and cognitive development and acquisition of literacy skills. She holds an Ed.M. from Harvard University and a B.A. from Yale. Her current research interests include methods of scaffolding teacher professional development.

FACE TO FACE: AN INTERVIEW WITH JANET COPENHAVER

Janet Copenhaver is director of technology at Henry County Public Schools in Virginia.

Senator Jay Rockefeller (WV) addresses the same questions in the Vision section.

FACE TO FACE:

LEADERSHIP

AN INTERVIEW WITH JANET COPENHAVER

Many people consider the E-rate program to be enormously successful in connecting America's classrooms to the Internet. What potential did you foresee for the E-rate, and has it lived up to or exceeded your expectations?

JC: Initially, when the E-rate first started, I perceived it differently. I thought this was a way that rural areas could get on the bandwagon to get things networked easily and get their schools connected to the Internet. However, when it first started, the paperwork was so difficult that I think a lot of people just decided not to do it. Those of us who are still in it have now mastered the paperwork and have found that the benefits far outweigh the problems of getting it established and completing the paperwork. It is a good program and has helped us tremendously. Our division is now up to approximately a 70 percent discount rate, and I can do things that I normally could not have done, particularly given the economic crisis that we are currently experiencing.

▶▶: ***What challenges remain, and how do you envision the E-rate program evolving over the next 10 years?***

JC: The challenge is still the paperwork. It is not easy to apply for the discount or to get vendors to work with you on your 486s. It is also difficult to get them to respond in a timely manner. The forms were changed this year, and I was audited because mine were correct and the others had an incorrect amount. Luckily, I had all my bills ready and passed

the audit. I had little warning. School divisions should know up front of changes to the program before they apply for any discount with their vendors.

In the next 10 years there needs to be a relationship between school divisions that are actually using E-rate to build their network infrastructure and the federal agency that administers the E-rate program. Site visits could be conducted to examine how schools are using new technologies, instead of the agency saying, "Okay, we've decided that this is what you are going to use it for." We are growing more rapidly, I think, than the E-rate infrastructure. For example, my division owns wireless towers and they are not subject to E-rate discounts. The fact that you own equipment doesn't mean you should not be able to apply for E-rate. Also, I have leases to consider which do not qualify for reimbursement under the program.

▶▶: ***E-rate funds have been capped at $2.25 billion since 1997, yet demand keeps growing. What steps should be taken to ensure that funding is available to meet schools' needs?***

JC: For the past two years we have had the highest unemployment rate in Virginia and one of the highest in the nation. Because our parents are proud and still do not want their children to be designated as qualifying for free and reduced-price meals, our E-rate is only at 70 percent, which means if we do any internal connections, we have to pay for them. In a school division with all students qualifying for free and reduced-price meal rates—an indication of a lower economic status than my division—they set the E-rate at 90 percent. The divisions with a 90-percent rate receive all of the money for internal connections year after year after year. That guideline needs to be reevaluated.

▶▶: ***Because the bulk of E-rate funds now supports recurring charges for connectivity, little remains for new connections or inside wiring. However, many classrooms in rural and disadvantaged schools still lack basic access to the Internet. What can be done to ensure equitable access to technology so that no schools are left behind?***

JC: More things need to be taken into consideration than just the percentage of students who qualify for free and reduced-price meals, because if you are in a low

socioeconomic community, it is difficult. Our budget has been slashed a million dollars from our county government. It is going to be slashed another million because we've lost another major employer. Sara Lee just closed. Furniture factories and a textile company are all that remain. If they were to move out, our budget would be cut once again. But because our parents still do not accept free and reduced-price meals, we're going to be penalized. So I think there needs to be new guidelines on the E-rate for internal connections. My division has 20 schools, some of which were built in the 1940s. It's very, very hard to get internal connections for those schools if they do not have a high percentage of students qualifying for free and reduced-price meals. To have equity, there needs to be guidelines that will assure that the older buildings can get internal connections. The newer buildings are fine.

▶▶: ***You made a good point that free and reduced-price meal rates are frequently used to determine need. What other kinds of data should be considered in determining need?***

JC: Unemployment and Title I data are also good indicators of need. I think the reason we received the Urgent School Technology Grant for almost a half million dollars for our area is because of our unemployment rate and our Title I population. We've lost 9,000 jobs in one year.

▶▶: ***In a report just released by the Pew Internet & American Life Project called*** **The Digital Disconnect: The Widening Gap Between Internet-Savvy Students and Their Schools,** ***students argue that the multibillion-dollar investment to connect schools to the Internet is in danger of being wasted because they are not realizing the benefits of Internet connections in their schools. The report suggests that teachers and principals are lagging behind students in tapping the Internet's vast resources. How do you suggest this concern be addressed?***

JC: I totally agree with the students. One computer connected to the Internet in a classroom is just not going to work. My division has integrated wireless technologies into our middle schools and high schools. I've put sets of laptop computers that 25 students at a time can use in a classroom, instead of just one student at a time using one computer. We've utilized our bandwidth drastically, which is the reason we had to obtain more bandwidth. I may have

500 students on at a time now rather than one student in each classroom. So you've got to give them more opportunities. If you have two labs in your high school and no more room to grow, what are you going to do? You need to make sure they have a lab that they can take to their room. Wireless is the only way to do that.

▶▶: *So you see connectivity as the biggest problem?*

JC: Connectivity is the largest problem. If you try to increase your bandwidth, it's more costly and, therefore, your recurring fees are going to be more costly. We are in all of this for the students' benefit. I don't care how fast the technology is; it serves no purpose unless the students can utilize it. If the students and teachers cannot adapt to it, technology is worthless.

▶▶: ***The lack of technical support and adequate staff to maintain the technology infrastructure can be a significant barrier to effectively integrating technology in education. In business, the ratio of computer support personnel to users is approximately one to 50, while in education, the ratio is one support person to every 500 students. The nation's schools now benefit from an enormous infrastructure as a result of the federal investment in educational technology. What steps must be taken to ensure the maintenance and expansion of this infrastructure?***

JC: I really do think that our state is working on that. I'm on the VETAC (Virginia Educational Technology Advisory Committee) and that's one of the issues we bring forward more and more. You can have all of the technology in the world, but if it is not supported, it is useless. As budgets are slashed, just as mine was, positions are slashed. It's very important to set aside federal dollars or state dollars saying, "We've given you millions of dollars for technology infrastructure and for your technology. Now we are going to make sure that you have the people to support it." That's a critical issue. It is difficult to see a class sitting in front of technology that doesn't work. If you have four support people for 8,000 students, you may say, "We will get to that tomorrow." That's why a lot of students get dissatisfied with technology.

▶▶: *Is that your ratio—four support staff to 8,000 students?*

JC: I have six support staff for 8,000 students and more than 700 teachers. Keep in mind that all of my middle school teachers and all of my high school teachers also have a wireless laptop that has to be supported.

▶▶: ***Much has been reported since September 11 about biometrics. Most of the attention has focused on airport security. Some schools are considering biometrics to authenticate personal identity in a variety of educational applications. One such application might be finger-scan technology in the school lunch line. Biometric systems are designed to preserve the privacy of students who participate in the free and reduced-price meal program and they have been shown to increase participation in that program. However, parents have concerns about the potential for misuse of biometric databases and feel discomfort with the notion of a government institution teaching children to use biometric identification. How should these issues be addressed?***

JC: There are many possible, appropriate uses for biometric identification. We have a child missing in our community, and there are not many records on her. We checked her emergency contact and attendance records. Perhaps fingerprint scans would have helped. I don't know. Another good use of biometrics might be in a situation where two parents are fighting over custody of a child. Adults who could legally pick up a child at school could be identified through fingerprint scan. Also, it's hard to get background checks on school volunteers. We require background checks on every single volunteer who walks into our schools, but many don't feel comfortable about it. Perhaps biometrics would help with this. Hopefully, it is something people will feel more comfortable with over time.

Janet Copenhaver is director of technology at Henry County Public Schools in Virginia. She is also an Apple Distinguished Educator.

H I N D S I G H T

Much has happened since we first launched IN ▸▸SIGHT a year ago. It seems appropriate to look back at last year's Leadership topics and the people who presented them and to report on how they have changed since they were first described in IN ▸▸SIGHT.

Customizable Content

As a companion to Walter Koetke's article, IAETE presented an overview of its work that employed imperceptible digital watermarking technologies in the creation of an interactive textbook. Since that time, IAETE has conducted a usability study and a small group interview with teachers. Seventy-five percent of the teachers rated the appeal of the interface as "excellent" while the remaining twenty-five percent rated the interface "good." IAETE has had limited success in presenting this concept to the publishing industry. Significant changes in the publishing industry and the enormous size of the companies have both made it difficult to locate people within the industry who might consider the interactive textbook a valuable alternative to Web-based content or other electronic book offerings.

Evidence-Based Education

IAETE created a prototype Web-based tool based on John Willinsky's work and gave an overview of the tool in the previous issue of IN ▸▸SIGHT. The tool was well received during several presentations this past year. Currently, IAETE is working to secure funding to move the tool, *Ask Smartypants!*, from prototype to full-scale implementation.

PhoneChannel

In the inaugural issue of IN ▸▸SIGHT, researchers at AT&T Labs and IAETE explored 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. Steve Greenspan, David Weimer, and others—inventors of PhoneChannel—have now developed a related technology called ActiveTV, also designed to accomplish the same purpose. Formerly of AT&T Labs–Research, Greenspan, Weimer, and colleagues have formed Omenti Research to commercialize new multimedia and multi-channel solutions, such as ActiveTV, that go beyond traditional methods of communication. A market trial in West Virginia is under development at this time. For more information, visit www.omenti.com.

Internet2

Last year, Louis Fox and Ron Johnson presented an overview of Internet2 and highlighted some of the innovative applications under way at that time. Today, Louis Fox, director of the Internet2 K20 Initiative, reports that in the past year the interest in Internet2 among K20 institutions soared beyond expectations. As of September 2002, 25 states were connected to Abilene, the Internet2 backbone network. Within those states, 7,200 K-12 schools; 500 community colleges; 550 four-year colleges and universities; 1,200 public libraries; and 100 museums, science centers, zoos, and aquariums are connected. For more information, visit www.internet2.edu/k20.

Electronic classroom adds interest to language classes

Stonewall's language department now boasts a fully equipped electronics class room for use in the French and Spanish classes. The facilities, located in room 134, include thirty separate sets of earphones and microphones which enable students to gain a better understanding of the spoken language.

One may visit the enchanting city of Paris, with its Champs-Elysees, travel the hot and dusty roads of Mexico to visit the arena where famous bull fights are in progress, or study the era of the Roman Empire. Russian students may become acquainted with the people, customs, and culture of this vast land to discover its differences from America.

"Nous parlons francais", flows through the wires to the ears of eager French students in the new electronic classroom.

Stonewall Jackson High School, Charleston, West Virginia. (1963). Jacksonian, 23, p. 32.
IAETE staff member Virginia Seale (first row, second from right) and classmates use 1963's "emerging" technology to learn French.

LEADERSHIP

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