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Hardware for Language Training: Coping with Confusion

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Introduction

Research and development efforts are showing that there are advantages of using new interactive technologies in the language learning process. Effective use depends on the availability of powerful hardware and software. The choice of these two elements must of course rest on the functionality dictated by an adequate theory base for how people learn languages. The purpose of this article is to discuss what types of hardware are necessary to meet the requirements of such a theory base.

One of the more important questions that needs to be addressed is the determination of those technologies that show the greatest promise for the future. To approach this issue one must know what emerging hardware platforms are prominent today and will continue to be prominent in the future. Addressing platforms that will be useful in the years to come has a lot to do with forecasting. As was once said, "Forecasting is really a tough job, especially when it involves the future."

Paradigm Shifts

One conclusion drawn from our experience at the Air Force Academy is that to consider what new technology can do for the language learning process, one must seriously consider the need for a paradigm shift. Stated another way, efforts with new technologies should not simply automate the past. Although there is a normal tendency to do with new technology what was done with the old, effort must be expended on discovering what can be done with the new that was not possible in the past.

The concept of paradigms has been applied in many diverse fields. Thomas Kuhn (1970) outlined the notion in his *The Structure of Scientific Revolutions* and talked about how, contrary to popular belief,

science has not made slow and steady progress. Scientists have followed a time line of discovery that has consisted of plateaus and spurts. During the time that no revolutionary changes in thinking are made, commonly held theories dictate the types of conclusions that scientists can draw from observations they make in the world around them. Any apparently conflicting conclusions are interpreted in terms of commonly held beliefs until someone comes along who can break away from conventional wisdom and derive new conclusions.

A commonly cited illustration of the concept of paradigm shift has to do with the Copernican notion of an Earth that revolves about the sun. Most people of that time believed that the Earth was the center of the Universe. All they had to do was look at how the sun rose in the morning and set at night. To think otherwise was heresy!

Somewhat like Copernicus, there are a few popular consultants and speakers today who go out into the business world and say, "We really have to change the way we look at the world around us." Doing this, they say, is crucial because we always look at our new way of doing things in terms of the old. But, to make revolutionary rather than evolutionary progress requires that one take a step back and look at things differently, with a new perspective.

New Paradigms for Language Learning

The parallel to be drawn is that the best hardware platform for language learning most likely should not be specified in terms of the old way of teaching languages. It is necessary to think about the crucial questions: Should new technology be used to do things the same old way? Should the problems be examined in a different light and a tack taken that is different than the way things have been done to date?

Unfortunately, change is difficult for most people. For example, the great inventor and scientist Nikola Tesla came to this country specifically with the idea of going to work for Thomas Edison. Some of Tesla's initial findings while working in Europe had to do with the advantages of converting to the alternating current (AC) model for transmitting electricity. Edison was totally opposed to this particular technology and said it would never go anywhere. Of course, Edison was installing direct current (DC) generators to serve the homes of the Vanderbilts, the Astors, and the other "robber barons" of the day. Because the generators had to be close to the point where the electricity was to be used, he was installing direct current generators sometimes in the basements of the mansions, underscoring just how totally unwieldy his technology was. Tesla was convinced that this was not the way to distribute electrical power and, in fact, totally revamped the way that electrical transmission is carried out (Cheney, 1981).

The language teaching profession needs to be just as radical in examining how languages are taught and must establish which of the current methodologies that have been developed over the last several hundred years need to be changed. There are probably things that will remain the same, but there are probably others that will be different. The particular technology and the particular hardware available as tools for the teaching process probably constitute the greatest impetus for change. Of course, it is not necessary that there will be change. Change does not come about because new technology is available; rather change takes place because new technology makes possible new ways to do things that make sense with the emerging theory base.

This technology will invariably change the way we do business. The older technologies of writing and movable type were at one time revolutionary. After their invention, people did not do things the same way as they had before. Therefore, in implementing technology, it is essential to be attuned to the idea of paradigm shifts. One must accept the requirement to assume a totally different mind-set regarding the language teaching problem.

Hardware for Implementation

The first step in considering technology or hardware for language teaching is to consider an old computer industry axiom, a dictum for implementing hardware in other areas. As the saying goes, one should go out and find the software that one needs and then buy the computer that will run it. Although that might be very appropriate for areas where software exists, language learning does not really have a corpus of existing material from which teachers can select that which is most appropriate for their objectives.

This is an exaggeration to establish a point. Nevertheless, it is possible to consider what sort of functionality language learning hardware should have. Due to the sorts of things involved in the language learning process, this notion of functionality for hardware delivery platforms decides in advance the characteristics that must be implemented. Although the federal government spends tremendous amounts of money, there are budgets that must be respected. It does not make sense to purchase systems with capabilities that are not essential nor to omit putting in capabilities that are.

Three guiding principles will help make hardware implementation decisions:

- Software
- Functionality
- Price

Each of these areas is discussed below:

Software

Although perhaps a bit simplistic, the first thing a technology-based learning environment can accomplish is the presentation of information to the student. This also means that students can be placed into an environment where they can receive comprehensible input, something one particularly prominent theory says is vital for the language learning process. On the other hand, it is possible to ask questions of the learner. The level of interaction required by these questions is dependent of course on the capabilities of the software. Given sufficiently powerful hardware and adequate programming, it is also possible to have some form of intelligent interaction with the learner.

This description of software is as straightforward as possible and condenses a lot of concepts into two high-level notions. The instructional designer can cause the system to:

- Present information to the learner
- Ask questions of the learner

These two categories evoke the same idea of "expository" and "inquisitory" in Merrill's notation of "transaction shells" (Li & Merrill, 1989). The decision to select either or both of these two global types of alternatives will dictate the type of hardware that will be needed to effect a particular type of interaction with the learner. Just to present simple materials is fairly straightforward. After information has been presented to the learner, it is then important for the student to be able to respond and for the system to take action on that response. This interaction implies two additional software capabilities that the hardware must be able to support:

- Student Input
- Assessment and Presentation Control

Simply stated, the student should be able to respond, to input something into the system, and the system should be able to act on that information. If the system is to do more than respond to student input of simple predictable answers (fill-in-the-blank, multiple choice, or true-false questions) its software must have some level of knowledge about the language system being conveyed to the learner. Providing this capability requires artificial intelligence techniques that are only possible using more powerful hardware and running more sophisticated software than is necessary for simple presentation of materials.

This does not mean that full natural language processing is required. The state of the art is not there yet, especially for affordable delivery systems for language learning. There are, however, "smart"

things the computer can do and these should be explored (Schank, 1990).

As part of the assessment function, the system should be able to perform a couple of functions. First, based on the learner's input, the system should be able to assess at what level the student is, in the learning process. Second, based on the response of the student, the software should be able to direct activity to some other portion of the presentation. Most commonly held definitions of interaction will contain these elements.

Functionality

Presenting information to the learner requires consideration of the type of data that constitutes the information. Based on how languages are learned in general, it is possible to subdivide the process into dealing with the presentation of three types of data:

- Sound
- Images
- Text

Language itself, together with the way language is learned and used, are both related to these three elements that are each very much a reflection of the world in which language exists. Because these elements make up a substantial portion of the way people communicate, any system that is to teach all aspects of communication must, by definition, be able to handle these three types of data. Stated in other terms, the functionality that must be in instructional delivery hardware should reflect the world in which the subject matter resides.

Because sound is the essence of language, any language learning system must have the ability to deliver sound. Anything less is a poor reflection of reality.

Images are important, because spoken language is often a comprehensible process only when participants can see each other, examining each other's faces to see if appropriate messages are being communicated. When there is difficulty, phrases can be restated or clarification can be requested.

Text, as a reflection of the spoken word, has become very important in communication. Text was also the first type of data that early computers could deliver and remains important in the era of multimedia computers.

Falling Prices

With this fairly simple yet comprehensive list of required hardware functionality, it is necessary to consider the means that will

make the hardware widely available. Interactive videodisc has captured scattered interest throughout the industrial and military training markets; however, it has not had the success that many predicted at the outset. Stephen Jobs, the founder of Apple Computer, said to a group of educators two or three years ago that videodisc would never be successful because it lacked the resolution really needed to solve interesting problems. Jobs' assertion may or may not be true, but other factors have hindered videodisc's success. Specifically, hardware and materials development costs have been prohibitive.

There are two current developments, however, that will have a tremendous impact on the price and the type of hardware that will be available for instructional delivery systems:

- Advent of digital media technologies
- Impact of the mass market

The world is experiencing tremendous development in the area of miniaturization and increased power of digital, silicon-based technologies (Gilder, 1989). As an illustration of the changes these technologies are bringing, consider a discussion that took place between a group of interactive videodisc people and Bill Gates, the young chairman of Microsoft. At the first Microsoft Compact Disc-Read Only Memory (CD-ROM) Conference in 1986, this group of people, several of whom had been in videodisc dating back to the mid-70s kept telling Gates, "With digital compact disc you don't have the bandwidth that is possible with analog videodisc." Essentially, this statement means that compact disc (CD) does not have the ability to put as much information (visual data) on the screen as does videodisc. To paraphrase his response, Gates said not to worry about it. Everything that can be done with videodisc will ultimately be do-able in some digital format; moreover, once the video is in digital format, many exciting things will become possible within the computer. Gates, the "Crown Prince of computing technology," and the videodisc people were on different wavelengths. Gates was also saying that computers would be sufficiently powerful and memory readily available for the mass market to supply affordable delivery platforms on a wide scale.

To illustrate how this will happen, consider that the mass marketplace has embraced CD-Audio in a way that Sony and Philips never anticipated: people are buying CDs at such an incredible rate that local department and record stores have more CDs than they do 33-1/3 albums. These same manufacturers of CD-Audio are creating Compact Disc Interactive (CD-I), a new CD-based delivery system significantly smaller than videodisc. Because CD-I will benefit from the market penetration and manufacturing economies of scale of CD-Audio, this technology promises ultimately to be every bit as powerful and significantly less expensive than interactive videodisc. Sony has shown

prototype CD-I units that can be carried around to provide high quality audiovisual presentations in the palm of the hand.

By benefitting from this mass market success, computers can be implemented that are no longer specialized systems. It is no longer necessary to specify and acquire Military Specification (MIL-SPEC) devices to deliver language training, as was perhaps the case a few years ago. Mass market electronics in large part has been made possible through the miniaturization requirements of the space program and defense acquisitions, and it is now getting to the point where the Department of Defense can turn around and benefit from mass marketplace technology not even existing five or ten years ago.

The incredible reductions in price are having an astounding impact in the mass market. As an example, the computing power in household appliances surpasses that of mainframe computers from just a few years ago. At least for the next ten years, one must assume that the electronics industry will continue its advances and continue to provide increasingly powerful hardware at decreasing cost and in extraordinarily smaller packages. Thus, the mass marketplace is now having a significant impact on the way language learning systems can deliver the text, images, and sound necessary to support the learning process.

How Much Technology is Enough?

The concept of increased power for decreased cost raises an interesting question: How much technology is enough? In language learning terms the question becomes: How much technology is sufficient to meet the problems encountered in the language learning process? The increased power of the resulting hardware and software systems can be applied in providing improved and additional capabilities in three main areas:

- Fidelity
- Feedback
- Open Architecture

Although the low resolution of videodisc mentioned above might be a problem for some applications, there is a level of fidelity that is possible with videodisc that is not possible with other types of computer presentations. People are accustomed to seeing high quality images, video with high production value. They have a lot of money to spend on what they see in the movie theater and what they see on the television screen, a relatively high fidelity technology. They are used to high quality and will demand it.

During the initial work on interactive media at the Air Force Academy in the early 80s, computer systems were only capable of

representing the world as squared-off presentations and stick figures. Many researchers were convinced that this resolution was not going to be suitable for instruction. So, to answer the question of how much technology is enough, a system should be able to provide the same level of representational fidelity that people are generally used to in other aspects of their lives.

The delivery system must be powerful enough to give good feedback; in other words to present information to the learners, and then to have them be able to see an alternative presentation based on their input or something else based upon their decision or a decision made by diagnostic software. Platforms available for two or three years are sufficiently powerful for presenting information. Only now are platforms both affordable and sufficiently powerful to adequately raise the level of feedback that can be provided.

Open architecture is a hot topic in the microcomputer industry. This has application in technology-assisted language learning. To be useful, a computer must not only have adequate power to execute powerful programs quickly but must also be able to display several forms of data: text, graphics, audio, and video. To reduce instructional materials development costs, the formats of these data should be transportable across the platforms that are available in the marketplace. Transportability relates to standards, a very critical issue if technology is to realize its potential in learning.

To illustrate, when one goes into the grocery store and walks down the cereal aisle to make a purchase, it is not necessary to worry whether any particular cereal is going to be compatible with the milk at the other end of the grocery store, nor what type of place setting is available at home. The delivery system for the cereal is the bowl and spoon that will be used. The bowl can be porcelain or Corelle Livingware, and the spoon can be stainless steel or silver. All will get the job done.

Such simplicity is far from the rule with technology. Machines will soon transcend the issue of binary compatibility. It will no longer be necessary to take a program that runs on an MS-DOS machine and have that exact same program run on a MacIntosh or in a UNIX environment. Each of these environments has its strengths. The Department of Defense is currently heavily into MS-DOS and will be more and more into UNIX through the POSIX operating system. Considering the power that is becoming available in each of these environments, it will be a simple matter to require that the data (i.e., the graphics, audio, video, and text discussed above) used in a presentation on one machine be easily transportable to the other hardware environments. A slight conversion process might be necessary, but with proper software this will be an easy step for most of these computers.

How much technology is enough? It is absolutely essential that delivery platforms be powerful enough to make use of the standard data structures for each of the various essential data types. As an example, one can take a Microsoft Word document on an MS-DOS machine, save it in Microsoft's Rich Text Format (RTF), and then save the document onto a NeXT computer using Sun Microsystems' de facto standard Network File System (NFS). Accessing the document using NeXT's word processing software makes the computer think it is reading an Apple Macintosh file. About 98 to 99 percent of the formatting information is present after the conversion. Being able to do this with text documents is exactly what that open architecture should bring to the multimedia data structures and file formats that are useful for machine-based language learning materials.

Quantity of Computers

How many computers should be implemented in the learning process? Several years ago Jean-Jacques Servan-Schreiber in his book, *The World Challenge (Le Défi Mondial)*, talked about silicon as the primary component of dirt. Because silicon makes up the major component of microcomputers, there is no reason why they should not be dirt cheap! Observing what is going on in the world, such an observation is very indicative of the price/performance ratio that exists in the marketplace today. Jerry Pournelle, a science fiction writer and columnist for InfoWorld and Byte magazine, has formulated what he calls Pournelle's Law. He says that as the price of computers drops, essentially approaching zero, the ratio of computers to people will be at least one to one. This means that every person will have immediate access to at least one computer.

This availability has interesting implications for the planning and budgeting processes. In such an environment, what is the proper ratio of computers per person? Will one computer for three people or one for every person be the right number? At the Air Force Academy, as well as at the other service academies, and at many other universities, management has made the determination that students will have their own computers. In the early 1980s, I was on some of the initial committees at the Air Force Academy that looked at this issue, and I remember how we analyzed various options. Our charter was to look at how many computers would be appropriate in the mid-1980s. One per student seemed to be the answer, but this ratio seemed a bit ludicrous to many at the time.

But, there are a lot of reasons to implement technology at this ratio on a larger scale throughout the educational system. Computers are going to be cheap enough. The interesting things that can be done with them are such that users will want to turn to the computer to

accomplish myriad information-related tasks. Computers will become essential tools, not unlike the allegory evoked some years ago about the idea of a time-sharing pencil—When pencils were invented, schools could not afford them in great quantities. Those that were purchased had to be passed around.

Configurations

Within the Department of the Army, many organizations are working with what are called the Electronic Information Delivery System, "EIDS-class" machines. Seven or eight years ago, the Army carried out a needs analysis and specified the type of technology that would be useful to deliver information electronically. Putting video and digital data capability together on videodisc, the Electronic Information Delivery System (EIDS) came into being.

There are problems that arise with implementing technology based on specifications that have to go through a process controlled by the federal acquisition regulations. Following the completion of a needs analysis, specifications are created and published to obtain contractors' bids. Following a contract award, those not receiving the contract protest. When the complaints are finally settled and the contract is awarded, the supplier builds and delivers machines that have become outdated during the process.

The other services, nevertheless, have implemented machines that fall into the same category of capability. However, there are much more powerful configurations possible today that can deliver some interesting interactive videodisc instruction with this class of machines. Furthermore, much can be done with these computers to keep them useful well into the future.

There are questions that need to be raised and issues that need to be addressed immediately:

- How should an organization upgrade existing technology?
- How is it possible to maintain a certain level of compatibility during technology advances?
- How can existing videodisc installations benefit from the compact disc systems that are coming from the mass marketplace?

Looking beyond the EIDS-class machine, the Language Learning Center (LLC) at the Air Force Academy is moving very quickly toward acquiring the capability to do multitasking. Multitasking means that the computer can seemingly do several things at once. For example, a typical desktop machine today used for typing a document is probably

idle about 95 percent of the time in terms of overall processing capability. Consequently, an operator could probably feed data to the computer at a rate a thousand or perhaps even a million times faster than can be typed. Only a small percentage of the computer's capability is being used during such operations.

How can this excess capacity be put to use? In learning centers it is desirable to diagnose students' status, to find out where they are and where they should go next, all based on their individual differences such as interests and learning styles. It is also desirable to implement the most intelligent ways possible to respond to the student input as discussed earlier. This implies the use of fairly sophisticated technology in the learning center.

There are other types of activities, however, that are possible for students to accomplish on their own as computer-assisted study. The consumer electronics market is developing Compact Disc Interactive (CD-I), a technology that will make this possible. First announced in 1986, CD-I companies are saying that it is finally to be available during 1991. Industrial CD-I players have been available for a couple of years and have been implemented in such applications as information kiosks.

At the Japan Electronics Show in Tokyo, Sony recently demonstrated a CD-I prototype that is hardly larger than the CD that is inserted in the player. The unit has a flip-up screen, 4-inch color liquid crystal display, and controls for interaction. It fits in the palm of the hand, obviously allowing the user to take it anywhere. Although this type of machine will not have the power to handle sophisticated answer processing that is possible on machines in learning centers, it will present high quality video with interaction as well as give the student access to tremendous amounts of data.

The quantity of data a CD can hold is enormous. For example, a standard compact disc will hold the equivalent of 650 megabytes, an amount that would require over 1,500 floppy disks. In terms of paper, this comes to about 270,000 typed pages of information. If audio is placed on the CD, it is possible to have random access to 16 hours of high quality audio and only use a small portion of the total potential bandwidth of the CD. On a disc that contains the maximum quantity of audio, it is possible to place several hundred megabytes of data.

This audio can be combined with good quality graphics, and very soon, full screen, full motion video (at better than VHS quality). Manufacturers anticipate that these devices will follow the same remarkable price drops that CD-Audio has experienced during its life cycle. Consumer players are expected to start around $1000, dropping to a few hundred dollars within just a few years.

No doubt the sort of capability seen with the robots of the movie Star Wars will some day be possible. It will eventually be possible to have tutors such as C-3PO that will have the ability to converse. Thus,

long-range plans should evolve and eventually include provisions for students to have individual tutors that carry on a focused conversation. Although technology will not be at that point in the foreseeable future, there are significant changes coming that demand an intelligent migration path.

Migration Path

Note: The highlighted text should have read: "there is always the tendency to overestimate the near term but yet underestimate the long term."

All along this growth path there will be a lot of exciting language learning activities that various technologies will make possible. This paper began with a discussion of forecasting. One aspect of forecasting is that there is always the tendency to overestimate the long term. Work at the Air Force Academy eight years ago was hopeful, but the things we anticipated then were nothing compared to what we see happening in the next two years. The changes that are now anticipated require solid planning functions to ensure that implementation is as smooth as possible and that technologies are implemented at the proper point in their life cycle and at the right juncture on the migration path.

There is no question that videodisc is today's multimedia technology. It is a powerful technology with exciting possibilities that has been implemented on a large scale in the language learning centers of each of the Service Academies. These centers are probably the three largest centers of their kind in use anywhere. Hundreds of students a day are using interactive videodisc to facilitate the language learning process. And they are enjoying it! This is not a technology that should be implemented sometime in the future. It is here today. It is true that there are problems with producing materials, but there are various hardware and software developments on the horizon that are going to help that process.

As a significant part of any migration path, developers and users of interactive videodisc need to be thinking about what it will mean to implement digital systems and data. In a move never seen with interactive videodisc, the microcomputer and consumer electronics industries are promoting CD-based delivery systems under the banner of "multimedia". The videodisc industry has never had the likes of Bill Gates, the $3 billion kid (chairman of Microsoft), or James Canavino, the President of IBM Entry Systems Division, or David House, the President of the Microcomputer Components Division of Intel, or John Scully, CEO at Apple, or Rod Canyon, CEO at Compaq Computers, proclaim that the future of any existing major industry is dependent on videodisc technology. They have made this statement about multimedia.

At the same time that the consumer electronics industry is supporting CD-I, several companies in the microcomputer industry (including Intel, IBM, and Microsoft) are supporting Digital Video

Interactive (DVI). DVI has full-screen, full motion video right now and the CD-I companies have shown what its video will look like, although the decompression chips to be included in the players are not yet available. Both technologies will most likely benefit from international standards that are being determined by the Motion Picture Experts Group (MPEG).

Because it is derived from CD-I and a part of the audio plans for DVI, CD-ROM Extended Architecture (CD-ROM XA) has great potential as a transition technology. It can deliver large quantities of digital data, 16 hours of audio, and lots of visual data; but it does not have full screen, full motion video. For those applications where videodisc is already present, it is a simple matter to add CD-ROM XA drives to the upgrade plans of system developers. The Air Force Academy will be installing 35 CD-ROM XA units into half of its IVD workstations.

Given the class of 80286-based machines into which they fall, the EIDS delivery systems have some capability to move into the future. By definition, EIDS is a Level IV system and consequently can handle digital data on the videodisc and thus, theoretically, does not need the additional capability provided by XA. The difficulty, however, is that these digital programming and data files are non-standard. Based on the concept of open architecture discussed above, producing and using data and program files in the EIDS format locks developers out of the mass marketplace, denying them access to all of the tools that will be produced to support CD-I, DVI and CD-ROM XA.

Summary

To summarize, educators will have access to powerful, interactive technology in the future. The exact form it will take is not known, but we can safely say that it will be digital. We can also safely conclude that some form of compact disc will be present in the delivery system. Whether the consumer electronics people are successful in putting a computer into the CD player or the computer people put a CD player into the computer, either way we are going to have multimedia capability. To arrive at this conclusion only requires that one look at *Newsweek, Time, Business Week,* and numerous other publications to see the new buzz word, "multimedia." Multimedia will give us, through the mass marketplace, capabilities that we could only dream about a few years ago. In fact, the computer companies are taking steps that show they feel their survival might well be dependent on how well they implement multimedia.

Why is this? The computer people are convinced that multimedia is going to help them sell computers, and this is a great motivation. There are 80 million or so microcomputers out there right now, but this

represents only a 20 percent penetration of the total potential market. The captains of the microcomputer industry want to sell more. They want one on every desk and in every home. However, to do that they must make the machines easier to use, a task they feel multimedia will help them accomplish.

The consumer electronics industry wants to continue on the wave of its success with CD-Audio. They feel like they've reached a plateau with this technology. But by putting visual information, full-screen, full-motion video, in interactive packages they will be able to get into consumers' pocketbooks as well. That is the bottom line.

Whether it comes through the consumer electronics or microcomputer companies, one way or the other language educators are going to have the capability to do some very exciting things. Making the software happen requires some new ways to store and recall visual and auditory information using digital systems.

Another event in the very near future will be stylus input or the ability to actually recognize handwriting. The devices to be produced will be so small there will not be room for a keyboard to type on. Manufacturers will produce these devices with sensitive screens for the stylus to make selections, somewhat like a mouse.

Now all of this is wonderful, but one cannot ignore the fact that all humans have a basic resistance to change. People are basically conservative. Marshall McLuhan said that, "Innovation to the holders of conventional wisdom is not novelty, but annihilation."

Some language teachers think along these lines and are afraid that their jobs are threatened. This is not so. As hardware and software become more powerful, the job of teachers will change, but their services will be required into the foreseeable future. They will do things differently in the classroom, but they will still be teaching and students will still be learning. Technology will be a new tool to be brought to bear on the teaching/learning process. Experience at the Air Force Academy has shown that one of the biggest challenges is teaching teachers how to do things in new ways. Hardware advances will continue, as will advances in software. A far greater challenge will be the political implications of helping teachers learn how to do their job differently, a challenge far greater than the technical ones.

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MICHAEL D. BUSH, Chief, Learning Technology Division, Department of Foreign Languages, *United States Air Force Academy,* CO 80810. Specializations: technical and pedagogical implications of using technology, innovative ways to produce materials.