


INTEGRATING DIGITAL IMAGES INTO COMPUTER-BASED
INSTRUCTION: ADAPTING AN INSTRUCTIONAL DESIGN
MODEL TO REFLECT NEW MEDIA
DEVELOPMENT GUIDELINES AND STRATEGIES

by


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(ABSTRACT)

By and large, contemporary design models do little more than acknowledge the art and science of media *development*, and instead, place inordinate emphasis on media *selection*. While many texts on instructional design will discuss, in general terms, the circumstances under which media needs to be developed, their primary focus is on the *selection* and customization (e.g., repurposing videodiscs) of extant materials that support previously adopted goals, objectives, and instructional strategies. Although contemporary instructional design models do acknowledge computer-assisted instruction in general terms as part of the media selection and development processes, they fail to address specifically the *development* issues confronted when digital video is selected as an integral component of computer-based applications. Practitioners wishing to develop their own instructional materials (particularly those which incorporate digital video) are provided few specific details for creating those products in the context of a systems

approach to instructional development. This study examined the essential design tasks involved in incorporating digital video into computer-based applications.

The strategy adopted for this study consisted of the following: 1) The author produced a computer-based application for The Museum of Natural History at Virginia Tech that integrated both digital motion-video sequences and still-image graphics; 2) Each of the development “steps” made by the author was preserved through a set of design notes as well as videotaped records of designer and participant comments; 3) The design notes and videotaped records were subjected to qualitative analyses borrowed from standard ethnographic research procedures; 4) Subsequent considerations for integrating digital video into computer-based applications were abstracted from the analyses and presented as practical guidelines for practitioner-developers pursuing media development.

A “traditional” model of instructional design was also modified to reflect state-of-the-art media *development* strategies. The model illustrates the general procedure of media development and places it in the context of a larger, systems approach to instructional design. The development steps include defining the product, conducting research, brainstorming ideas, generating design solutions, developing the prototype, testing the prototype, and developing the end-product. The model also illustrated (by way of example) the creation of the computer-based application developed for The Virginia Museum of Natural History at Virginia Tech.

Dedication

In honor of my mother, Carol A. Purcell
and in honor and memory of my father, Carroll L. Purcell

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Chapter 1

Introduction

Over the past 50 years, instructional designers have witnessed the genesis of many technological developments that promised, in one fashion or another, to revolutionize education. Many of the most popular technological advances were geared for either generating or displaying realistic images and included such technologies as 35mm slide and 8mm film projectors, broadcast television receivers, and VHS tape and videodisc players. It was not the devices themselves that stirred the imaginations of instructional designers, rather, it was the devices' capability to generate realistic pictures that so captivated designers' attention. Of particular interest were those devices that generated realistic *moving* pictures, and instructional designers diligently strove to effect gains in learner achievement through the use of those technologies that supported full-motion video.

Although their instructional efforts generally have been met with success, designers have had to face the reality that many of the devices capable of generating or displaying full-motion video, particularly broadcast television, never gained the practical credibility expected of them in educational settings (O'Bryan, 1982). The devices were either too passive (instructional television), too inefficient (interactive videotapes), or too expensive to produce on limited budgets (interactive videodiscs). This should not be misconstrued to imply that these technologies hold no value in educational environments; their use

brought the realism and excitement of full-motion images to a world of instruction that was otherwise constrained by the prevalent utilization of static printed pages.

Today, digital video production tools permit instructional designers to combine the advantages of full-motion video, desktop computer interactivity and power, and random access to information into dynamic, high-quality computer-based instructional courseware. Such development tools effectively challenge the limitations inherent in past technologies including the passivity of interactive television, the linear access of videotape information, and the expense of production and permanence of video images associated with interactive videodiscs.

Digital video production tools represent some of the most recent advances in cutting-edge, high-tech educational technologies. And just as with any other tools, they certainly have the capability to be misused if their integration into educational arenas fail to reflect the contemporary views surrounding learner cognition and instructional design. In retrospect, the successful integration into and effective application of past instructional technologies to educational and training environments were inextricably linked through the purposeful execution of the instructional design process. Their introduction into educational and training environments both necessitated and precipitated corresponding alterations in existing instructional design models, most notably with regard to media *development* strategies.

The instructional design is the cornerstone of all effective instruction, regardless of whichever media are used to communicate the content.

But just how important is the instructional design process in eliciting gains in learner achievement when new technologies are used for instructional purposes? Clark (1983) contended nearly a decade ago that most reported academic gains were directly attributable to the increased attention imparted to the instructional design when new technologies were considered and adopted for educational purposes. He maintained that it was not the devices themselves that effected the changes, rather, it was how designers chose to apply them as part of the overarching design. And just as it was with instructional television, videotapes, and videodiscs, the successful integration of digital video into computer-based instruction (CBI) is incumbent on the purposeful execution of sound instructional design principles and media *development* strategies.

By and large, contemporary design models do little more than acknowledge the art and science of media *development*, and instead, place inordinate emphasis on media *selection*. While many texts on instructional design will discuss, in general terms, the circumstances under which media needs to be developed, their primary focus is on the *selection* and customization (e.g., repurposing videodiscs) of extant materials that support previously adopted goals, objectives, and instructional strategies. Practitioners wishing to develop their own instructional materials (particularly those which incorporate digital video) are provided few specific details for creating those products in the context of a systems approach to instructional development. Consequently, media developed outside the framework of the

instructional design may do little to support the instructional outcomes of specific learning environments.

The integration of digital video into CBI presents some heretofore unrecognized development challenges that software developers can no longer afford to stumble blindly into. Historically, video was an analog medium, and as such, precipitated volumes of development considerations for its use in instructional arenas. However, advances in computer hardware technology now make it possible to convert analog images to digital images that desktop computers can manipulate, display, and store. What is missing are development guidelines and strategies that reflect the integration of digital video into instruction. It was the purpose of this study, then, to adapt traditional instructional design models to better guide educators whose practical *development* problem was to incorporate digital video as part of computer-based instruction. For the purposes of this study, the term “video” comprised both motion-video sequences as well as still-image graphics.

Why Use Video?

If one picture is worth a thousand words, are thirty pictures worth thirty thousand words? Well, perhaps not. But the capability to display 30 pictures per second certainly holds some interesting possibilities. Pictures that “come to life” can stimulate our senses and pique our curiosities as they approximate the richness of our everyday worlds. And

when the mechanism to control how these pictures are displayed is added, the possibilities can dazzle the imagination. But granting educators access to these capabilities does not ensure students will engage in meaningful, thoughtful, purposeful educational experiences simply by virtue of the technology itself. Gano (1988) submits, "Simple access to new technologies cannot by itself guarantee us a brighter future. We have to know what they can do and how we might use them in order to tap their liberating potential. We can either project a new context for the new technologies, or misuse them in old contexts" (p. 260). Illich (1973) writes of convivial tools--those that enable the individuals who use them "to enrich the environment with the fruits of his or her vision" (p. 21). These statements speak precisely to the challenges confronting CBI developers and instructional designers today.

Given the technology that currently exists, instructional designers who fail to employ instructional videos as convivial tools risk creating applications that are as passive as most television programs. Clearly, the onus is on them to design instruction that permits learners to manipulate video in such a way as to view objects and events as they've never been viewed before. Nanny (1990) says that as humans, our views of objects and events are necessarily constrained because we have so little control over space and time. Since we are stuck in one location, we cannot see things in faraway places. We cannot shrink ourselves down to observe the anatomy of microscopic organisms nor can we enlarge ourselves to obtain a birds-eye glimpse of the solar system. In short,

Nanny submits that the use of video can help overcome the constraints of being human, of only having control over ourselves.

When purposefully executed, instructional videos can empower learners with control over space and time including such elements as location, size, moments in time, and the rate at which time passes (Nanny, 1990). When learners are granted control over location, their positions shift in space so that they can view entirely new objects and events or observe existing ones from different perspectives. For example, at one moment students may be viewing the curvature of the earth from atop Mount Everest and the next moment from the moon's surface. When granted control over size, learners can see things that are too big or too small to view from a normal perspective. Patterns and relationships that were otherwise too difficult to notice may become apparent. Gaining control over moments in time not only allows learners to revisit historical events, but it also allows them to play back the moment for closer analysis. An especially poignant example of this is the instant replay on televised sports. Finally, controlling the rate at which time passes permits learners to view events that occur in nature either too fast or too slow to be observed naturally. Using time-lapse photography, an entire day's weather pattern can be charted or the growth of a plant over an entire year can be viewed in only a matter of minutes.

The point of this discussion has been to underscore the tremendous potential that videos possess for instructional purposes. Although much of their appeal lies in the realistic environments that can be recreated on

a display device, the true power of videos emerges when learners are permitted to manipulate images in their quest to better understand objects and events. In deciding to incorporate video as part of computer-based instruction, designers must not only consider how and why video should be used, but they must also possess a certain familiarity with those factors that contribute to overall image quality. Indeed, how the images appear on the display device is as important as which images appear.

Video Fundamentals

When learners are given control over space and time, they can observe objects and events from new points of view, that is, they are not constrained by their “humanness.” Such control encourages learners to propose alternative solutions, consider rival explanations, and cultivate a more global awareness of objects and events. That was the theoretical perspective.

In practical terms, integrating video into CBI applications is not as straightforward as one could be led to believe. Video, in its most general sense, is nothing more than a series of realistic pictures being reproduced on some type of display device in “real time.” What constitutes real time is a function of who is asked. Average persons will likely respond that real time is what’s happening right before their very eyes; to the television engineer, real time may mean thirty frames per

second; to the multimedia developer working with embryonic digital capture hardware, fifteen frames per second is as real as real-time gets. Moreover, the term “video” does not convey the fact that there are numerous sources that can generate the originating signal, and that each source may store and transmit this signal differently. When combined with the unique characteristics of display devices and the variations in source signal formats, they add up to a widely varying range of image qualities. And though the general public does not know or perhaps care to know what’s going on behind the scenes, the average television viewer can certainly discriminate even slight discrepancies in image quality.

It is not important for recipients of video information to understand how it is made, how it is stored, how it is transmitted, and how it is received in order for them to use it. In fact, it is no more important for them to understand how the images on their television screens are produced than it is for them to understand how their automobile works, how jet airplanes fly, or how bread makers bake bread. As consumers of information, they simply want to be able to use it (or ignore it). The case is quite different, however, when instructional designers make a conscious, informed decision to incorporate video as part of instruction. As noted above, slight disparities in image quality come under scrutiny even by the casual viewer. This scrutiny is magnified proportionately when that video is used for instructional purposes, particularly in the case where the viewer may be held accountable for documenting specific details. As a result, instructional designers must possess at minimum, a

basic understanding of the factors underlying video production, storage, transmission, and display that bear directly on video image quality.

A Time of Transition

By and large, the video technology used for instructional purposes today was born of equipment developed for the television industry. As a result, many contemporary instructional video devices are fabricated upon the standards set forth by the National Television System Committee (NTSC). These standards specify a number of parameters influencing video image quality such as storage, broadcast, and recording media formats. Of prime concern, however, for instructional designers planning to combine the realism of television with the interactivity of personal computers is the analog nature of source video signals.

Luther (1991) posits that there are two reasons why television has evolved as analog technology. First, televisions were designed to reproduce natural images and sounds, and nature is basically analog. Of this, he writes,

“In nature, the brightness of an object can have any value, and the object can be shaded with minute gradation.

Likewise, a natural object can take on any position that is consistent with the action of gravity, and it may be moved smoothly with microscopic precision. Real images and sounds thus are made up of intensity values and positions

that can have any level--continuous functions in both space and time--that is, analog" (p. 2).

In an effort to make television images appear as realistic as they do in nature, engineers designed devices that could reproduce brightness levels and color levels at any point along the continuum.

The second reason that television technology is analog has to do with the capabilities and limitations of the existing hardware at the time when television was developed. Vacuum tubes simply were not capable of performing the necessary functions to process digital signals (i.e., signals represented by discrete values). Today, low-cost integrated circuits can accomplish the work that took thousands of vacuum tubes to do in the 1950's.

As noted above, many of the instructional video devices available to CBI designers are constructed with the purpose of creating, storing, transmitting, and displaying analog (television) video signals. It was only natural that these devices would make their way into education arenas. Recall that during the 1950's, the use of television as an instructional medium was given increased attention. This interest was spurred partly due to the Federal Communication Commission's decision to set aside 242 television channels for educational purposes and partly due to funding provided by the Ford Foundation (Reiser, 1987). In the 1980's, there was renewed interest in using television for instructional purposes, only this time, it manifested itself in the guise of interactive video. Starting initially with videotape, and then maturing to videodisc

technology, designers who incorporated video as part of instruction could not mix analog and digital video into one consolidated instructional delivery medium. Why? Because most computers can only process digital data, and much of the video available for instructional purposes exists only in analog format.

•Instructional designers must recognize that an incompatibility exists between the format of analog motion video and that of computers. To more fully understand this incompatibility, there are some general characteristics of video that must first be considered. Among these are issues related to source video signal formats, broadcast formats, and video quality, all of which need to be taken into account as analog video signals are converted to digital computer data.

Source Video Signals

There are three primary ways that video signals can be represented, each differing in the number of channels used to carry the video information. As a rule of thumb, the greater number of carriers or channels used to transmit the video, the higher the quality of the image. The lowest quality, yet most widespread format, is composite video. This is the type of signal that is generated by most color television cameras in which the information describing color (chrominance) and brightness (luminance) is modulated onto one channel. At an intermediary image-quality level is S-video. This format sends the brightness description over one channel and the color information over another separate channel. The result is improved image quality over the composite format.

By far and away, the best image quality is achieved when video is generated as a component signal. Three separate channels are utilized in this format in which the color information is transmitted over two channels and the brightness information over one (Hoffert, 1991; McQuillin, 1991).

Instructional designers should bear in mind that when converting analog video to digital computer data, all other things being equal, the higher the quality of the source video image, the more realistic that video will appear on the computer display. With the exception of high-end professional video production equipment, the majority of video sources will transmit video information in composite or S-video formats. As with most things, quality is directly proportional to cost, and hence, S-video equipment is more expensive than composite devices.

Broadcast Formats

It was noted previously that the television industry has exerted considerable influence on computer-based instruction, particularly in the manner in which motion video is transmitted. Again, this is an outgrowth of the characteristics of the devices used to distribute the video images. Additionally, there are differences in broadcast formats that affect the quality of the video image as well. Generally speaking, there are three primary broadcast formats: NTSC, PAL (Phase Alternating Line), and SECAM (Sequentiel Couleur avec Memoire).

NTSC is a color broadcasting system standard that is subscribed to by North America, Japan, and a few other countries. Convened in the

1950's to select a color television system for the United States, the NTSC adopted one that transmits the video signal in composite format (Luther, 1991).

PAL and SECAM are two other broadcast formats that originated in Europe that transmit in composite format as well. The basic difference between these two formats lies in how the color (chrominance) signal is encoded. It is beyond the scope of this paper to consider just how that is accomplished, but a detailed account can be found in Luther's (1991) book *Digital Video in the PC Environment*. From a practical standpoint, these formats are more tolerant to distortions which can occur along the transmission path, and hence, can yield higher quality video images (Luther, 1991).

Video Quality

To this point, CBI designers who commit themselves to incorporating video as part of computer-based instruction have to consider two variables affecting the quality of the source video images: the format of the video signal itself and the format of the broadcasting system. In defining and establishing the distinctions between differing levels of image quality, the video industry divides video-image quality into three categories: broadcast quality, industrial quality, and home-video quality (McQuillin, 1991). Although there are numerous factors affecting image quality (of which only two were considered previously), the balance of this discussion will address two additional measures, namely, horizontal resolution, measured in lines per inch, and signal to noise (S:N) ratio,

measured in decibels, as they relate to the three levels of image quality. Note that at approximately the 40-decibel level, obvious image degradation begins to appear (McQuillin, 1991).

At the high end of the spectrum is broadcast quality. This level is typically associated with network television stations and video production houses. These operations employ sophisticated professional-grade video production equipment that yields horizontal resolutions of 400-600 lines per inch and S:N ratios of 50-55 decibels (McQuillin, 1991). In general, such equipment can cost in the hundreds of thousands of dollars and requires operators with specialized training.

The next best level of image quality is referred to as industrial quality. Image quality levels are maintained by using low-end professional-grade video production equipment which returns horizontal resolutions of 300-400 lines per inch and S:N ratios of 50-55 decibels. Since a smaller (3/4-inch) recording media is used during the production process, NTSC signals have to be translated to a lower frequency. As a result, there is an additional loss of color quality (McQuillin, 1991).

Finally, at the low end of the spectrum is home-video quality. This level encompasses the majority of video production equipment available to most instructional designers. Although media and storage formats are discussed in a subsequent section, designers will likely be working with either VHS and 8mm or S-VHS and Hi-8mm recording media. Obviously, video production equipment in this category is far less expensive than that used to achieve industrial or broadcast qualities. It should be stressed, however, that acceptable levels of image qualities can be

achieved using S-VHS and Hi-8mm formats as source video signals (Hoffert, 1991).

Recording Media Formats

There are at least nine media formats for recording and originating the source video signal. Ordered from highest to lowest by the degree of image quality inherent in the signal, the list includes:

D-1

1-inch

Betacam

D-2

3/4-inch

S-VHS, Hi-8mm

VHS, 8-mm

Extended play VHS (Hoffert, 1991)

With the exception of D-1 and D-2 formats, all the others store the video information in analog form. One of the fundamental limitations of analog video becomes particularly apparent when video tapes are copied for distribution as part of the computer-assisted instructional lesson. Accordingly, a high-quality master tape must first be created that represents the finished video product. Not surprisingly, it is expensive to create the master tape since image quality requirements for instructional video are high and necessitates production on high-end video recording

and editing equipment. The appropriate number of copies, which can number in the tens of thousands, are then reproduced from the master tape. As the master tape is played, rewound, replayed and so on, physical wear induces degradation of the media, thus adversely affecting image quality. Moreover, when analog copies of tapes are made, the copy is said to be one generation in quality away from the master tape. As additional copies are made from copies, there is greater and greater generation loss; copies that are only three generations away from the master tape reveal significant video image degradation (McQuillin, 1991).

It is most probable that CBI developers will have access to S-VHS and Hi-8mm equipment and below. More than likely, they will not have access to professional video production services or their representatives. Since designers may not possess the technical expertise and video production skills needed to generate high-quality video for use in computer-based instruction, then they may be apprehensive about incorporating desktop computer video production technology when instructional design models fail to consider this technology as part of the media *production* process.

Discrete versus Integrated Multimedia

Much of the electronic technology used to augment instruction is subsumed under a much larger umbrella referred to as *multimedia*. With respect to computer-based instruction, multimedia simply combines text, audio, motion video, animation, and computer-generated graphics into one instructional lesson or event (Stefanac & Weiman, 1990). Until

recently, computer-based multimedia implied multiple media sources. Such systems could be termed *discrete* multimedia systems since they involve linking separate multiple-media sources (VCR's, CD-ROMS, videodisc players, external monitors, audio CD's, etc.) to a computer. Today, the technology exists that permits instructional designers to combine all these media sources into one delivery medium: the computer. A general discussion of how that is accomplished as well as the advantages for doing so follows in a later section, but CBI developers should be aware that the future of computer-based instruction that incorporates full-motion video lies in *integrated* multimedia presentations.

Summary

This discussion began with the premise that much of the equipment available to CBI designers for integrating video as part of computer-based instruction stems directly from developments in the television industry. Furthermore, these developments bear directly on the attributes of video and pose situations that are especially problematic for designers contemplating merging the realism of video with the power of personal computers. Though video exists in several different signal formats and quality levels, and though video information may be transmitted in one of several broadcast formats, it is the analog nature of the video image that challenges CBI developers most. Given this scenario and the advances being made in computer hardware technology, CBI developers are witnessing the transition from the analog world to the digital world.

Before addressing how the challenges of that transition are being met, it might be beneficial to briefly examine how analog video is currently being merged with digital computers.

Analog Video and Digital Computers

Perhaps the greatest obstacle in merging computers and video is the incompatibility that exists between the analog nature of most instructional video media and the digital format of computer data. Acknowledging this incompatibility, hardware and software developers turned their attention to devising interactive workstations that were composed of both analog and digital devices. Such workstations might include at minimum a CPU, display monitor, videodisc player or VHS videotape player (each with a RS-232 serial port), and an external NTSC compatible monitor. Using an appropriate authoring environment (e.g., HyperCard), CBI developers could create interactive instructional applications in which the computer controlled the presentation and sequence of the video segments.

Although VHS and Beta video playback devices provided CBI designers with the means to incorporate "real-time video" as part of computer-based instruction, the linear nature of the tape medium posed the greatest obstacle to efficient learning. Aside from those factors affecting image quality introduced during the production and editing

processes, the inability for tape formats to access information randomly, accurately, and efficiently led to the development of videodisc technology.

When instructional designers select videodisc instruction over other analog formats, they must make a choice to either create a disc from scratch or repurpose an existing one. If a suitable disc cannot be acquired for repurposing, designers may be reluctant to undertake creating an original disc due to both the complexity of the production process and the inherent expenses. In developing a videodisc from scratch, instructional designers must first gather or create all the video materials to be used in the instructional sequence. Such sources might include, but are not limited to, 16 mm or 35 mm slides, off-air television signals, videotape, a camera, or other electronically generated signals. The source videos are then transferred to 1-inch tape for editing and sequencing, and special effects, if any, are added. Next, a master videodisc is generated from the 1-inch master tape, and it is used either as a stamper itself or as the basis from which other stampers are created (Isailovic, 1985).

As described above, producing an original videodisc from scratch involves considerable expense. Although development costs have decreased markedly in recent years, they are still beyond the budgets of most instructional designers, especially classroom teachers. Original videodisc development requires access to high-end video production equipment, and as noted before, that equipment is not only expensive, but it also requires highly skilled technicians to operate it. In fact, most of the costs incurred in developing an original videodisc are born from

generating the source video, editing and recording the 1-inch master tape, and creating the master disc. If the designer hires a production company that specializes in interactive software development to perform the work, a 15 to 20 minute presentation may cost \$50,000. If the production is sophisticated and involves multiple levels of branching, the costs may range from \$100,000 to \$250,000. In comparison, disc replication costs account very little of the total development costs. For example, a single distribution disc may be pressed for between \$100 and \$360, and copies of that disc made for as little as \$10 each (McQuillin, 1991).

Interestingly, videodisc players and videodiscs comprise somewhat of a hybrid system. The information on the videodisc is stored in digital format, yet the player outputs an analog video signal. The question might then be asked, "If the videodisc stores digital information, and the computer manipulates and processes only digital data, then why can't information on the videodisc be transferred to and played directly from the CPU's storage device?" The answer to this question lies primarily in the limitations of existing hardware to process the enormous amounts of data needed to recreate full-motion video in real time. For example, one 24-bit color frame of standard NTSC video at 640 x 480 pixels consumes 921,600 bytes of information (McQuillin, 1991). If real time is defined as 30 frames per second, then the microprocessor's bus must transfer 27,648,000 bytes of information per second to reproduce full-motion video in real time. Even if the other tasks performed by the microprocessor are ignored, these data rates are considerably faster than

what the most efficient and powerful microprocessors are capable of transferring now. Since it was not technologically feasible to play back the digital video data from desktop digital storage devices, videodisc players were designed to convert the digital signals back to analog format. This allowed the video to be viewed on standard analog monitors and effectively solved the instructional designer's problem of how to incorporate full-motion video as part of computer-based instruction.

Towards Digital Video

The idea of bringing full-motion digital video to the desktop of a personal computer is not new; for example, John Sculley, former CEO of Apple Computers, Inc., portrayed this notion with a prototypical demonstration he called "The Knowledge Navigator" in 1987. Others have shared in this vision and espoused the potentials of this "revolutionary" technology with the same fervor that they promoted desktop publishing. Desktop video production has not lived up to its expectations, however, principally because of the problems inherent in bringing analog video to the digital desktop. Fortunately, technology is advancing at such a rate that these problems are being overcome.

Over the past several years, hardware designers and engineers have undertaken a technological challenge to combine the realism of analog video and the data manipulation and processing power of personal computers. Their goal was to devise a way in which ordinary analog

video signals could be input to the computer where they could be manipulated and displayed on the computer's monitor. Accordingly, once the analog signals were converted to digital data, they could be edited in much the same way that text is manipulated in word processing programs (i.e., cut, copied, pasted, deleted, inserted, etc.). As noted previously, in order to play back full-screen, full-motion video in real time on a desktop computer, the CPU's bus must be able to process roughly 27 megabytes of information per second, and that simply was not feasible given the limitations of existing computer hardware. As a result, several interim solutions were introduced that at least initially, enabled CBI developers to combine analog video and digital computers. Among these were video digitizers, frame grabbers, and specialized devices known as video-in-a-window.

Video digitizers were the first products to actually "marry" the realism of television and the power of personal computers. These generally took the form of video cameras that were connected to the computer through an interface box. Having very slow scan rates, they were not useful for capturing moving images and yielded low fidelity images which were not suitable for instructional purposes. Frame grabbers, or video capture boards, were essentially enhanced video digitizers that could capture a single frame during real-time playback of the video. Since the captured frames were stored in the computer's working memory, the number of frames that could be grabbed was limited by the computer's RAM capacity. When the RAM filled up, the frame grabber stopped working. The practical result was a series of video stills that could be edited and

displayed individually, but not in any manner that resembled motion. The final interim solution was a device that permitted analog video signals to be displayed on a computer monitor and became known as video-in-a-window. This was accomplished by converting the incoming analog video signals to the analog RGB display of the computer monitor; the converted signal was then combined with the monitor output of the display card. These devices did not actually convert analog data to digital data, rather, they simply passed the analog video through the display card to the monitor. Therefore, the images could not be cut, copied, pasted, stored, or manipulated in any manner whatsoever by the computer (Bradley, 1991).

Video digitizers, frame grabbers, and video-in-a-window were among the initial attempts to convert analog images into a form that computers could both store and manipulate. This conversion process is known as digitizing (or analog to digital conversion), and it transforms continuous functions (in terms of both amplitude and time) into noncontinuous ones. More specifically, the process of converting amplitude into discrete values is called *quantizing* whereas the process of converting time into discrete values is called *sampling*. Together, these operations are referred to as *digitizing*. Although it is beyond the scope of this document to consider how that procedure is executed, it should be understood that the digitizing process creates only an approximation of the original waveform. Moreover, it can be done with such precision that, when displayed on digital systems, any errors in image reproduction are virtually undetectable (Luther, 1991).

Inasmuch as the digitizing process effectively solves the problem of converting analog data into a form that desktop computers can store and manipulate, it does not reconcile the enormous storage and processing requirements necessary to display digital video in real time. The nearly 30 megabytes of information that must be processed for each second of motion video greatly exceeds the capabilities of nearly every desktop computer. From a storage perspective, it is easy to see that 20 seconds of full-frame, full-motion, full-fidelity video will consume over 600 megabytes of hard disk space, or roughly the equivalent of one CD-ROM disc. Even the best instructional designers would find it difficult to squeeze the simplest of procedures into only a few precious seconds.

In resolving the obstacles related to the processing and storage requirements of digitized video images, engineers have developed digital image compression techniques that reduce an image's file size to such an extent that many images may now be stored on moderately-sized hard drives. Accordingly, there are two compression algorithms that have promoted the greatest advances in desktop video production and are ostensibly responsible for making this technology more than just a futuristic dream. They are the Joint Photographic Expert Group (JPEG) and Motion Picture Expert Group (MPEG) standards for still image and full-motion video compression, respectively.

The JPEG standard, developed under the auspices of the International Standards Organization (ISO), is a general purpose algorithm for coding still-image pictures. JPEG compression is applicable to all imaging-intensive work areas including photovideotex, desktop publishing,

graphic arts, color facsimile, newspaper wirephoto transmission, and medical imaging (Jurgen, 1992). It can reduce file size while maintaining excellent image quality even with compression ratios as high as 24:1. For example, at a 20:1 ratio, a 1 megabyte file is compressed to only 50 kilobytes, and there is no perceptible loss of image quality. Moreover, JPEG reduces the file size of images to such an extent that a series of frames may be displayed quickly enough for movement to appear realistic (Bradley, 1991).

Even though the JPEG standard has at least provided a way for designers to create the illusion of video motion, it is the MPEG standard that is paving the way for compressing and decompressing full-motion (30 frames per second) video sequences in real time. MPEG “deals with the synchronization and multiplexing of multiple compressed audio and video bit streams” (Jurgen, 1992, p. 26) . It is currently being applied to such digital storage media as CD-ROM, digital audio tape, hard disk drives, and writable optical drives and to such communications channels as ISDN (Integrated Services Digital Network) and local-area networks (LANs). Luther (1991) cautiously points out, however, that “the field of image and video compression is complex and fast-moving...there are over 40 companies participating in the standards work, so it is likely that standards in this field will evolve over a number of years” (p. 205).

Summary

Before concluding this section, there are several points that have emerged from previous sections that bear repeating. First, video

instruction has a role in education. When learners are permitted to manipulate video sequences, they attain new perspectives on objects and events and gain some measure of control over their humanness. Second, an incompatibility exists between analog video and digital computers. Historically, attempts to amalgamate the two successfully have been impeded by the passive nature of the instructional approach, requirements for supplementary external peripherals, prohibitively expensive development costs, or inefficient methods of video information access. Third, interim solutions have been developed that enable digital computers to process analog video data, but they are limited in terms of their functionality for instructional purposes. Fourth, the digitizing process permits analog video to be captured and stored in a format that computers (and ultimately end-users) can manipulate. Finally, advances in compression algorithms have helped resolve the issue of large file sizes and makes it possible to display full-motion digital video sequences on desktop computers. As Bradley (1991) notes,

“...Computer and video technologies are no longer incompatible partners. They have been integrated in a far-reaching technology that will soon make it unnecessary to distinguish one from the other. The result of this alliance is an exciting new generation of communication and productivity tools that invite entirely new ways of thinking and working” (p. 23).

What's So Great About Digital Video?

Up to this point, much of the discussion has centered around the nature of video as well as those factors CBI developers must consider as they combine analog video instruction and digital desktop computers. The purpose was not to discourage instructional designers from employing the technology, nor was it to downplay the value of video instruction. Rather, it was to underscore the inherent limitations of using analog formats when such factors as image reproduction quality, production expense, and supplementary hardware requirements are taken into proper perspective. The advent of digital video production provides instructional designers with an economical and technologically feasible alternative for incorporating video as part of computer-based instruction. Designers no longer have to juggle tape formats, broadcast formats, editing formats, and distribution formats. They no longer have to wonder if end-users possess the necessary external playback devices required to transmit or display the video. And designers are freed from their reliance on expensive, high-end, technically sophisticated video production equipment. Kemske (1991) notes, "Like everything digital, it promises one day to be cheaper than its analog alternative. But the lure of cost might well be minor compared to the promise of versatility" (p. 18). But what of this digital video production technology? What's so great about digital video?

Digital video production is not subject to many of the problems inherent in producing and reproducing analog video formats. More

specifically, there are a number of key differences that make desktop digital video production attractive to instructional designers. Bradley (1991) discusses several of them including:

Faithful reproduction of copies: As noted previously, when analog copies of tapes are made, the copy is said to be one generation in quality away from the master tape. As additional copies are made from copies, there is greater and greater generation loss. In contrast, when digital information is copied, none of it is lost during the reproduction process. Therefore, each copy is a faithful reproduction of the original, and the one hundred thousandth copy will have the same integrity as the first.

Greater media stability: One of the problems with analog media is that the video information may actually decay over time and result in degraded video image quality. In contrast, the shape and force of the pulses of information used to represent digital video data are basically irrelevant, so the pulses can weaken over time and still faithfully reproduce the original signal.

Format compatibility: There are at least nine different standard tape formats (D-1, 1-inch, betacam, D-2, 3/4-inch, S-VHS, Hi-8mm, VHS, and 8mm) as well as three different broadcast standards (NTSC, PAL, and SECAM), each influencing the quality of the video image to one degree or another. Given this diversity of standards, the potential for inducing generation loss as part of the recording and editing processes is quite

high. To illustrate this point, consider that creating a master tape requires various source tapes to be recorded onto a common format for editing. Simply transferring these source tapes to the common editing format induces one generation loss. Then, after the tape is mastered, it is transferred back to the original formats for distribution, thus inducing yet another source of generation loss. The case is quite different when it comes to digital reproduction of an analog signal. In general, most digital video capture cards recognize all the major broadcast formats of source video devices so that they may process that information faithfully without injecting a source of generation loss.

Rapid and random access to video data: One of the primary drawbacks in using videotape (used generically here) for instructional purposes is the linear nature of the medium. Accessing information from one end of the tape to the other takes time and may leave recipients of the information frustrated or bored. Random access to video sequences alleviates this situation by providing near instantaneous retrieval of the motion segments. Videodisc players are best known for this capability, however, their use requires that a master disc first be produced. The mastering process is not only expensive, but it also requires recording and editing equipment not typically available to most instructional designers. Moreover, each interactive learning station must have its own dedicated player which effectively increases the cost of instruction.

Today, CBI designers are no longer dependent on videodisc players as the sole means by which information can be accessed randomly. Disk-

based digital media provides for both random access of information as well as nonlinear editing capabilities. Using the appropriate hardware, analog video segments are first digitized and transferred to disk. Once they are stored on the hard disk, they may be accessed in any order, thus facilitating the establishment of the appropriate in and out points (edit points). After the edit points are logged, the corresponding frame numbers are added to a list which the computer uses to build the instructional video sequence. Inserting and deleting video segments are accomplished as easily as inserting and deleting text in word processing applications.

Less cost and less time: “Much of the time and cost of producing analog video can be attributed to the linear nature of the videotape” (Bradley, 1991, p. 18), and this becomes especially significant during the editing process. When analog video is edited, the edits and special effects are physically recorded onto the recording medium. Once recorded, making alterations to either the sequences or special effects requires the CBI designer to master new edits over the old ones. Not only is this process time consuming, but it also induces problems related to excessive tape wear and generation loss.

In contrast, digital video allows editing and special effects generation to be performed by software, rather than hardware. Accordingly, edits and effects can be previewed, changed, and recorded any number of times without suffering media degradation and generation loss. There are no new tapes to master; instructions for alterations are simply added

to the list of segments and the software does the rest. Software-based editing also eliminates the need for expensive analog editing hardware such as VCR's, switchers, synchronizers, and special effects generators. Since a single disk drive replaces multiple source video decks and the master recording deck, digital video production becomes an affordable and feasible alternative for CBI developers wishing to incorporate video motion as part of an instructional lesson. As an added benefit, software-based digital special effects are often more sophisticated than hardware-based analog effects and can be more readily created, edited, substituted, and distributed.

There are other differences (that Bradley doesn't consider) that make digital video more attractive than its analog counterpart. These include:

Flexibility in image manipulation: Once an analog video sequence is recorded and then output to an external monitor, users have little control over how and where the image is displayed. In fact, users must rely on the designer's best judgment in deciding where and in what size the image is displayed. In addition, such systems do little to accommodate learners' preferences and deny learners one element of control over their own learning environments.

When video is stored in digital format, the computer treats the data in much the same way it treats any other type of data including text, graphics, and computer-generated animations. As a result, images can be rotated, moved, resized, cut, copied, pasted, cropped, and enhanced

(Bunzel & Morris, 1992). Multiple images may also be resized and then viewed side-by-side to permit learners to detect patterns, similarities, and differences among the images.

Image editing capabilities: As noted above, the only way to edit analog video is to physically redo the edits and then remaster the tape. Given the expense associated with this process, designers may be compelled to leave intact slightly erroneous content or they may elect not to update the instruction even as new information becomes available. In contrast, software-based editing capabilities allow digital images to be edited easily. Portions of the video may be deleted and replaced with new sequences so that the instruction always reflects the most up-to-date information about an object or event.

Complete user control over playback: Often, the decision to convert from an older technology to a newer one means relinquishing some features of the older process or device in order to take advantage of some new aspect of the emerging technology. For example, in moving from videotape to videodisc technology, end-users were rewarded with random access to information but gave up the flexibility where the video could be viewed (surely, there are greater numbers of videotape players in homes, schools, libraries, etc. than there are videodisc players). When analog video is converted to digital format, users retain the same elements of control over the playback of the motion sequences. Accordingly, digital motion sequences can be played forward and backward, stepped forward

and backward one frame at a time, viewed in slow and fast motion, and stopped at any point along the way. Moreover, other types of control are available including a looping function (video loops back to the beginning and starts playing) and a palindrome function (video plays backward when it reaches the end). The point is, instructional designers do not have to be concerned with giving users less control of their learning environments but instead, can focus on giving them more.

More than two audio tracks available: One of the features that makes videodisc instruction appealing is the availability of two audio tracks. Since each track can contain separate information, differences among end-users can be accommodated. For example, *The Creative Camera* videodisc has one audio track recorded for novice photographers and the other recorded for more advanced audiences. When digital video is used for instructional purposes, the number of accompanying digital audio tracks that can be played along with a single motion sequence is only limited by the amount of storage space on the distribution media. Consequently, a single CBI lesson may have as many audio tracks as there are levels of learners or numbers of native languages. Since the audio also resides in digital form, it can be edited and changed as easily as other computer data.

External analog video playback devices no longer required: From a design standpoint, it is most desirable to distribute the instructional video on the media that provides the greatest image fidelity. But from an

economic standpoint, not all end-users can afford expensive high-end videotape decks. Consequently, instructional designers are forced to make trade-offs in image quality in order to distribute instructional video materials on tapedecks that consumers find most economically attractive. When CBI developers use digital video to augment computer-based instruction, they do not have to compromise image quality based on the proliferation of low-end, affordable playback devices.

Video instruction may be telecommunicated: The ability to transmit digitized video over computer networks may have profound implications on the manner in which computer-based applications are used for instructional purposes. Educators could preview packages in advance and then order customized instructional materials electronically in less time and ultimately for less cost.

QuickTime™: The Missing Link

Just getting to the point where it is *possible* to capture and play back full-motion digital video from digital storage devices has been nothing short of an engineering marvel. Video digitizers effectively solved the problem of converting the diversity of analog broadcast and signal formats to a digital representation which could be stored and manipulated by desktop computers. Unfortunately, most digitizers use their own proprietary schemes for storing and accessing the digital data,

and this constrains the display and manipulation of digital video to only a few applications.

The single greatest obstacle to making digital video accessible to any application is the lack of a standard data type. Prior to the introduction of QuickTime™, multimedia developers had to divide their efforts between two distinctly different, yet vitally important tasks: that of creating high-quality applications and that of establishing and evangelizing their own format as the standard for interapplication dynamic data exchange. Without these standards, software developers were relegated to customizing their applications for each hardware manufacturer's graphics and video cards which substantially increased both the cost of developing applications and the time that it took to bring them to market (Bradley, 1991). In releasing QuickTime™, Apple has not only set that standard, but it also frees developers from their evangelical roles. Now, developers can concentrate on what they do best: creating and marketing high-quality instructional applications covering a variety of subjects for a host of audiences.

QuickTime™ is more than a mechanism for capturing digital images; it is a new architecture for integrating dynamic data types (animation, video, and sound) into computer-based applications. These data types represent a new set of communication tools by which developers can more closely approximate the richness of the everyday world. Accordingly, there will be QuickTime™ animations, QuickTime™ still images, QuickTime™ audio in addition to QuickTime™ digital video (Rosenthal, 1992). In practical terms, average users will be able to cut,

copy, and paste moving images in the same way they do most text or graphic objects and then play those “movies” back without any additional software or hardware

The advent of QuickTime™ means more than just being able to display digital video; it means being able to display video from within any application. Given the ease with which digital video can now be incorporated in computer-based applications, designers must be cautious not to use the technology simply because it exists or because it is faddish to do so. As discussed previously, video clearly can fulfill a role in educational environments, however, its use must be driven by need rather than convenience, by design rather than happenstance, and with assurance rather than hope. For CBI developers, the practical implication remains that the rationale for employing instructional video (in general) supersedes the decision to adopt any mechanism (analog or digital) to generate it.

Designing for Digital Video

There are many models of instructional design (perhaps as many as several hundred), and most have evolved during the past twenty-five years of extensive research into the learning process (Dick & Carey, 1990). Some of the more prominent models include those written by Dick and Carey (1990), Gagné, Briggs, and Wager (1988), and Reigeluth and Stein (1983). Logan (1982) owes the plethora of unique design

models to educators' failure to search for existing models, the lack of validation of existing design models, the "ingrained biases" of designers who reject the rigid, structured approach of others' instructional designs (and thus, they create their own), and the exclusive application of certain design models to specific learning situations. The sheer multitude of systems models provides testament to the fact that no single best procedure has yet emerged and that the field of instructional design, as a discipline, is quite dynamic.

When specifying the design of instruction, most models take a systems point of view. Systems are characterized by the interrelationships that exist between each of the component parts which in sum, work together toward a defined goal (Dick & Carey, 1990; Logan, 1982). "The result of using the systems view of instruction is to see the important role of all the components in the process. They must all interact effectively... in order to bring about the desired outcomes" (Dick & Carey, 1990, p. 4). Romiszowski (1981) defines instructional systems development as the three-phase process of establishing precise and useful objectives, planning viable routes, and then testing them out. Reigeluth and Stein (1983) say, "The result of instructional design as a professional activity is an 'architect's blueprint' for what the instruction should look like. This 'blueprint' is a prescription as to what methods of instruction should be used when for that course content and those students" (p. 7).

Regardless of the names attached to them, most instructional design models share, but are not limited to, the same basic components:

analysis of the problem, analysis of learners' needs, definition of goals and objectives, design and development or selection of appropriate media, implementation, and evaluation (Briggs, 1968; Briggs & Wager, 1981; Carkhuff & Fisher, 1984; Dick & Carey, 1990; Logan, 1982; O'Bryan, 1982; Romiszowski, 1981). Although some models can be summed up in three simple steps (input, process, output), others are significantly more sophisticated. Romiszowski (1981) depicts one such design used by the Royal Navy that fuses together twenty-seven separate components. For the purposes of this study, one model, Dick and Carey (1990), will be used as a standard example to represent the field as a whole.

Perhaps one of the most well known and most widely used models of instructional design is the Dick and Carey model. As noted above, while the Dick and Carey model does not represent the sole systems approach to instructional design, such systems have proven to be quite effective. The reasons for their success is threefold. First, the focus is on what the learner is to know or be able to do when the instruction is concluded. Without that precise statement, subsequent planning and implementation can become ineffective. Second, there are careful links between each step of the process. Instruction is focused on the skills and knowledge to be taught and provides the conditions for the learning to take place. Finally, the systems approach is an empirical and replicable process. Hence, instruction that is generated may be evaluated and revised and then reimplemented (Dick & Carey, 1990).

What follows is a brief description of each of the components of the Dick and Carey model (see Figure 1):

Identify instructional goals: These goals are stated in broad, general terms. They represent the knowledge a teacher hopes to convey to his or her students and around which the course content is developed.

Conduct instructional analysis: The purpose of this step is to determine the skills involved in reaching an instructional goal. These skills may be determined by using either procedural analysis, information processing, or both.

Identify entry behaviors and learner characteristics: This component specifies the prerequisite skills a learner needs to bring to the learning task.

Write performance objectives: The needs of instructional goals are translated into specific, detailed, measurable statements that support the broader, more general instructional goals.

Develop criterion referenced test items: These are measures of learner performance that may identify the entry level skills possessed by the student, check student learning during the progress of a lesson, or document student progress at the conclusion of a lesson, unit, or course.

Develop instructional strategy: This is a plan for assisting the learners to achieve each performance objective.

Develop and select instructional materials: This component is concerned with the development and selection of media used to support the instruction (examples: printed materials, CAI, films, slides, interactive video, etc.)

Conduct formative evaluation: This is an ongoing attempt to identify and rectify deficiencies relating to the feasibility or effectiveness of a particular lesson.

Conduct summative evaluation: Normally conducted after the system has passed through the formative stage(s), the summative evaluation permits conclusions to be drawn about how well the instruction has worked.

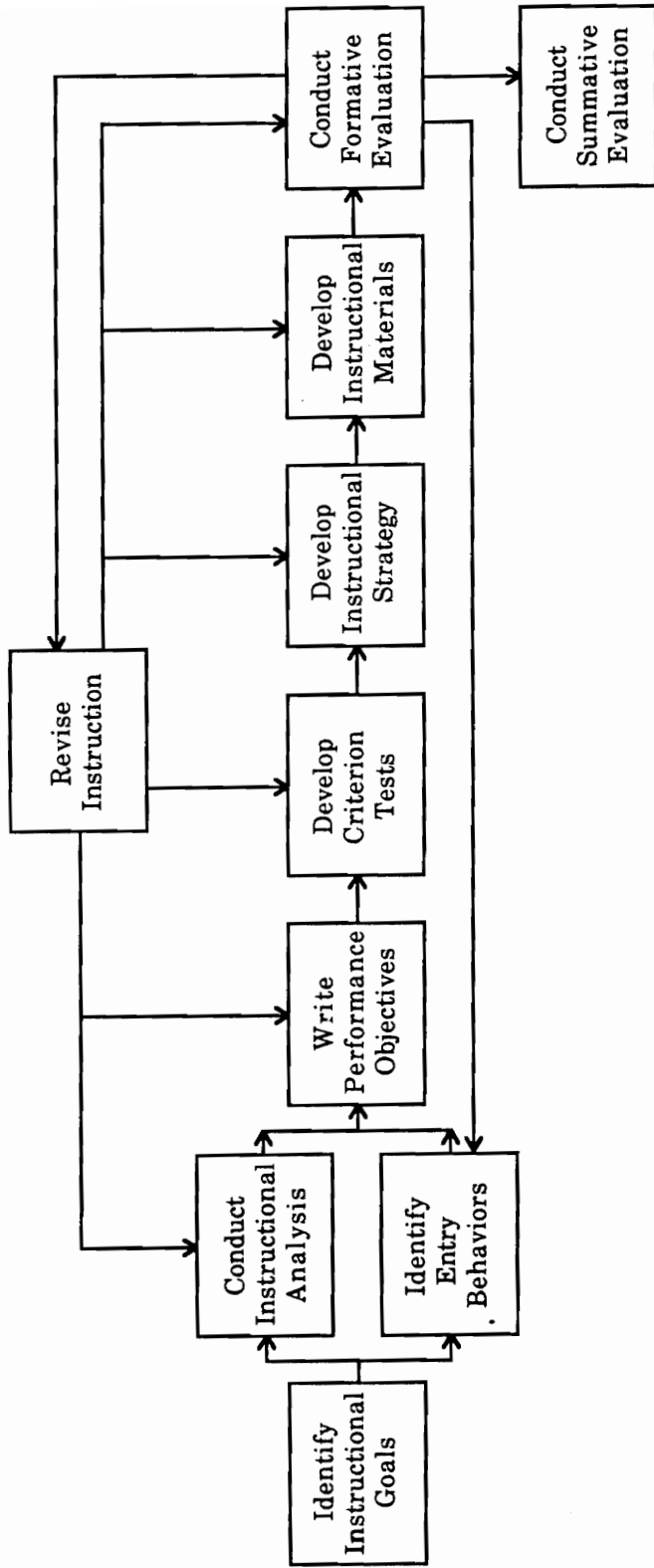


Figure 1
The Dick and Carey Model of Instructional Design

The design process is iterative, and many of the earlier stages have to be reworked based on the findings of new information uncovered during later stages. Although each component lays the foundation for the next, one cannot be altered without precipitating some change in at least one of the others.

Although the Dick and Carey model is representative of many other instructional design systems in terms of its component parts, it is equally representative in its failure to reflect emerging educational technologies, especially with regard to media *development* strategies. Many models presume that instructors will select off-the-shelf, readily available materials when instructional media utilizing motion pictures are chosen for educational purposes. But recent advances in computer hardware technology now make it possible for CBI developers to capture and manipulate motion video on desktop computers in ways that they may have never imagined or was only achievable with expensive, high-end professional broadcast studio equipment. Consequently, instructional designers now possess new tools for communicating course content, yet they are not provided with any guidelines by which the integration of these tools might lead to gains in subject-matter comprehension and ultimately overall student achievement.

Summary

Over the years, instructional designers have witnessed the genesis of many instructional devices that have promised, in one fashion or another, to revolutionize education. Although none of them ever fully realized that expectation, they were quite useful in their own rights. The evolution from interactive television to computer-assisted instruction to interactive videotape to interactive videodisc can be seen as a refinement of the technology whose goal was not to revolutionize education but simply to provide a consistent, affordable, feasible approach to enhancing student learning. Each of those technologies was accompanied by corresponding alterations in existing instructional design models; for example, Braswell (1987) proposed an adapted systems model based on repurposing extant videodiscs. If interactive videodisc instruction represents "state-of-the-art" educational technology, then concern must be given for those learning environments constrained by the limitations of videodiscs. Not all instructors can afford to produce an original videodisc nor can they repurpose that which does not exist. Moreover, what options do instructors have when the information on the videodisc becomes outdated? The integration of digital video into computer-based applications may assist in the resolution of those shortcomings.

In considering the importance of instructional design with respect to interactive technologies, O'Bryan (1982) writes:

In interactive video, instructional design is the teacher. The design creates the scope, extent, nature, and form of the interactive learning experience. Properly handled it replaces the teacher in the medium and itself becomes the mediator between the content of the audiovisual program and the learner....The content of the program will be enhanced and the user will learn to the extent that the instructional design is an effective teacher....Mere transportation of current instructional design techniques...will not suffice... (p. 69).

Although contemporary instructional design models do acknowledge computer-assisted instruction in general terms as part of the media selection and development processes, they fail to address specifically the *development* issues confronted when digital video is selected as an integral component of computer-based applications. Failure to recognize these issues may result in the creation of an ineffectual body of computer-based instruction whose disregard for *development* principles may stand little success in promoting student achievement.

Flouris (1989) notes that by some estimates "only three to four percent of the software for education can be considered excellent...(p. 15). Since the capability and overall quality of CAI programs--as well as of any other learning system--depends on their design, it is of paramount importance that instructional procedures are systematically designed and delivered to the learner(s)" (p. 17). Moreover, he writes, "...computer software which is based on instructional design models and/or systems

has the potential to increase effectiveness by ensuring high-quality standards in the design, *development* [italics added], implementation, and evaluation stages of instructional computer programs” (p. 14). To that, Snelbecker (1987) adds, “...there is growing interest in ways in which instructional design procedures may be helpful both in *producing* [italics added] and in selecting computer-based educational materials. This concern about design is emerging as educators recognize that the value of what we ‘get out of computers’ will depend to a great extent on the quality of the instructional design...” (p. 39).

Chapter 2

Methodology

The purpose of this study was to explicitly examine the essential design tasks involved in incorporating digital video into computer-based applications. More specifically, such an examination was accomplished through completion of the following efforts: 1) producing inductively a set of guidelines illustrating the design decisions and strategies used in incorporating digital video into computer-based applications and, 2) proposing an adapted systems design model for instructional development that incorporates digital video as part of its overarching structure. The guidelines were derived from the design considerations utilized in the development of a computer-based application for The Virginia Museum of Natural History at Virginia Tech. While some work has been performed on the general design and development of computer-based materials (e.g., interactive videodiscs), no attention had been given by the media production and selection components of contemporary instructional design models to those considerations specifically associated with incorporating digital video. Guidelines developed through the present study should add to the design literature as well as provide a practical source of information for designers (particularly educators) who desire to incorporate digital video as part of their computer-based educational media.

Overview

This study was designed with two goals in mind. The first was to design and produce a multimedia application which could serve as an example of how it is possible to integrate digital images (including both motion-video and stills) into computer-based instructional applications. The argument was made that the media *development* procedures underlying the integration of digital images into computer-based applications are substantially different from typical media *selection* procedures addressed in well-known designs cited earlier. Consequently, a second goal of this study was to create inductively a set of guidelines suitable for practitioners and researchers who wish to pursue further the integration of digital images into computer-based applications even as the technology becomes more and more refined. Through these guidelines, an adapted model based on Dick and Carey's (1990) model of instructional design was developed. Methodologically, the strategy adopted to meet these two goals was as follows:

1. First, a multimedia application was produced that exemplified both the incorporation of digital images into computer-based applications and the design problems encountered.
2. Each of the design steps made by the author was preserved through an extensive set of design notes as well as a videotaped record of designer and participant comments.

3. All process data, the design notes and the videotaped records, were subjected to qualitative analyses borrowed and adapted from standard ethnographic research procedures.
4. Design considerations for incorporating digital images were abstracted from the qualitative analyses and subsequently presented in Chapter 3. An adapted design model, which is based upon the guidelines derived from the design considerations, is shown in Chapter 4.

It should be noted that the author entered into this study with both a well-established understanding of multimedia development and an extensive knowledge of personal computers. Consequently, the author's decisions to pursue the specific avenues of all-digital multimedia development connected with this study may not appear obvious to the reader (a more detailed description of the author's background appears in Appendix A). However, the media development guidelines developed for this study should still prove quite useful to both novice and experienced designers alike.

The Client

The Virginia Museum of Natural History at Virginia Tech served as the client for which the prototypic computer-based application was developed. Like many other institutions of its type, the museum faces two challenges. First, it is concerned with how to catalog a primarily visual collection whose holdings fluctuate regularly as objects are

acquired for and deleted from the collection. Text-based computerized databases have performed this task adequately in the past yet they only provide written descriptions of the specimens. Moreover, the data records are often kept in one part of the museum while the specimens are displayed in another. Integrating digitized images with text-based computerized databases would not only permit the museum to maintain up-to-date data records of the collection, but it would also permit researchers to examine both the records *and* the specimens at the same time, even from a remote location.

A second problem the museum faces is its inability to display the bulk of the contents of its collection due to lack of space. At any given time, only a portion of a museum's holdings can be observed in the public viewing areas while the majority of it resides in cabinets, drawers, and other storage areas throughout the museum. Part of the museum's mission is to share the collection with the public at large, but it simply does not have the financial and human resources necessary to make the collection widely available. The situation is further complicated by the fact that many of the specimens are very fragile and may experience accelerated deterioration due to excessive handling, exposure to ultra-violet light, and fluctuations in temperature and humidity when brought out into public display. The computer-based application developed for this study serves as a prototype of a visual database of the museum's collection, and a fully-implemented version (funding conditional) would permit the general public to browse a substantial portion of the collection without engendering any additional harm to the specimens.

Description of the Computer-based Application

The computer-based application developed for The Virginia Museum of Natural History at Virginia Tech was entitled "Wildlife Habitats of the New River Valley." Five local habitats were identified (a duck pond, a lawn habitat, the New River, Mountain Lake, and Ellett Valley Nature Trail) and filmed (and subsequently digitized) for use in the application. From the main menu, users could access information about specimens dwelling within any of the five local habitats or they could obtain additional information about the museum itself. When selecting a habitat, users could view motion sequences of that area as well as access general information records for wildlife within that habitat. The records permitted users to view both motion video clips and an assortment of still images depicting that specimen. Furthermore, selected specimens were linked to museum information cards that revealed detailed text-based collection information and also provided access to close-up views of actual museum specimens. In considering user preferences, an index was included that permitted users to locate specimens within the application by either alphabetical name, classification, or habitat. At every screen, on-line help was available in the form of digitized audio instructions that were supplemented with graphic overlays.

It should be understood that the developed application best serves as a prototype for the types of computer-based programs that museums might be interested in creating and that it in no way stands as the "final product." Although this study was concerned with neither the content of the application nor the cognitive gains achieved by its users, it did serve

as the catalytic real-world foundation for which the integration of digital images into computer-based applications were considered.

Participants

In collecting information related to the design of the application, eleven museum patrons were videotaped interacting with the prototypic multimedia program and were then interviewed individually regarding concerns about ease of navigation, realism of pictures and videos, likes and dislikes, expectations and frustrations, efficacy of selected features, general overall appearance and screen design, and recommended alterations. The original intent was to observe grade-school level children only that visited the museum as part of the field trip experience. However, it became apparent that students below the fourth grade really did not possess the necessary skills to interact with the program in such a manner that significant data could be extracted by which the program could be embellished. That is not to say the information collected from them was fruitless; it was quite apparent that those children were more enamored of the pictures and videos than of the accompanying text. This might be something to consider as multimedia applications are created for age-specific audiences. Nonetheless, since the point of the study was to consider neither age-specific audience responses nor measures of cognitive gain between specific groups (age or otherwise), the decision was made to include any patron, grade-school level or otherwise, as potential participants in the study. Accordingly, the eleven museum patrons observed in this study ranged in age from about twelve to late

adulthood. As they navigated through the various wildlife habitats, their actions and comments were preserved on videotape. This data formed the basis from which guidelines illustrating the design decisions and strategies for incorporating digital video into computer-based applications were generated.

Equipment

It should be noted that development of the computer-based application could have been performed satisfactorily on either the Apple Macintosh or MS-DOS platforms. However, given that the technology needed to complete such a project was readily available in the Macintosh environment, all of the authoring was conducted from that platform. Accordingly, the following equipment was needed to create the computer-based application for The Virginia Museum of Natural History at Virginia Tech:

- Color capable Macintosh: any 68030 CPU or above; 512 K video RAM preferable, but optional; large capacity hard disk (300 megabytes) or greater
- Authoring software (Aldus SuperCard™ version 1.6)
- Video digitizing card (in this case, a VideoSpigot™ digitizing board)
- Digital graphic editing application (Adobe Photoshop™ version 2.0.1)
- Video editing software (Adobe Premier™ version 2.0)
- Audio digitizer and software (Mac Recorder™ and SoundEdit™)
- Audio recorder

- Cannon digital imaging camera
- VHS camcorder
- Hi-8 camcorder
- Elmo copystand and NTSC video camera
- Videodisc player
- Color flatbed scanner
- Syquest® 88 megabyte removable cartridge drive

Procedures

As noted previously, the developed computer-based application was not intended for direct instructional use, rather, it functioned on a less formal level resembling an information kiosk. One of its purposes was to bridge the gap between the museum's ability to disclose its collection (on a limited basis) and the general public's undiminished access to it. Accordingly, there was no formal testing of the application in terms of learner achievement as evidenced between differences in pre- and post-test scores. Rather, users' reactions, comments, suggestions, and criticisms were compiled as they navigated through the application in a nondirected (browse) mode of inquiry. The compilation of data from these formative evaluations served as part of the basis from which the design guidelines were extracted.

Data Sources and Analysis

The purposes of this study were twofold: to produce a set of practical guidelines and an adapted model of instructional design that address the

design scenario when practitioner-developers wish to incorporate digital video as part of computer-based instruction. Accordingly, an application was developed for The Virginia Museum of Natural History at Virginia Tech that examined the design process in detail.

A think-aloud strategy was employed throughout the design process to trace the decision making steps involved in incorporating digital video into computer-based applications. Not only were design notes preserved during the authoring process, but as users interacted with the database, their comments and reactions were recorded on videotape. As described by Ericsson and Simon (1984), one form of the think-aloud strategy involves examining verbalizations depicting users' thought processes. Such verbalizations comprised an essential element towards the formulation of the proposed design guidelines.

Spradley (1979) has several good examples in which he uses think-aloud techniques to understand one's culture. For example, one of his projects involved examining the hierarchy of people involved with a city jail in an attempt to better understand the subject's culture. He recommends using a taxonomic procedure to analyze the information gathered from think-aloud sessions, and accordingly, there are three key steps: 1) select a domain for taxonomic analysis, 2) search for possible subsets among the terms included in categories, and 3) construct the taxonomy. Below is a partial taxonomy (in outline form, rather than box diagrams or lines and nodes) developed from the think-alouds conducted for this study:

Design Considerations

A. Authoring platform

1. Resources
 - a. People
 - b. Time
 - c. Money
2. Equipment
 - a. Hardware
 - b. Software

B. End-user platform

1. Levels
 - a. Novice
 - b. Intermediate
 - c. Expert
2. Hardware
 - a. Display device
 - b. RAM
 - c. Fixed disk storage capacities
 - d. Microprocessor

Once the taxonomy was constructed, development guidelines were formulated around elements in the subsets that would facilitate the incorporation of digital video into computer-based applications. For example, display device was a subset of the category hardware. Since monitor pixel-depth was an attribute of display devices that could bear on the overall quality of digitized images, that attribute was investigated in closer detail during the media development process. Not only were users asked to comment on the realism of images displayed in 4-bit, 8-bit, 16-bit, and 24-bit color, but the images were examined relative to such considerations as image file size and overall end-product

performance. Written design notes documented the considerations associated with creating and displaying digital images at various pixel-depths (see Appendix B). Those examinations ultimately culminated in the generation of general media development guidelines with respect to display devices and appear in Chapter 3.

At each stage of the media development model, the modifications which resulted from redesigning the museum's project were incorporated into the taxonomic analysis. The combination of design notes and information obtained from the think-aloud protocols were compiled to generate a set of guidelines. The guidelines were then used to adapt a model of instructional design for those CBI developers wishing to incorporate digital video as part of computer-based applications.

Chapter 3

Development Considerations

One of the major purposes of this study was to develop guidelines that will assist developers in creating computer-based instructional materials that incorporate digital video. Earlier, arguments were advanced that traditional instructional design models place greater emphasis on media *selection* than media *development* and that materials developed outside the framework of design models may provide little support for unit goals, lesson objectives, and instructional strategies of specific learning environments. Each of the considerations presented below evolved from the attempt to solve problems that occurred during the development of the application created for the Virginia Museum of Natural History at Virginia Tech. These are general guidelines and considerations and hence, do not reflect the idiosyncrasies of particular authoring environments or platforms. Accordingly, they should be quite useful to those developers planning to incorporate digital video into computer-based applications regardless of the specific authoring hardware and software selected.

Development Considerations

- *CBI developers should consider the characteristics of the intended display device when incorporating still images into instruction.*

Today, affordable flat-bed color scanners can scan still-image graphics at resolutions of 300, 600, even 1200 dpi (dots per inch) or greater. Scanning is simply a process whereby the hardware and software work in concert to sample information from the original artwork and then interpolate between the scan lines to create the reproduced image. The higher the scanning resolution, the greater the amount of information that is sampled from the original artwork. When the software has more sampled information to work with, it performs less interpolation (“guessing”) and yields a more faithful reproduction of the original artwork.

Designers should bear in mind that there is a direct relationship between scanning resolution, image file size, and image quality. As scanning resolution increases, so too does the file size of the reproduced image, and so too does the overall quality of the reproduced image. Interestingly, however, this increased level of image quality is only detectable when images are displayed on devices capable of reproducing those enhanced resolutions. Common output (display) devices include computer monitors, dot-matrix printers, laser printers, plotters, film recorders, and image setters, yet none of these devices necessarily displays the same image with the same level of image fidelity. While image setters are capable of reproducing images with resolutions as fine as 2400 dpi, many dot matrix printers can only achieve output resolutions as high as 72 dpi. As an example, consider a graphic scanned at 300 dpi. If the graphic is printed on a 72 dpi dot-matrix printer, then all of the additional sampled information above 72 dpi is

lost, and the printed graphic would look exactly the same as if it had been scanned only at 72 dpi. On the other hand, outputting the 300 dpi graphic on a 2400 dpi image setter still only yields a graphic rendered with 300 dpi of sampled information. Merely displaying a lower resolution graphic on a higher resolution output device does not alter the amount of information sampled from the original artwork. The software still only has 300 dpi worth of data to work with, and simply increasing the resolution of the output device will do nothing to enhance the fidelity of the reproduced image.

When the computer's display monitor is chosen as the output device for instructional graphics (which is the case of all-digital CBI applications), designers should understand that they are designing for a device that is capable of only displaying graphics at 72 dpi. Therefore, graphics scanned at resolutions greater than 72 dpi can be resampled to 72 dpi without any noticeable degradation in image quality. Furthermore, these lower resolution graphics also have smaller file sizes which may permit designers to incorporate greater numbers of these types of graphics into their instructional applications, particularly in cases where fixed media storage capacities are limited.

- *Different authoring environments support different features, therefore, designers must select development software in accordance with final-product functionality, ease of development, end-user expectations, authoring environment development limitations, and speed of product development.*

As noted earlier, the application developed for the Virginia Museum of Natural History at Virginia Tech was developed in Aldus SuperCard™, and the adoption of that authoring environment (as opposed to HyperCard™ or FoxBase+/Mac™) precipitated compromises in the design and development of the final product. For example, one of the initial project goals was to provide the museum with a mock-up of the types of applications that museums might be interested in developing. Accordingly, such mock-ups would include colored objects (buttons, text, backgrounds, and fields) that could, among other things, assist users when navigating the interface, provide emphasis for important points, or create an overall aesthetically pleasing appearance. However, the selection of SuperCard™ also meant that only 8-bit (256 colors) graphic images could be displayed, and these certainly were not of photo-realistic quality. Interestingly though, based on comments received during formative evaluation of the developed application, the 8-bit images were still perceived as very realistic.

As another example, SuperCard™ did not permit the inclusion of the standard movie controller during playback of QuickTime™ movies. Since the current version of SuperCard™ (version 1.6) was released nearly three years prior to the advent of QuickTime™, special external functions (XCFNs) originally written for HyperCard™ were imported into SuperCard™ that permitted QuickTime™ movies to be viewed from within SuperCard™ projects. Unfortunately, the underlying SuperCard™ control code did not support complete functionality of those particular XCFNs, and hence, they performed in only limited, yet usable, capacity.

The point is, there are advantages and disadvantages to every authoring environment, and designers will necessarily be challenged to make compromises during instructional development. At some point, the designer must ask, "Which package supports the greatest number of significant design features for my particular application?" and then select one knowing full well that not every design feature can necessarily be implemented.

- *In an effort to minimize file storage requirements of digitized movies yet maximize their playback performance, designers should examine the degree to which scenes are changing within selected video sequences prior to capturing the movies and then select appropriate frame capture rates.*

When creating digitized movies, the extent to which the background of video sequences changes can influence the choice of frame capture rates. Optimally, movies captured at or as close to 30 frames per second (fps) produce the smoothest transitions in motion sequences, however, they also require the greatest amounts of file storage space. Unless designers have access to unlimited capacities of fixed media storage devices, they must always be concerned with maximizing video playback performance while minimizing file storage requirements. Accordingly, if the background of selected video sequences does not change much (e.g., a talking head), then movies can be digitized at slower frame capture rates without sacrificing video playback performance. The reason for this is

simple: since scenes from video frame to video frame are changing very little relative to each other, the increased “jumpiness” that accompanies slower playback rates is not as noticeable to the viewer. Conversely, if the background of selected video sequences does change a lot (like during a panning sequence) or if the objects being filmed are in rapid motion, then faster frame capture rates are required since the scenes from video frame to video frame are changing more in relation to each other.

- *Hardware should be configured to facilitate maximum frame capture rates prior to digitizing movies.*

Some of the equipment used in developing the product for this study included a SuperMac VideoSpigot™ digitizing board and SuperMac’s accompanying ScreenPlay™ digitizing software. Designers should be aware when capturing movies through ScreenPlay™ that this particular digitizing software uses available hard disk space as its working memory rather than the computer’s random access memory (RAM). The reason for this is because in general, most computers have significantly more fixed disk storage space than they do on-board RAM, and hence, longer (temporally speaking) movies can be captured.

Given this, there are two ways that hardware can be configured to facilitate maximum frame capture rates prior to digitizing movies. The first is to simply optimize the hard disk that ScreenPlay™ is using as its working memory. As computer data files and applications are deleted

from the hard disk, they leave gaps or unused areas that get filled-in when new files are saved. Since these gaps are not necessarily arranged contiguously along the hard disk, the read/write head has to search over the entire disk for empty spaces to which to write files, and this takes time. The more scattered about these empty spaces are, the greater the level of hard disk fragmentation, and the longer it takes for the read/write head to perform its job. Although the increased time it takes to save a file may seem imperceptible, hard disk fragmentation can significantly reduce frame capture rates when digitizing movies. For example, when capturing movies for this project using a non-optimized hard disk, frame capture rates of only 10-12 fps were achieved. When that same hard disk was optimized, frame capture rates of 22-23 fps were achieved, and that was using an unenhanced (meaning straight from the factory) Macintosh II ci. Interestingly, most of the supplied literature indicated that frame capture rates of around 15 fps were only achievable on that particular Macintosh model; clearly, hard disk optimization made the difference.

The second way to maximize frame capture rates is to simply dedicate a large partition of a hard drive, or even an entire external hard drive, as the volume that ScreenPlay™ uses as its working memory. It is important that all applications and data files be stored elsewhere and that all files on those volumes be deleted prior to digitizing the movies. If the volume is completely empty prior to capturing the movies, then the read/write head can lay down the ScreenPlay™ data along contiguous areas of the hard disk, and digitizing performance will be at its optimum.

- *QuickTime™ movies can be integrated into projects “transparently” by overlaying the movie onto a PICT image of the first frame of video.*

QuickTime™ movies are files that reside separately from the applications and projects that use them. For example, in the application created for the Virginia Museum of Natural History at Virginia Tech, the SuperCard™ project was programmed to “call up” the appropriate movie and display it in the proper location. Since some computers process information more efficiently than others, there can be a noticeable delay between the time the project “calls up” the movie and the time it takes for the central processing unit (CPU) to actually display it on the computer’s monitor. One way this delay was made less perceptible to users in the present study was to create a PICT image that was an exact duplicate of the first frame of the video “called.” This image was then pasted into the project and appeared as a card graphic. When the call was made to that movie, the movie was displayed in precisely the same location as the PICT image; the result was near-transparent integration of movies into the project, that is, they did not just suddenly pop onto the screen.

- *When scanned artwork must be enlarged prior to display in a CBI project, first it should be scanned at the highest scanning resolution and greatest pixel-depth, scaled to the larger image size, and then resampled back to 72 dpi.*

The images used in developing the project for this study came from a wide variety of sources, principally nature and wildlife magazines. As such, the images also came in a wide variety of sizes. Many of the images were too small to be used “as is”, and a process was devised whereby the images could be enlarged and still represent the original artwork faithfully. First, the original images were scanned at the highest scanning resolution available (300 dpi in this case) and at the greatest pixel-depth (32-bit color). This combination of settings assured that the digital editing software (Adobe Photoshop™) had compiled the greatest amount of information from the original artwork. Next, the scanned images were enlarged in Photoshop™ and then cropped to the sizes specified on the screen design layout sheets. At this point, the file sizes of the images were still as large as 3000-5000 kilobytes (3-5 megabytes) each. Finally, the images were resampled down to 72 dpi at 8 bits per pixel, and the image file sizes were correspondingly reduced to around 366 kilobytes. This process seemed to yield the highest quality reproduction over other attempted enlargement methods, and hence, was adopted for use in creating the product for this study.

- *The characteristics of the hardware that authors use to develop CBI applications will not necessarily mirror the characteristics of the hardware end-users use to view the final product.*

Not surprisingly, the hardware used in authoring CBI applications will likely be more sophisticated, more expensive, and of a greater variety

than the hardware end-users use to run the developed application. Over fifteen separate pieces of equipment were used to develop the product for this study, and much of it was considered state-of-the-art by today's standards. In contrast, the developed application ran on a system composed of as few as three components.

The diversity between authoring and playback platforms as well as the diversity among end-user platforms themselves raises some interesting questions for designers and developers of CBI applications. Do all monitors display the same number of colors at the same resolutions? What effect do different microprocessors have on the overall performance of the application? Does the end-user platform have sufficient fixed media storage space to which the application can be loaded? Are there any additional external peripheral devices needed to run or retrieve the application (e.g., a CD-ROM drive or a modem)? How will the application be distributed to end-users? Via high-density floppy diskettes, magneto-optical cartridges, optical diskettes, or will it be loaded onto a file server and then downloaded at runtime? Does the end-user platform support the latest and greatest technology that might be used in creating or distributing an application (e.g., older low-end Macintosh models do not support the playback of QuickTime™ movies nor do they accept high-density floppy diskettes)? What are the absolute minimum end-user hardware requirements necessary to run the application in an efficient fashion?

The implication for designers and developers of CBI applications is that the look and the feel and the functionality of an application may be

constrained by the limitations of the end-user platform. Applications cannot be built blindly and with the thought that a computer is a computer is a computer. Designers must constantly consider the implications of platform diversity and develop and distribute applications accordingly, and often this means making compromises between form, feel, and functionality while striving to maximize instructional impact.

- *Taking time to steady still-image cameras during the photography sessions will reduce the amount of time and work needed to “clean up” the digitized images during the authoring process.*

Some of the still images that appeared in the museum application were collected using either a digital or analog (film) media format camera. Many of the initial hand-held shots lacked the crispness and clarity that was desired for use in the application, and subsequently, alterations were made in the photographing process. One of the simplest ways to steady the camera was to mount it on a tripod or some other stable object (table, shelf, counter, etc.) and do away with the hand-held shot altogether. The camera was also be steadied by using a cable release to “snap” the picture rather than depressing the shutter release button on the camera by hand (as an aside, if a cable release is not available or handy, the camera’s self-timer can be set to make the exposure without having to depress the shutter button manually). This development consideration may sound like just good common sense, however, it always stands the chance of being overlooked during the rush and

excitement that accompanies product development, and it may be particularly appropriate for consideration by new or inexperienced developers (i.e., teachers and students). Sometimes, even the little things can make a big difference.

- *When shooting video footage for mastering as QuickTime™ movies, the highest grade video media that is available should be used.*

In the section on recording media formats it was noted that all of the nine different formats listed have a unique degree of image quality inherent in their signals. This project provided the opportunity to examine whether discrepancies in image qualities could be detected for two of those formats--VHS and Hi-8 mm. During the initial development phase of the project, two of the five wildlife habitats were each filmed on both VHS and Hi-8 mm media. Interestingly, the discrepancies in image quality were hardly perceptible when the scenes were viewed on standard NTSC monitors. However, once the scenes were digitized and played back on the computer's display, the differences became quite noticeable. Apparently, the video capture board was much more sensitive to the differences inherent in the source signals, and these differences were manifested in overall image quality. Not surprisingly, the Hi-8 mm format yielded the highest quality digitized movie. The bottom line is that when given the choice, CBI developers should opt for the highest grade video media that is reasonably available. It should be remembered,

however, that even 24-bit color won't improve the fidelity of low-quality VHS images.

- *CBI developers should be aware that authoring compatibility problems may arise between hardware and software as advances in technology continually propagates refinements in them both.*

The advance of technology that results in more powerful microprocessors and more sophisticated authoring environments may create a situation in which newer software may not run on older hardware, and older software may not support the full range of capabilities of state-of-the-art hardware. Consider the case of newer software and older hardware first: the latest version of Adobe Photoshop™ (version 2.5) requires at minimum a color monitor, expanded RAM, fixed media storage, and an 8-bit video display card. Clearly, this particular application will not run on older Macintosh models (Pluses, SEs, and Classics). This situation is not unique to Photoshop™; there are literally dozens of applications being released that necessitate access to high-end authoring equipment to fully exploit their integrated features.

Conversely, older software may not support the capabilities of the most current hardware or its operating system; for example, SuperCard™ (v. 1.6) was not compatible with QuickTime™ (v. 1.5). Even though the latest version of QuickTime™ supports faster frame capture and playback rates and larger movie window sizes, SuperCard™ could not

take advantage of those features. As a result, an older version of QuickTime™ (v. 1.0) was used instead, effectively eliminating the compatibility problems that emerged. Disappointingly, larger movies and more efficient playback of those movies would have constituted significant improvements to the overall look and feel of the project developed for this study, but they were unable to be implemented.

- *Avoiding the use of custom Color Look-Up Tables (CLUTs) will enhance overall run-time performance of the developed CBI application.*

Simply put, CLUTs are essentially palettes of colors that the computer accesses when “painting” graphics on the display (monitor). Each digital image can have its own CLUT, and indeed, this is often beneficial. When a graphic is drawn from the colors in its own custom CLUT, then its image is faithfully reproduced on the display device. If the image is displayed using the colors from another CLUT, then the operating system must remap the colors as closely as possible to the original color information. Depending on the array of colors contained in the CLUT, there can be either subtle or dramatic differences between the colors in the original artwork and the colors in the on-screen image.

It would seem, then, that when developing CBI applications, multimedia authors would want to import custom CLUTs along with their corresponding digital images. But there are some decided disadvantages to using custom CLUTs as well. Each custom CLUT is seen by the authoring software as a separate resource. Theoretically, there is no

limit to the number of resources an application may access, however, in general, the greater number of resources that are “attached” to an application, the poorer its run-time performance. In addition, paging from picture to picture means that each custom CLUT must be loaded into memory before the image is displayed on the monitor. Not only will the monitor “flash” as each custom CLUT is loaded into memory, but depending on the number of colors contained in the CLUT, there may be a noticeable delay in the time it takes display the image, again effectively eroding run-time performance. If multimedia developers are striving to maximize the speed at which the project “runs” (particularly on less efficient, low-end CPUs), then they should minimize the number of resources that the project has to account for.

The project developed for this study provided an opportunity to examine the developers’ dilemma of faithfully representing original artwork as on-screen images while minimizing the impact on run-time performance. Accordingly, a satisfactory compromise was achieved. Having known that a color Macintosh uses a special System palette (CLUT) to display colored icons, menus, and desktop patterns, an idea occurred to observe how the digital images would be displayed if their colors were remapped from the custom CLUT to the System palette. An informal “experiment” was devised in which pairs of digital images were displayed, one in colors from the System CLUT and the other in colors from the custom CLUT. Interestingly, the differences between the two images were barely perceptible, if at all. As a result of this inquiry, all of the images that appear in the museum’s application were remapped to

the System palette. Not only did this drastically reduce the number of resources (indeed, there was the potential to have several hundred custom CLUTs), but it also eliminated the “flashing” that occurred as each image was displayed on the monitor. Moreover, overall run-time performance was enhanced since only one CLUT used to render the images (and it always resided in RAM) plus the application had far fewer resources to account for.

- *When copying images via the clipboard, image dimensions may not transfer exactly from one application to the next.*

To facilitate readability and to maximize visual appeal, substantial time was invested in the generation of screen design and layout sheets. Sizes and colors of on-screen objects were specified in an attempt to illustrate the concepts of good interface design. Schneiderman (1987) stands as a particularly good reference on the subject of interface design, and some of his ideas were advanced in the design and development of the museum’s project. One of the unexpected events that occurred during the development of the project was the discovery that the dimensions of the images imported via the clipboard were subject to change. Images that were sized to their layout specifications in Photoshop™ were found to have changed slightly when imported into SuperCard™ via the clipboard. The same phenomenon occurred when other identical hardware was substituted, and it is surmised that the discrepancy must have occurred somewhere in the translation of the

images between the two applications. There was no real remedy for this situation other than to acknowledge its existence, but to that end, preliminary authoring activities might include, among others, conducting image transfer tests.

- *The development of high quality, all digital multimedia applications may consume enormous amounts of time to achieve professional looking results.*

One of the purposes of this project was to record the design and development steps taken in the course of developing an all-digital multimedia application. Not only were the practical design and production considerations explored, but an attempt was made to examine the temporal aspect of multimedia development. Accordingly, the time invested (ballpark figures) in creating the application for the Virginia Museum of Natural History at Virginia Tech broke down as follows:

Number of Hours	Task
30	Initial screen designs, HyperCard™ rapid prototyping
25	Screen design and layout
30	Research, collect, input content
15	Shoot video footage
20	Digitize actual museum specimens
100	Scan, edit still images
15	Record, digitize audio clips
20	Master QuickTime™ movies
150	Program, debug the project; refine user interface
30	Test the prototype
435	Total hours

Again, it should be noted that the project developed for the museum still constitutes a fairly artistically-rendered prototype, and it was not intended to stand as the “final product.” It does stand, however, as a representative accounting of the types of activities that might be performed in the course of authoring all-digital CBI applications.

- *CBI developers should understand that the greater the number of colors that on-screen images are displayed in, the poorer the run-time performance of the application.*

In practical terms, pixel-depth (specified in bits per pixel) refers to the number of bits used to generate the color value of each pixel in a

digitized image. The greater the number of bits per pixel, the greater the number of colors that are available for “painting” the image on the screen, and the better the overall reproduction of the original artwork. Common display systems permit digitized images to be displayed in either 24-bit (over 16 million colors), 16-bit (over 32,000 colors), or 8-bit (only 256 colors) modes. Although 24-bit systems yield the highest quality images, they are expensive in terms of memory usage, storage, and processing power. As an alternative, 16-bit systems work well with highly colored images, but their weakness (contouring) shows up in images which have subtle shadings of colors over large areas. At the low end of the scale, 8-bit systems are capable of rendering realistic images while using less file storage space, less RAM, and only require reduced processing power. The disparities in 8-bit images become most apparent only when the original artwork is displayed side-by-side with its corresponding on-screen digitized image.

CBI developers should recognize that their decision to display images as realistically as technologically achievable (in this case, 24-bit color) often translates to less efficient run-time performance of the end-product. More color information means more data to process per graphic which in turn means longer image load-times, and this is manifested as reduced performance.

As noted several times previously, designers must make compromises between what is technologically feasible and what is realistically practical. Often, these decisions are effected more in response to expense, development time, end-user platform limitations, and authoring

constraints than they are in response to raw performance of the developed end-product. As was exemplified with interactive videotape (IVT) instruction, poor run-time performance can leave users frustrated or bored, or perhaps worse yet, could instill in them a negative attitude toward computer-based instruction in general.

Summary

Inasmuch as the proliferation of multimedia authoring tools has brought revolutionary capabilities to desktop computers, it is still one thing to possess the tools and yet quite another to master their techniques. In other words, the mere availability of functionally professional-grade multimedia tools (professional means) does not ensure professional ends. Much of the frustration endured in the development of the museum's project stemmed from the desire to apply those tools in a manner that would achieve those professional ends. To the extent that time is not a factor, then there is every reason to expect those ends to be attained.

The development considerations presented herein provide the basis for adapting a well-known instructional design model to address media *development* (specifically, all-digital CBI applications) and not simply just media *selection*. To this point, practitioners have, by and large, been viewed as consumers of prepared products, and little guidance has been given those educators who, with the advent of professional-quality desktop multimedia development tools, dare attempt to author their own CBI materials in the context of a systems approach to instructional

development. Accordingly, a model was developed that attempts to illustrate where such media *development* strategies fit into the larger process of an instructional design that places disproportionate emphasis on media *selection*.

Chapter 4

Adapting the Instructional Design Model

This study was conducted primarily to discern ways of adapting traditional instructional design models to better guide educators whose practical design problem is *developing* instructional materials rather than simply *selecting* them. More specifically, this study investigated the design and development of computer-based applications that employ both digitized motion-video sequences and digitized still-image graphics. Based on the advent of a host of multimedia development tools, the incorporation of digital images into CBI applications represents a unique *development* situation that has not been adequately addressed in existing instructional systems development (ISD) theory. The advent of affordable, professional-quality multimedia development tools, when coupled with the advantages of all-digital media, may pose a particularly attractive situation to those practitioners who are no longer satisfied to simply *select* instructional media, but instead, would rather *develop* their own instructional media.

Note that the proposed development model was not intended to supplant the design model, rather, it was intended to supplement it; the steps preceding the selection or development of instructional materials must still be carried out. Although the development model was generated using specific guidelines and process data compiled during the development of the application for The Virginia Museum of Natural History at Virginia Tech, it was intentionally sculpted in general steps

that other instructional media might be created using the same developmental scheme.

The Adapted Model

Figure 2 represents one attempt to represent more fairly the *development* of instructional materials (in the case of this study, computer-based applications that integrate digitized still-images and motion-video sequences) in the context of a larger, systems approach to instructional design. Such traditional approaches, like the one constructed by Dick and Carey (1990), place disproportionate emphasis on the *selection* of instructional materials and provide less guidance to those practitioners pursuing actual *development*. Although there are a number of good sources to which practitioners can refer in creating and implementing less technologically current instructional media, this model seeks to reconcile state-of-the-art-media development strategies with the typical design scenario expected when one follows the traditional paradigm. A description of each *development* component follows:

1. *Define the product.* As in the creation of any new product, developers must first begin by defining what it is they intend to develop. Given the types of computer mediated applications that have been developed over the years, the final product could potentially resemble anything from a drill and practice session to level III interactive video.

Moreover, it could provide as little as a few minutes worth of instruction or perhaps as much as a couple of hours. The developers' task at this stage is to begin defining what that end-product might look in terms of content and presentation mode. The following considerations may assist developers in making those determinations. They include:

- *Will the product stand as a complete instructional package or will it communicate only a portion of the content and supplement other forms of instruction?* Historically, many of the CBI applications created for educational markets were comprehensive instructional packages. That is, not only did they present the content, but they also provided the remediation, directed the presentation, and conducted the evaluation of the learners' progress. However, given the advent of desktop multimedia authoring tools, practitioners may now be interested in creating "mini-modules", or short lessons, that may simply supplement or enhance other modes of instruction. In this case, the end-product could be one of several instructional strategies employed by the instructor to communicate course or lesson content.
- *What features will be incorporated?* Multimedia applications may include text, audio, still-images, motion-video sequences, and computer-generated animations, and developers must decide which and how extensively those elements will be employed to satisfy the goals, objectives, and strategies of the overall instructional unit.

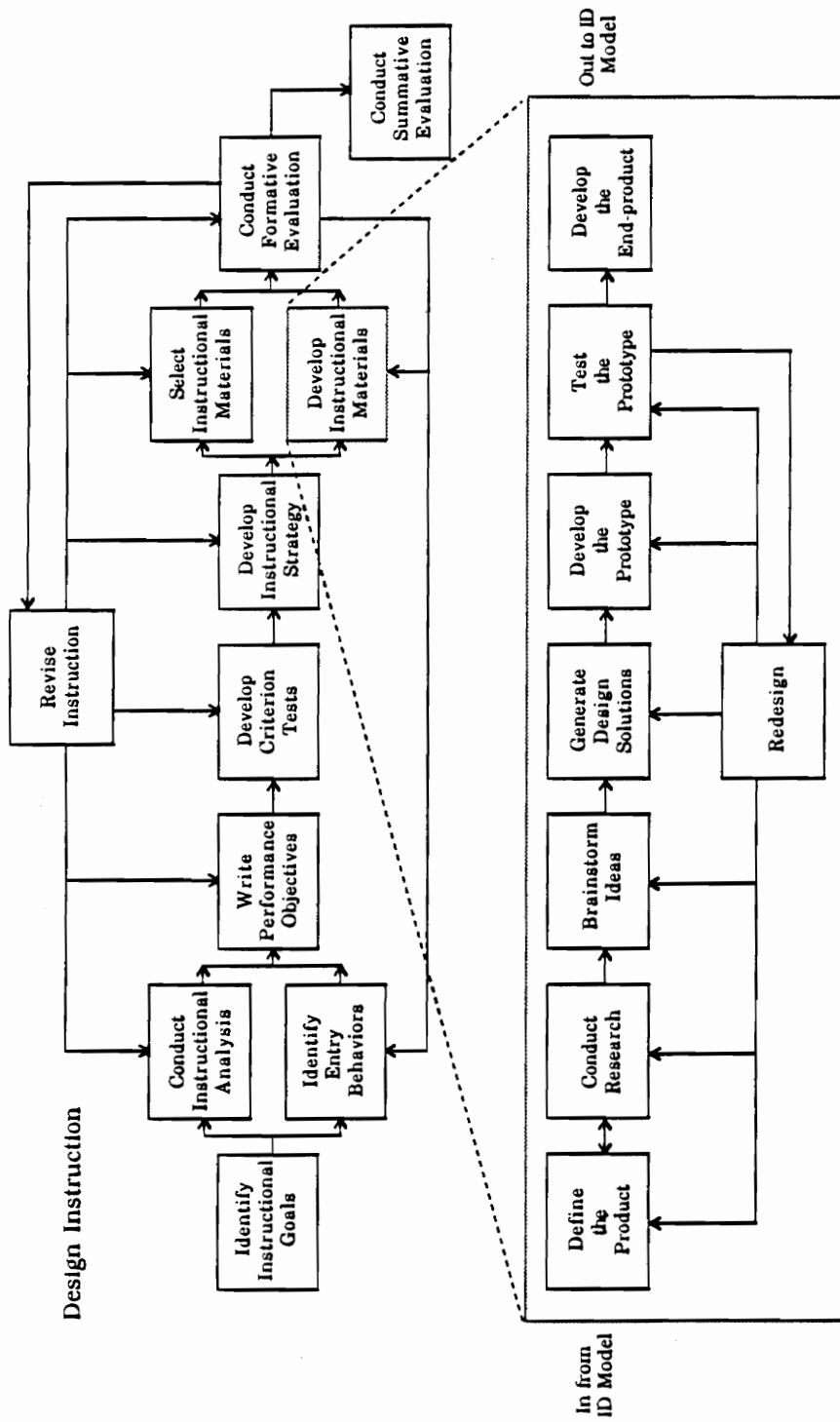


Figure 2
Design Model Reflecting Media Development Strategies

- *Will the end-product be primarily instructional or informational?*

Instructional applications will (ideally) effect some change in what students think or say or feel or do; typical instructional applications might teach students to type or to add and subtract fractions.

However, practitioners could develop products that are primarily informational as well. The science teacher who does not have enough microscopes for each student could create a digital database of microscope slides; the “digital slides” could then be displayed via an overhead before the class as a whole. In this sense, the slide database does not actually instruct per se, but instead serves as a resource for instruction.

- *Will the end-product be used by an individual or by a group?*

Depending on the instructional strategies selected by the instructor, the developed product may need to reflect the learning preferences of individual users or it may need to allow for group dynamics and interactions and foster team building and consensus.

- *How much content will be covered?* In defining the scope of the end-product, developers must consider both the breadth and the depth of the content to be covered. Consider the example of a graphic communication instructor developing a unit on offset lithography. Course content would likely include design and layout, producing a line negative, stripping a flat, making a plate, printing the job, and binding and finishing the document. If computer-mediated

instruction is selected as a viable instructional strategy for communicating any or all of that unit, then the developer must initially decide how much will be included and how comprehensively it will be detailed. By and large, these decisions will be based on both the goals of the instructional unit and the objectives of the instructional lesson.

At the end of the product-definition stage, the developer should have a pretty well established concept of what the end-product will attempt to accomplish in terms of both content and presentation. For example, the product definition *might* take the following form:

“I am going to develop a supplemental instructional module on the effects of ozone depletion on global warming. The module will last approximately 15 minutes and will utilize still-image graphics, audio, and computer-generated animations.”

Although the details have yet to be worked out, the statement does communicate in general terms, the intended form of the end-product.

2. *Conduct research.* During the research phase, developers gather information to assess not only whether the product needs to be developed, but whether it is feasible to do so based on available resources. It could be that there are previously developed products that teach the same concepts, or the available resources--time, money, equipment, and expertise--just are not available to bring the

product to fruition. The research component not only reduces product duplication, but it can also identify weaknesses in existing products and strengthen the instructional impact of the end-product. Accordingly, there are a number of questions that developers can raise during the research phase of the development model. They include:

- *What resources are available to develop the end-product in a timely, efficient, and cost-effective manner?* One of the most precious resources that practitioner-developers have is time; there never seems to be enough hours in the day to do everything that needs to be done. In the preceding chapter it was noted that over 400 hours were invested in the development of the project for this study alone. Multimedia development can be very time consuming, and developers will have to plan ahead accordingly.

Money is another resource that may play a key role in whether the project can proceed as planned. Money may need to be appropriated for hardware and software purchases that are required to develop the end-product. Depending on the sophistication of the authoring environment, this could run into the thousands of dollars.

People represent yet another resource to developers. There are many roles to be played out in the course of developing the end-product. Some of these roles include artists, videographers, editors, programmers, content experts, and evaluators. Practitioner-developers will have to decide how much they can do on their own and

how much they will have to rely on others in completing the proposed project.

- *What are the characteristics of the end-user platform?* It was noted in the previous chapter that the characteristics of the end-user platform may, to a certain degree, limit the functionality of the end-product. For example, if teacher-developers have only Macintosh SEs in their classroom, then they won't be able to display colored images on the screen or even play back digitized motion-video sequences. If developers take the time at the research stage to consider the characteristics of end-user platforms, then they won't run the risk of creating dynamic, high-quality applications that can't be used in the classroom.
- *What other materials are already available on this particular subject?* Since multimedia development can be expensive in terms of both time and money, the research phase permits developers to step back and ask, "Do I really need to develop this project or do materials (both textual and computer-based) already exist that can perform the same instruction satisfactorily." Practitioner-developers should evaluate the adequacy of existing materials on the basis of previously developed goals and objectives (generated earlier in the *design* model). If those materials appear to be usable and resources are tight, then a decision could be made at this point to *select* instructional materials rather than *develop* instructional materials. But where do practitioner-

developers turn in establishing what materials already exist? A number of good sources include software reviews, trade magazines, other teachers, conference attendees, and vendor catalogs. Many software vendors will even permit teachers to try their software on a trial basis at no charge.

- *Have functionally similar end-products been developed around different subject areas?* Although this relates closely to the preceding consideration, developers may want to pay particular attention to these products. Developers would not only want to establish how well the programs worked (in terms of pedagogy) but also how end-users reacted to the programs themselves. What were their likes and dislikes? Did the product behave consistently? Were the screens easy to read? What provisions were made for alternative learning styles? Weaknesses identified in existing products can be corrected and turned into strengths in newly developed products. It is at the research stage that developers become uniquely aware of what's out there, how well it works, and how it can be improved.
- *What equipment (both hardware and software) are needed to author the proposed product?* In the previous chapter, the points were made that the characteristics of the authoring platform may not necessarily mirror the characteristics of the end-user platform, and that the authoring environment will likely consist of more sophisticated and more expensive equipment. But that does not always have to be the

case. Depending on how the end-product is defined, practitioner-developers may or may not have to acquire additional equipment. This point in the development model presents a prime opportunity for developers to determine exactly what the capabilities of their existing hardware and software are. Those capabilities are then weighed against the product definition to establish whether new equipment needs to be purchased or the end-product needs to be redefined.

It should be noted that certain developers may prefer to conduct some research first and then define the product, rather than the other way around as the development model suggests. Indeed, in some cases, it might be appropriate to do so. Still, in other cases, elements from each of the two stages may be “interwoven”, that is, some product definition work is performed, then some research is conducted, and then more product definition is undertaken. It’s not so important that one stage necessarily precedes the other as it is that all the elements of both stages are considered.

3. *Brainstorm ideas.* In the brainstorming stage of the development model, developers generate as many different ideas as possible that reflect the product definition. The encouragement of developers’ creative energies reduce the possibility that they will pursue the first idea that comes along without considering other, possibly superior, solutions. These ideas may be quick, simple sketches on paper or they could be HyperCard™ stacks that have be “rapid prototyped.” At

this point, any idea is seen as a viable alternative, and judgments regarding feasibility and practicality are withheld until all ideas have been advanced.

4. *Generate design solutions.* Once the brainstorming stage has been completed, all of the ideas forwarded are evaluated on several fronts. Such criteria would include the extent to which the product definition is matched, the feasibility of development based on available resources, the practicality of development based on existing materials, and the degree to which the product supports the previously defined unit goals, lesson objectives, and instructional strategies.

Next, the two or three most favored ideas are selected and then expanded in further detail. Such details would include overall functionality, the size and placement of on-screen objects (fields, buttons, graphics, etc.), font sizes and typefaces, and even screen colors. This information is prescribed on screen design and layout sheets, and developers use these to make decisions about which one of the proposed solutions will likely achieve the highest instructional impact. It is around the one most favored solution that the prototype is created.

5. *Develop the prototype.* Working from the screen design and layout sheets, the developers begin the task of building the prototype. Essentially the prototype is an approximation of the finished product, both artistically and functionally. Depending on the instructional

strategies employed, graphics may have to be scanned, video sequences shot and digitized, audio clips recorded and digitized, and text-based content researched, input, and edited. If the resources permit (particularly people resources), developers may wish to divide these responsibilities among a development group. That is, some persons will be videographers, some editors, some content researchers, some programmers, and so forth. In this respect, developers assume the role of project managers or coordinators, and their role is to see that each of the component pieces are created so that the prototype can be assembled.

6. *Test the prototype.* Once the prototype has been developed, it is tested in the context of real-world users. Ideally, these users would be representative of the kinds of learners that would be interacting with the program in the classroom setting. The developers now-turned-researchers are looking for instances which might diminish the overall instructional impact of the product. This would include problems with students being lost in the application, the program not functioning correctly or reliably, or the product not supporting the projected learning styles of the end-users. The comments and reactions of the prototype testers are compiled, and depending on the results, either adjustments are made to the prototype or earlier components of the design model are revisited and reconsidered. After the adjustments have been performed, the prototype is tested again; the cycle continues until the developers are assured that the

developed end-product will satisfy the goals, objectives, and instructional strategies generated earlier in the *design* model.

7. *Develop the end-product.* Only after developers are satisfied with the prototype's performance will they begin work on end-product development. A list of all the necessary graphics, motion-video sequences, and audio clips is created, and each component is generated. In addition, the authoring environment is selected in accordance with end-product functionality and end-user platform characteristics. Again, developers may assume a role as project coordinators or managers during end-product development or, perhaps, may assume all the roles themselves in bringing the project to completion.

Using the Model: An Example

The following is an example of using the media development model detailed in the previous section. Each of the major components of the model have been identified and are discussed in the context of the product created for the Virginia Museum of Natural History at Virginia Tech.

Define the Product

Since the project was developed for the Virginia Museum of Natural History at Virginia Tech, the first step was to tour the museum to gain a better understanding of what the museum was about and what holdings were maintained in its collections. Throughout the project, Llyn Sharp, the Collections Manager, was consulted frequently and made significant contributions to the project from its inception. A client-developer relationship was established, and each stage of development was conducted subject to approval from the client.

After gaining a basic understanding of the mission of the museum, the developer (i.e., the author of this document) worked with the client to start defining what type of product could be developed that would complement the museum's mission. Since one of the museum's missions was to share its collections with the public at large, ideas were explored to create a product that would both encourage and facilitate public access to the those collections. Since many of the specimens were fragile and could not be brought out into public display, a computerized "digital-image database" of the holdings was conceived.

Given that concept of an image database, it became clear that the product would rely heavily on visuals. At this point, the project began to take shape as a database of selected holdings that would incorporate primarily still-image graphics and text-based information, but it might also be expanded to include audio and video as well. Since the project represented a completely new endeavor for the museum, it was decided that only a prototype would be developed, and lessons learned from the

project would help the museum determine if a larger database, encompassing all the museum's holdings, could be reasonably developed. Accordingly, the prototype would be developed around only a very small subset of the museum's holdings, and an attempt would be made to represent each of the different collections (mammals, birds, insects, etc.). Subsequently, approximately 25 specimens were selected for inclusion in the prototypic database.

At the conclusion of the product definition stage, the developer and the client agreed that the end-product (in this case, the computerized image database) would be designed to foster public access to a small subset of the museum's holdings (content). Moreover, it would be utilized by individual users, rely heavily on visuals, and could be navigated by end-users completely in about one hour.

Perform Research

Based on the product definition, the developer began this stage by conducting an inventory of the available resources. The Learning Resources Center (LRC) and the Education Technology Laboratory (ETL), both at Virginia Tech, already possessed the authoring hardware and software, so the project was deemed achievable from an authoring standpoint. Since the product developed for the museum was a prototype and not a full-scale version of the end-product, the developer was not constrained by the limitations of the end-user platform. Decisions were made, however, to include only those functions that could be implemented on both DOS and Macintosh platforms. That way, the

functionality of the full-scale version would mirror the functionality of the prototype regardless of which platform was chosen for final-product development.

In addition to researching available resources, the developer also identified other similar products already being marketed. One product, a CD-ROM disc entitled *The Virtual Museum*, was purchased and then evaluated in terms of functionality, ease of use, and instructional use. Since it, and others, did not represent the holdings of the Virginia Museum of Natural History at Virginia Tech, the product defined in the first stage of the model was viewed as a worthy project, that is, one that would support the client's mission and reflect its collections.

Brainstorm Ideas

Since the purpose of the brainstorming stage was to generate as many design ideas as possible, several potential prototype scenarios were spawned. The first was simply to create a computerized version, that included visuals, of a book that the museum uses to record data about each specimen in its holdings. Earlier it was mentioned that the specimen data records were kept in one part of the museum while the specimens were kept in another; integrating digitized images into the text-based records would allow researchers and staff members to examine both the records and the specimens at the same time, even from a remote location. So one of the ideas generated initially was essentially an enhanced database, one that provided a bit more functionality than the current text-based version. This was seen as more of a tool for the

museum's staff than as a product that the general public could peruse at its leisure.

Another idea forwarded was to design any host of *instructional* units around the specimens in the museum. For example, lessons could be developed on butterfly identification, insect anatomy, or even the evolution of bears. Since the museum promoted field trip experiences from local public schools, applications of an instructional nature seemed quite appropriate.

Finally, in keeping with the idea of making the collection more accessible to the general public, the concept of an information kiosk was introduced. Although it might include information from the specimen records, it would not necessarily be used as a tool by the museum for maintaining its inventory records. It would, however, make available to the public those specimens that were too large or too fragile to be displayed in the public areas.

At the conclusion of the brainstorming stage, several ideas had been generated that, more or less, supported the outcome of the product definition stage. These ideas were pursued in greater detail at the next stage of the development model, generating design solutions.

Generate Design Solutions

At this point, all of the ideas generated in the brainstorming stage were explored in further detail with the client. Each of the ideas were evaluated in terms of feasibility (based on information compiled during the research stage) and to the extent it was consistent with the product

definition. The client favored the information kiosk theme, and consequently, it was selected and pursued in further detail.

At that time, the client was already working on a text-based workbook on lawn habitats, and design solutions were cultivated around that project. Figure 3 shows one of the initial design solutions for the lawn habitat theme. Later, the project was expanded to include other diverse local wildlife habitats as well. Accordingly, the product design was taking the form of an information kiosk that would tie selected museum specimens to their corresponding local wildlife habitats.

Working with the local habitat theme, the developer laid out sample screen designs for the project. During his conversations with the client, the developer introduced the idea of filming some of the real-life specimens in their habitats as a means of making the product more dynamic. The client agreed with the idea, and screen designs were modified to reflect the incorporation of motion-video sequences.

Develop the Prototype

Working from the screen design and layout sheets, the developer then created the prototype. Before any real programming could take place, all of the individual pieces were constructed first. That work included researching and editing the text-based content, shooting and digitizing the wildlife videos, scanning and editing the still-images, recording and digitizing the audio sequences, and digitizing the specimens from the museum's collection. In terms of the project, the developer played

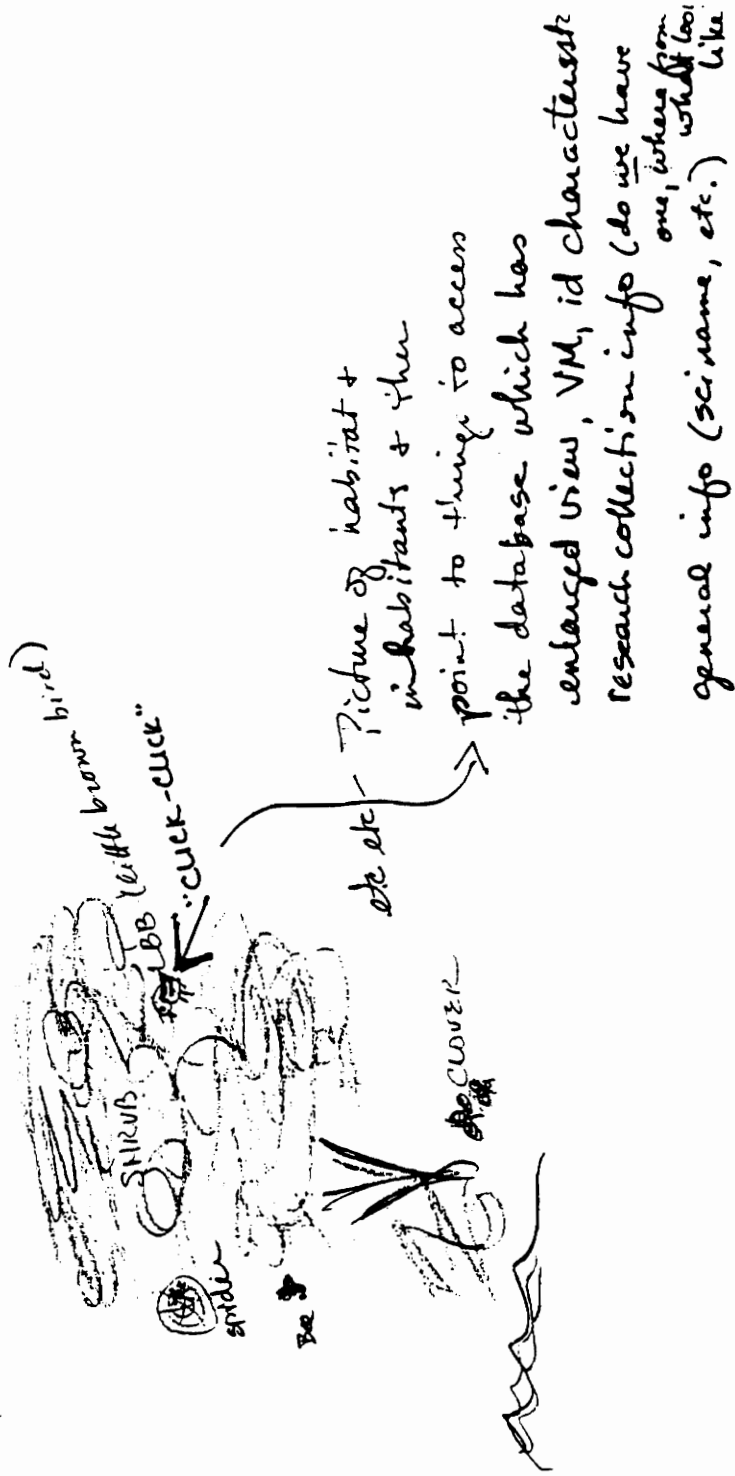


Figure 3
Initial Design Solution for Lawn Habitat

several key roles including programmer, videographer, artist, content expert, designer, and evaluator.

Test the Prototype

After the prototype was assembled, arrangements were made for museum patrons to interact with the developed product. Note that the information garnered during the prototype testing phase applies only to the product developed for the museum. Had the project gone further, that information subsequently would be used to refine the prototype even further. The information obtained during user testing was compiled and appears below.

Users double-clicked, rather than single-clicked buttons: One of the ways that popular authoring environments depart from conventions used by the operating system (and this holds true for both Macintosh and Windows™ platforms) relates to single-clicking an icon versus double-clicking an icon. Those users familiar with graphical user interfaces (GUIs) know that applications are launched and folders are opened by double-clicking on the appropriate icon. However, many of the popular multimedia authoring applications do not permit “trapping” for double-clicks. In fact, unless some provision is made to train users otherwise (particularly experienced users), it can be expected that they will continue double-clicking icons and buttons within the developed application. In most cases, this does not pose any problems, however, developers should be aware that depending upon the authoring

application used, the second mouse click may be “buffered” to RAM. A situation could arise in which the first mouse click takes users to another screen that contains a button in precisely the same location. If that button performs some other task, then the second mouse click (which had been buffered to RAM from the previous screen) could trigger a response from the button on the current screen even though users had not clicked on it! Such unexpected results could leave users confused or frustrated.

Although users did double-click on buttons within the application developed for the Museum of Natural History at Virginia Tech, the buffered mouse click did not initiate any unintended actions on the users’ part. From a developer’s standpoint, some provision should have been made to at least alert them that single-clicking buttons was sufficient.

Some users were unfamiliar with the term “hot spot”: One of the dangers of gaining heightened familiarity with hypermedia-type applications over extended periods of time is to start making assumptions that users will necessarily speak the same language as developers. The term “hot spot” that was adopted for use in the project did confuse some users concerning its function. Although its function was clearly defined in the on-line audio help, many users simply failed to use the help feature. Alternative user-suggested terms included “magnified views”, “close-up shots”, and “zoom areas.”

The “Main Menu” icon was unclear: Several users commented that the graphical representation on the “Main Menu” button “did not make sense.” Since icons represent intended actions or events, it is important that they clearly convey their function to the users with minimum explanation. Accordingly, for this particular application, a different icon should be crafted to represent the “Main Menu”, one that is more in keeping with its function. Additionally, at least one participant commented that the “Main Menu” button should be removed from the main menu, even though that button was “grayed out” and nonfunctional.

Users were unable to scroll backwards through the “general information” card pictures: Once users selected a particular habitat from the main menu, they could then access general information about the specimens residing in that area. A button was included on the general information card that permitted users to view additional digitized images of the specimen; clicking on the button simply cycled through the different images. Unfortunately, no provision was made to allow users to cycle backwards through the pictures; they had to keep clicking the button until the desired image cycled around again. This could have been remedied with a “View Next Picture” and a “View Previous Picture” button.

Another problem with this “view another picture” feature was it did not disclose to the users how many pictures were “in the cycle.” For example, there were four images of canada geese and only three of

cardinals. Consequently, the program could be improved by disclosing to users that they are viewing picture number one of five or picture number three of three, for example. Additionally, it was suggested that the button be renamed from “Another Picture” to “More Pictures” since, in fact, there was more than just one other image in the viewing cycle.

Incorporate audio enhancement of still images: Even though the still images were displayed only in 8-bit color and at 72 dpi, they were perceived as being very realistic by the users. However, some users admitted that they were left wondering, “Why am I looking at this image and what are its significant features?” One suggestion was to attach a spoken explanation (digitized, of course) to each of the images that would emphasize the graphic’s significance. Such an explanation might resemble the following:

“This is a female cardinal. By and large, nature made the female of the species less colorful, although no less important, than her male counterpart. Notice her brownish coloring. This was nature’s way of camouflaging her as she protects her brood in the nest.”

Notice that the explanations do not have to be long and arduous; they simply need to provide enough information to set the context of the image.

Develop the End-product

Since primary interest of the client (The Virginia Museum of Natural History at Virginia Tech) was to explore the kinds of applications that could be developed for a museum setting, the project terminated at the “testing the prototype” stage of the development model. As noted previously, the developed product was not intended to stand as the “finished product” and merely served as the real-world catalyst for which the integration of digital video into computer-based applications were considered.

Summary

The purpose of this section was to illustrate the suitability of the development model in the context of producing a computer-based application that utilizes digital motion-video sequences and still-image graphics. Since the product was informational rather than instructional, no attempt was made to evaluate the product with regard to the specified unit goals and lesson objectives of a formal educational environment. However, any instructional computer-based product, whether supplemental or complete, would need to be assessed at the summative evaluation stage on the measure of its achieved (or perceived) instructional impact. Subsequently, as the course is redesigned, designers will decide whether to include the end-product or redesign it based on that impact.

Conclusion

This study began with the premise that traditional instructional design models, for the most part, provide practitioners with very little guidance with regard to media development and instead, focus much of their attention on the selection of preexisting instructional materials. While this is fine when materials can be identified that support specific unit goals, lesson objectives, and instructional strategies, practitioners are otherwise relegated to constructing their own instructional media. Even though there are numbers of good sources to which they can turn for creating less technologically current media, practitioners will find few of them for developing state-of-the-art media in the context of a systems approach to instructional development. The advent of digital video production tools looks especially promising for instructional development, particularly by practitioners who are no longer satisfied to *select* media, but instead wish to *develop* media. However their integration into CBI also presents some heretofore unrecognized development challenges.

Historically, instructional designers have enjoyed only limited successes in the application of past technologies in educational arenas. Many of the devices were too passive, too inefficient, or too expensive to produce on limited budgets. But recent advances in digital video production technology may finally bring a successful, feasible resolution to those problems.

The leap from the analog world to the digital world is not without its problems, however. Much of the video that exists today, as well as what we see in the world around us, exists in analog form. Technology allows us to approximate the richness of real-world analog images, but at a cost. For all its costs, the advantages of digital video are manifested in decreasingly less-sophisticated computer hardware and in increasingly more-efficient display and reproduction of analog images. The instructional designers' challenge is how to maximize this potential.

This study has attempted to show, through the development of a computer-based application, that existing design models do not adequately represent the development of instructional media based on the advent of new technological advances. It has, however, uncovered some questions which should be studied and answered through further research. Of prime concern is the application of the development model to an instructional, rather than informational, environment. That is, the development model should be implemented and tested in other settings and with other media in light of new technological inventions. This study marks the beginning of a commitment to questioning and understanding and reporting the wealth of opportunities that new technologies bear for instructional purposes and to see that they are able to sustain maximum instructional impact. As Braswell (1987) notes:

Existing design models provide a strong, well-tested foundation from which to proceed with instructional design. Designers of instruction must, however, have the ability to

adapt these models to reflect the changes which technology will inevitably bring. It is through this adaptability that instructional design will be able to benefit both from the strengths of existing design models and the potential of new technologies (p. 96).

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Appendix A

Author's Background

My interest in computers emerged about 13 years ago, not long after my father purchased an Apple II⁺ personal computer. As computer novices, we studied Applesoft BASIC and began developing simple “household” programs. Eventually, the Apple II⁺ gave way to an MS-DOS personal computer, and I gained greater experience with word processors, spreadsheets, and databases. In 1987, I purchased my first Apple Macintosh computer, a Mac SE, and I was forever changed by its power, flexibility, and ease of use. As both a student and a teacher, I was fascinated by its potential, yet I knew very little of how to apply it. To that end, I committed my studies and my time to forging those understandings.

As a former graphic communication instructor, it was almost “natural” that I would focus on digital imagery given my interest in both computers and the visual communication medium. However, prior to this study, I had also gained considerable authoring experience on both Macintosh and MS-DOS platforms using such environments as QUEST[™], Toolbook[™], HyperCard[™], SuperCard[™], IBM InfoWindow Pilot[™], Super Pilot[™], and also with the Pascal programming language. Moreover, I had completed graduate studies in the areas of computer interfacing, interactive video design and development, digital video interactive (DVI), desktop publishing, multimedia development, and interface design. The point is, I came into this study with a fairly

substantial grounding in the field of computers, yet I've never felt like I've known it all. Perhaps that's precisely the excitement and the challenge that instructional technologists relish--to continually strive to push the technology to new horizons that, at this moment in time, seem nearly limitless.

Appendix B

Sample Transcript and Analysis of Data Obtained from Design Notes and Participant Comments

10 October 1992 design notes

Researcher: This project will rely heavily on digitized still-image graphics. My choices are to display them in either 4-bit, 8-bit, 16-bit, or 24-bit color. I know that the more realistically images are displayed on-screen, the greater the files sizes of the digitized images. However, can end-users really discriminate between images displayed at different pixel-depths? My challenge is to display the images as realistically as possible while minimizing the image file size and maximizing precious disk storage space. What I had better do is scan and display some images at various pixel-depths and see if users can really tell the difference.

11 October 1992 design notes

	4-bit	8-bit	16-bit	24-bit
Picture #1	77kb	366kb	2.3mb	5.6mb
Picture #2	124kb	707kb	3.6mb	7.1mb
Picture #3	90kb	403kb	2.9mb	6.2mb
Picture #4	44kb	267kb	1.9mb	4.9mb

Researcher: I've scanned and logged the image sizes, now I need to see if users can really tell the difference between them.

13 October 1992 Participant notes (partial)

Researcher: I'm going to display some pictures on the screen and I want you to point out the picture that looks the best to you. (The four different images of Picture #1 are then displayed on the screen.)

User: Oh, I think this picture looks the best (pointing to the 24-bit image).

Researcher: Well, what about this image over here (pointing to the 4-bit image)?

User: That picture looks weird. I can hardly tell what it is.

Researcher: If you hadn't had these other pictures next to it on the screen to view, would you have known what this is?

User: No.

Researcher: What about this picture over here (pointing to the 16-bit image)? Can you tell me what the difference is between this one and the one you picked as best?

User: Well, not really. They both look pretty much the same. I wasn't really sure which one to pick. I thought they might both be the exact same picture.

Researcher: How realistic are those two pictures?

User: Very.

Researcher: What about this last picture (pointing to the 8-bit image)?
How realistic is this picture?

User: It's OK, I guess. It's certainly better than the one over there
(the 4-bit image) but not as good as the other two.

Researcher: Could you tell what the picture was in this image?

User: Definitely. It just doesn't look as sharp and clear as those
other two.

*The test then continued with the Pictures 2-4 and with two additional
users.*

15 October 1992 design notes

Researcher: At this point, I definitely know that 4-bit pictures are out.
The users seemed to have a hard time distinguishing
between the 16-bit and 24-bit color images. The 16-bit
images lost a bit of detail over subtle color changes. The 8-
bit images were judged to be fairly realistic, yet they take
up the least file storage. One thing I hadn't counted on
was the time it took to load those images to the screen.
Those 24-bit images really took some time. Not only do I
need to consider realism of the images, but I need to
consider their effect on the overall run-time performance of
the end-product. There's no way that users will sit and
wait for a whole string of those images to be displayed.
They'll be bored silly.

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Education

- Ph. D., Instructional Technology*; July, 1993.
Virginia Polytechnic Institute and State University; Blacksburg, Virginia.
- M.S. Ed., Technology Education*; December, 1988.
Virginia Polytechnic Institute and State University; Blacksburg, Virginia.
- B.S. Ed., Technology Education*; March, 1987.
Virginia Polytechnic Institute and State University; Blacksburg, Virginia.

Professional Experience

- Assistant Professor of Education*; August, 1993.
Old Dominion University, Norfolk, Virginia.
- Graduate Assistant*; August, 1992 - May, 1993.
Education Technology Laboratory (ETL).
Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Provided instruction and technical assistance to faculty and students in the installation and use of software and hardware in the Macintosh, MS-DOS, and Apple II environments; researched and recommended hardware and software purchases; developed and installed Local Area Networks that supported multi-platform connectivity; upgraded, maintained, and performed system diagnostics on Macintosh, IBM, and Apple II computers and peripherals; scheduled the lab's graduate assistants; conducted ETL user software training sessions.

Graduate Assistant; July, 1992.

Education Technology Laboratory (ETL).
Virginia Polytechnic Institute and State University, Blacksburg,
Virginia.

Assisted in the instruction of Summer Professional Development Workshops; content areas included multimedia development in the Macintosh and MS-DOS environments, telecommunications, and desktop presentation graphics.

Graduate Assistant; August, 1991 - May, 1992.

Education Technology Laboratory (ETL).
Virginia Polytechnic Institute and State University, Blacksburg,
Virginia.

See *Graduate Assistant; August, 1992 - December, 1992* for responsibilities.

Doctoral Internship: Instructional Designer; May, 1991 - August, 1991.

Kraft Foodservice.
Corporate Headquarters, Deerfield, Illinois.

Revised training materials for nation-wide implementation of management development courses; designed, produced, and analyzed the results of a survey assessing computer training needs at corporate headquarters; programmed the KFSTI computerized database; coordinated the ordering, packaging, and shipment of KFSTI training materials; conducted software training seminars; participated in OSM and MSW meetings; produced KFSTI presentation graphics.

Graduate Assistant; August, 1990 - May, 1991.

Education Microcomputer Laboratory.
Virginia Polytechnic Institute and State University, Blacksburg,
Virginia.

See *Graduate Assistant; August, 1992 - December, 1992* for responsibilities.

Instructional Designer; May, 1990 - September, 1990.

Institute for the Study of Exceptionalities.
Virginia Polytechnic Institute and State University, Blacksburg,
Virginia.

Designed, developed, and conducted seminars that provided high-school principals and administrators with strategies for the

successful implementation of the Special Education Process at the school-building level.

Instructor; July 1-28, 1990.

Governor's School for Science and Technology.
Virginia Polytechnic Institute and State University, Blacksburg,
Virginia.

Courses taught: Computer-aided Drafting and Design (CADKEY);
Desktop Publishing (Aldus PageMaker).

Graduate Assistant; August, 1989 - May, 1990.

Education Microcomputer Laboratory.
Virginia Polytechnic Institute and State University, Blacksburg,
Virginia.

See *Graduate Assistant*; August, 1992 - December, 1992 for
responsibilities.

Consultant; January, 1989 - May, 1989.

Graduate School.
Virginia Polytechnic Institute and State University, Blacksburg,
Virginia.

Conducted seminars demonstrating Macintosh software
applications and their capabilities as they pertain to desktop
publishing.

Graduate Teaching Assistant; September, 1987 - June, 1989.

Graphic Communication Technology Laboratory.
Virginia Polytechnic Institute and State University, Blacksburg,
Virginia.

Taught Introduction to Graphic Communications course; content
included desktop publishing, offset lithography, line and
continuous tone photography, screen printing, gravure,
flexography, and computer graphics generation.

Teacher; March, 1987 - June, 1987.

Blacksburg High School, Blacksburg, Virginia.

Employed as a Graphic Communications teacher in a program
that provided students with relevant educational experiences in
design and layout, computer typesetting, screen printing,
continuous tone and line photography, and offset lithography.

Presentations

Does Hypermedia Really Deliver--Where Should We Be Looking? A paper presented at the annual Conference of the Eastern Educational Research Association; Hilton Head, South Carolina; March, 1992.

The Effects of Matched and Unmatched Student Learning and CAI Teaching Styles on Student Achievement: A Research Prospectus. A paper presented at the annual Conference of the Eastern Educational Research Association; Clearwater, Florida; February, 1990.

Publications

Purcell, S. L. (in press). Integrating digital video into computer-based applications: Picking up where analog video falls short. Proceedings of the 34th Annual Convention of the Association for the Development of Computer-based Instructional Systems.

Professional Organizations

- Phi Delta Kappa (PDK)
- Association for the Development of Computer-based Instructional Systems (ADCIS)
- Association for Education and Communication Technology (AECT)
- American Educational Research Association (AERA)
- Eastern Educational Research Association (EERA)
- Council on Technology Teacher Education (CTTE)
- Epsilon Pi Tau (honor society)

Other Professional Activities

Session moderator: Commonwealth Outstanding Dissertation and Faculty Research Conference; Blacksburg, Virginia; April, 1992.

Session chair: Eastern Educational Research Association; Hilton Head, South Carolina; March, 1992.

Graduate Honor Court Justice; Virginia Polytechnic Institute and State University;
August, 1990 - May, 1991.

Session chair: Eastern Educational Research Association; Clearwater, Florida; February, 1990.

Newsletter Editor for the Multimedia Special Interest Group of the Association for the Development of Computer-based Instructional Systems; October, 1989 - May, 1990.

Graduate Honor Court Justice; Virginia Polytechnic Institute and State University;
August, 1988 - May, 1989.

Session chair: International Visual Literacy Association; Blacksburg, Virginia; October, 1988.

President, University Students in Technology Education; Virginia Polytechnic Institute and State University chapter; August, 1986 - May, 1987.

Scholarships

- Virginia State Scholarships: 1988, 1989, 1990, 1991, 1992, 1993.
- Graphic Arts Technical Foundation: 1985 - 86.

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