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An Assessment of Asynchronous Transfer Mode (ATM) Training for Educators

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by

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A Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

School of Computer and Information Sciences
Nova Southeastern University

1996

We hereby certify that this dissertation, submitted by Dan A. Niswander, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

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Certification Statement

I hereby certify that this dissertation constitutes my own product and that the words or ideas of others, where used, are properly credited according to accepted standards for professional publications.

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An Abstract of a Dissertation Submitted to Nova Southeastern University
in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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The purpose of this dissertation was to develop and evaluate a hypertext-based training tutorial/guide on asynchronous transfer mode (ATM) technology for use by school district educators and technology planners. A review of literature indicated training needs on new broadband technologies were not being adequately met from the point of view of an educational environment. An interactive hypertext solution was proposed, designed, and developed based on the needs of adult learners. An analysis of these needs indicated adults prefer flexibility in navigating between training topics as well as in the pace of material presentation, that is, whether to proceed at a faster or slower pace based on their personal preference, not the pace selected by an instructor. Interactive hypertext was found to support these specific needs. The procedures followed in this study included the selection of an appropriate authoring system, development of the tutorial/guide on ATM technology based on a structured methodology that focused on hypertext development, and an evaluation of the tutorial/guide. This evaluation included measuring its learning effectiveness through the use of pretests and posttests as well as an evaluation of the population's preferences, attitudes, and opinions toward this type of learning (hypertext-based) as measured by a comparison of precourse and postcourse surveys. A case-study research approach was proposed. The results, as evaluated by a comparison of mean scores, indicated that there was a statistically significant higher mean score on the topic mastery posttest than on the pretest when the hypertext-based tutorial was given to each participant. Furthermore, the preferences toward this type training also increased significantly as measured by the comparison of means of the precourse and postcourse preference surveys.

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Introduction

Relevance of the Study

Purpose and Significance

The purpose of this dissertation is to develop and evaluate a hypertext-based training tutorial/guide on asynchronous transfer mode (ATM) technology for use by school district educators and technology planners. This contribution is significant, as a review of literature indicated there is considerable support for increased involvement on the part of school district staff in planning for the purchase, implementation, and use of new computer and telecommunications technologies (Branscum, 1992; Dyrli & Kinnaman, 1994d; Friedman, 1994; Kaman, 1993; Kinnaman, 1994; VanSciver, 1994, 1995). Increased training in these technologies is required to prepare educational staff for this involvement. The review of literature indicated this training is lacking (Dyrli & Kinnaman, 1994a; Friedman, 1994; Gross-Peck & Beyda, 1993; Killian, 1994; Pickelsimer, 1994; Van Horn, 1995a; West, 1995).

A case study approach, based on an evaluation of the use of hypertext-based ATM technology training for professional staff in the Seminole County Public Schools, was proposed. This evaluation included an analysis of learning effectiveness and attitudes surrounding the use of this type of training.

Background

The integrated services digital network (ISDN), or narrowband ISDN (N-ISDN), is one of the major services leading toward the integration of voice, video, and data transmission via the same network (Tanenbaum, 1988). This transport service is currently offering network transmission at a rate of 64 Kb/s (Taylor, 1993b). Broadband ISDN (B-ISDN), the next phase of the evolution toward voice/video/data integration, is a high-speed service with rates extending far beyond those of N-ISDN. B-ISDN rates are expected to range from 1.5 Mb/s in the U.S. (AT&T Bell Laboratories, 1992) to 622 Mb/s and above (Kaman, 1993; Salo, Cavanaugh, Spengler, & Thomas, 1992). Heinanen (1995) cited speeds of up to 2.4 Gb/s as potential for B-ISDN.

The transfer mechanism chosen for B-ISDN implementation is the asynchronous transfer mode, or ATM (Chen & Liu, 1994; International Telecommunication Union, 1991d). This technology has been in the laboratories since 1987 (Briscoe, 1993). ATM employs a connection-oriented technique that provides for the transport of fixed-length cells from a variety of sources (Salo ., 1992). According to these authors, these connections can be switched, semi-permanent, or permanent.

Broadband Technologies in Education

Pilot projects and installations exploring the educational opportunities presented by B-ISDN and ATM technologies are currently underway. The North Carolina Information Highway (NCIH) began by providing broadband ISDN capabilities to three sites in North Carolina via ATM switches and synchronous optical network (SONET) links, the primary components of the broadband ISDN technology (Bernier, 1993; O'Shea, 1994a).

Initially, the project provided three-dimensional graphics and computer-generated modeling to assist doctors in planning radiation therapy. This was the first fiber network in the nation to deliver information at the B-ISDN rate of 622 Mb/s (Bernier, 1993; Grovenstein, Pittman, Simpson, & Spears, 1994). The NCIH was "an experiment of fiber optic networking, interactive scientific computing, supercomputer communications, interactive graphics techniques, and medical research" (Bernier, 1993, p. 10). The number of sites accessing the network increased from the original three to thirty by late 1994 with approximately fifteen more scheduled for access (Grovenstein et al., 1994).

Five areas of concentration have been identified as applications to be delivered via the NCIH (Patterson & Smith, 1994). These are education, health care, criminal justice, economic development, and government efficiency. Education applications include (1) exposing students to a variety of technologies they may encounter as they enter the work force and (2) video field trips where students can investigate potential occupational choices without actual travel. Health care applications now provide advanced diagnostics and treatment, expert consultation availability to rural areas, continuing medical education, and improved insurance claim processing. Criminal justice applications deliver video arraignments, depositions, and appearances without the related transportation expenses while providing training alternatives for inmates. Economic development applications make North Carolina resources available to prospective businesses regardless of their location in the state, facilitating growth in the state's more depressed areas. Government administrative areas can become more operationally efficient via use of the network. For example, redundant databases can be eliminated, video conferencing can reduce travel expenses, and information sharing among different state agencies can be increased to the benefit of the public.

A second example of the planned use of broadband technologies for educational purposes is offered by the state of Iowa where learning opportunities are being improved through a distance learning network ("Iowa taps," 1994). In Iowa, access to a fiber-optic network is planned for 3,000 sites that will provide transport of full-motion video, audio, and data communications. The plans call for (1) every county in Iowa to have at least one classroom connected to the network and (2) each citizen to be no more than twenty minutes from access to the network.

A third example is provided by the Fort Bend School District in Texas, which has interconnected its local-area networks (LANs) through a wide-area network (WAN) to link four administrative buildings, an alternative school, a technical-education school, five high schools, eight middle schools, and twenty- eight elementary schools (Aaron, 1995). This WAN became operational August, 1994. The interconnections are mixed between ISDN, T1, fractional T1, and 56 Kb/s lines. Inter-district communication, shared educational programs, modem banks, electronic mail, and access to outside educational information sources are provided via the implemented WAN. Diagnostics and maintenance of the network can be performed from any of the connected sites.

A fourth example of broadband implementation planning is Pacific Bell's announcement of its intention to provide broadband capabilities to all public schools, libraries, and community colleges in its territory by 1996 and to link all classrooms via its broadband network by the year 2000 (O'Shea, 1994b). O'Shea further stated that Pacific

Bell is also working with other telecommunications providers to expand these goals and eventually provide broadband capabilities outside its defined territory.

Also in California, San Jose State University, San Francisco University, and California State University, Fullerton, are beginning to participate in a unique graduate program in library and information science (Littman, 1996). This program "includes collaborative videoconferencing and simultaneous access to distributed software and multimedia resources" (p. 179). ATM networks will assist in bringing these distance education applications to reality. Further, ATM will be used in San Jose to enable video and voice exchanges between marine experts at the Monterey Bay Aquarium and youngsters from San Jose's Tech Museum of Innovation. This project is being sponsored by the California Research and Education Network (CalREN).

Another example of broadband migration is the deployment of an ATM backbone connecting all classrooms in the Mt. Clements, Michigan, School District (Feldman, 1995). This 200 Mb/s network is expected to provide access for the district's 750 teachers and 3,300 students to educational software that includes Jostens Learning Company's Writing Center, Broderbund Software products, and various spreadsheet and word processing applications. This network was operational in September, 1995.

A further example of a pilot project currently under study was on launched by Telecom Finland in May, 1993 (Heinanen, 1994). This pilot network connects two universities in Helsinki and Tampere, Finland, 120 miles apart. In 1994, the ATM backbone of this network was upgraded from 34 Mb/s and now transports data at a rate of 155 Mb/s. The overall experience from this ATM pilot project was "very positive" (p. 5109).

The single real problem encountered in this pilot project was the lack of availability of high-quality ATM adapter cards that offered any form of traffic rate control. Specifically, according to Heinanen, the problem was that the cards made available for the pilot project sent ATM cells through the network faster than they could be received. This lack of control over the rate of traffic resulted in many discarded cells.

A final example of a broadband implementation is the Partnership for Access To Higher (PATH) Mathematics project (Chavkin, Kennedy, & Carter, 1994). This network was funded by the U.S. Department of Education and implemented by Southwest Texas State University (SWTSU), San Marcos School District (SMSD), and the San Marcos Telephone Company (SMTC). The goal of PATH Mathematics is to investigate ways to provide access to algebra and geometry through the use of a fiber-optic network. Its objectives are to:

- Use digital fiber optics to develop and implement a new prealgebra curriculum;
- Develop and implement a systematic tutoring program with mathematics majors at SWTSU; and
- Develop and implement a support program for SWTSU interns to mentor and provide social services and motivational activities to SMSD students interested in furthering their education.

The interactive system used by PATH Mathematics, as shown in Figure 1, consists of three basic components; an interactive teaching studio at the SWTSU, an interactive high school classroom, and a digital, fiber-optic network linking the sites (Chavkin et al., 1994). The teaching studio consists of cameras, a microphone, television monitors,

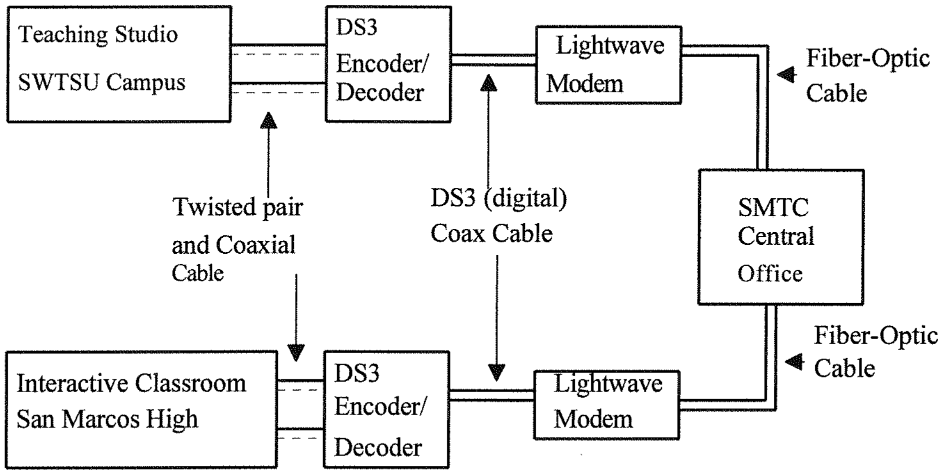

Figure 1. PATH Project Network (Chavkin et al, 1994)

and other support video and audio equipment. The total cost to equip this studio is approximately $17,000. The classroom was specially designed and equipped with cameras, microphones, and television monitors. The equipment for this classroom costs approximately $21,000. The fiber-optic network provides sound and full-motion video at DS3 rates (45 Mb/s).

Chavkin et al. (1994) have reported significant improvement in student achievement and aspiration for higher education based on results achieved from the PATH project. A survey tracking the success of PATH "clearly showed a positive response to the project and to the interactive network in particular" (p. 38). The use of the network has subsequently expanded beyond its original objectives. SWTSU has begun a concurrent enrollment plan with SMSD for calculus, English composition, and foreign language courses. The SWTSU School of Education also uses the network to provide their elementary education students with a distance, field-based approach for their undergraduate work.

Involvement of School District Personnel in Technology Planning

In addition to these broadband pilot projects, the overall market for computer and telecommunications technologies for use in educational environments is growing rapidly. According to the 1994 article "Interactive Education: Opportunities Abound for Investors and Students" from the Multimedia Business Report, "While the educational market holds promise, it is a complicated one in which the status of the textbook is changing and the line between the school and the home is blurring" (p. 7). This article demonstrated the strength of the market by indicating that spending on technology-related instructional materials is expected to reach $5.7 billion in 2003 compared with $3.8 billion for traditional printed materials. The article went on to say that technology-related educational products should be "based in solid pedagogy, reflecting an understanding of the learning process and child development. Teachers need to relate to the products, which should be correlated to what is done in the classroom" (p. 7).

Kaman (1993) also supported increased involvement and participation on the part of potential users of broadband technologies. In speaking of these new technologies, the author maintained that "greater public involvement, strategic partnerships, and universal cooperation are essential for its long-term success. Strategic partnerships are critical for providing more cost-effective and complete solutions for customers and for improved interoperability . . . Greater public involvement must complement the technological development" (p. 18). Unfortunately, according to this article, technical literature is rare "that addresses social consequences or issues related to the social/cultural impact of that technology on its users. There is a tendency to strive for technological richness and lose sight of the customers' needs" (p. 13).

Long-range planning for implementation of these computer and telecommunications technologies in schools has become critical. Without a sound technology plan, school districts run the risk of making poor hardware and software purchasing decisions. Acting without a plan has the effect of wasting resources and diminishing the impact of the use of technology in schools (Dyrli & Kinnaman, 1994d). In addition, a strategic plan provides school districts a focus by which they can identify and channel existing resources necessary to implement their technological decisions (VanSciver, 1995).

There are indications that school districts are beginning to take a more proactive role in technology planning (VanSciver, 1994). According to VanSciver, in Delaware, for example, a school district made a decision to create a strategic long-range technology plan. In support of this plan, school district planners identified their technology goals, which not only included the acquisition of "state-of-the-art" technology, but also emphasized staff training. VanSciver noted that by 1995 "100 percent of the staff would be using tools of technology on a daily basis, and by 1997, 100 percent of the students would be doing so as well" (p. 72).

Outsourcing is a means by which organizations can benefit from specific professional expertise without adding permanent staff (Weston, 1996). Outsourcing may have financial advantages as experts and other resources are available, and hence paid for, only as needed. The experts can be released as soon as projects are completed. A major disadvantage of outsourcing is that the expertise is no longer available once the experts are released. External consultants often provide this outsourcing capability. Consultants as well as communications service providers are beginning to play a major role in planning for the future communications needs of school districts ("Interactive education," 1994). The reason for this is the growing interest in education as an industry and a market opportunity for broadband technology providers and investors. Paul Kagan, moderator at a seminar on investing in interactive education, claimed that "we are in the foothills of this industry in terms of growth" (p. 7).

An example of this involvement on the part of consultants and technology suppliers is provided by a recent proposal submitted by Comsul Ltd, a communications consultant, to upgrade the Seminole County (Florida) School District's telecommunications infrastructure (Pickelsimer, 1994). Comsul's plan called for an expenditure of over $27 million over the next five years for an anticipated implementation of several technologies related to broadband ISDN. B-ISDN services proposed by Comsul included the installation of fiber-optic cable throughout the school district, wide-area video networking, and video teleconferencing. In addition, an interactive television service pilot project was proposed for five schools within the school district.

This expenditure might have been approved by the school board had it not been for the efforts of Wynn Pickelsimer, a middle school technology facilitator in the Seminole County School District. Pickelsimer had been an employee of the school district for over twenty-five years. During that period, he served in such technology-related positions as media evaluator, school technology chairman, science department chairman, manager of the voice mail system, LAN administrator, staff telecommunications instructor, and software tester. Pickelsimer had also been the recipient of two technology-related grants including one for a telecommunications project. Additionally, Pickelsimer was an adjunct instructor in technology at the postgraduate level at Stetson University. In Pickelsimer's then-current role as school technology facilitator, he worked with the middle schools' staff in matters dealing with the installed computer and telecommunications products and technologies.

Pickelsimer provided a detailed evaluation of the communications growth plans recommended by Comsul (Pickelsimer, 1994). Although he was not formally asked to participate in this planning project, he documented over eighty issues lacking or in error in the consultant's proposal. Examples of these included the following:

- The plan called for teachers to enter attendance and grades via classroom data terminals located in each classroom. However, the plan did not address equipping each classroom with a terminal nor was a network traffic study conducted to determine the load on the proposed network even though voice and video would also be contending for the same resources.
- The consultant's proposal did not address the network security measures necessary to allow for entry of grades and attendance information from a classroom-based terminal.
- There were no provisions for continued support of existing technology-related equipment installed at the schools.
- A central voice processor (at a cost of $1.4 million) was proposed with no

backup plan or equipment in case of failure. This was particularly critical as all voice calls and school bells were to be centralized and controlled by this equipment.

- A teleconferencing function was to be made available. Operational costs and issues, however, were not addressed in the plan.
- Staff training was not addressed.
- Operations, administration, and maintenance (OA&M) issues, staffing, and related costs were not addressed.

Pickelsimer stated that "conversations with [technical staff from the school district] demonstrated the limited scope of the individuals actually involved in the decision making process of this program" (1994, p. 3).

Kinnaman (1994) further supported increased involvement on the part of the school district staff in planning for the implementation of computer and telecommunications technologies. This author cited a visit to a school district that had recently made a substantial investment in technology. Kinnaman stated the school district's major mistake was launching this key initiative without first establishing broad ownership among the faculty and staff. This ownership, according to the author, begins with involvement in the decision-making process surrounding the purchase, implementation, and use of new equipment and facilities to include initially defining expectations of how the technology is to be used.

VanSciver (1995) also supported increased staff involvement in planning for and implementing technological initiatives. This author stated:

> We realized early in our process that no program in our district would enjoy success in the absence of staff and community member ownership. That ownership is best realized if staff and community members have opportunities to provide their input in the decision-making process. (p. 28)

In a series of articles by Dyrli and Kinnaman (1994a, 1994b, 1994c, 1994d, 1994e), staff development and involvement in the implementation of new technologies were further stressed. In planning for the implementation of these new technologies, the authors stated:

> If schools are really to improve, teachers can't settle for limited or second-rate technology resources. Individually and collectively, we need to take an active role in learning about technology and in determining and then articulating-the basic technology needs of our classrooms. . . It is time for teachers to make technology a well-defined priority. (1994a, p. 14)

A key strategy for school improvement, presented by the authors, is the development of a technology plan. The authors suggested three specific activities for classroom teachers supporting effective plan development. First, goals for the teachers should be clearly articulated. Next, staff should participate in professional growth activities to expose themselves to specific technologies and related applications. Finally, support from administrators should be sought.

Need for Increased Technology Training for Educators

Dyrli and Kinnaman (1994a, 1994b, 1994c, 1994d, 1994e) continued to stress increased staff development throughout their series of articles. In supporting this critical need, they reported the findings of a technology committee from Windham, Connecticut. This committee "found that teachers wanted more technology-related professional development, but they didn't want to put in long hours after school" (1994c, p. 48). The authors further suggested that a district priority should formally be established and implemented to ensure that all teachers are offered "technology-related professional development" (1994d, p. 54). It is important however, according to these authors, that this development be "much more customized to the needs, inclinations, schedules, and experience levels of the teachers toward whom it is targeted" (1994c, p. 52).

An overall lack of training in telecommunications technologies on the part of school district staff and planners has also been recognized by Killian (1994) during summer training sessions on the Internet. According to Killian, "Fear of the Net has several causes: technological, pedagogical, and psychological. To some extent each cause aggravates the other two . . . They (teachers) get little or no training - or if training is available, it's too far from their own classrooms" (p. 86).

Gross-Peck and Beyda (1993) also noted the gap in staff development. These authors claimed that, due to the high cost of implementing technological initiatives, school districts have "little left over to provide the needed staff development" (p. 38).

West (1995) summarized a report prepared by the U.S. Office of Technology Assessment, a research agency of Congress, that provided further evidence of educators' lack of technology training. The report indicated that, although public schools have spent more than $2.13 billion on computers and other equipment, less than 15 percent of that money was used for training and technical support. West stated, "Given the nation's interest in providing education for students, the lack of attention to teachers and technologies is ironic . . . For at the center of effective use of instructional technologies by students are those who oversee the daily activities of the classrooms - the teachers" (p. 11). The author continued in summarizing the conclusions of the report by indicating that, although there appears to be a relatively broad base of equipment, schools spend too little in training educators in the technologies and their effective use. Barriers include (1) a lack of a clear vision or rationale for technology use and (2) a lack of training and technical support.

Van Horn (1995a) was particularly critical in his analysis of the state of technology awareness on the part of school staff. He stated:

> The impact of technology on schools grows in proportion to our understanding of it. Since few teachers know much about technology, the impact of technology on schools is, at present anyway, minimal. This is a shame, and the shame falls squarely on teachers and administrators - period. (p. 420)

This author continued by asking "tough and embarrassing questions" including "When will we realistically assess the magnitude of the problem of teaching teachers about technology?" (p. 420). Van Horn believed the public school system is teaching everyone except teachers. The author further claimed that most American school districts spend a very small portion on the education of their teachers and what they do spend is spent poorly. Johnson & Johnson is cited as spending 12-15% of its annual salary budget on training. Many other corporations pay college tuition for their employees. School districts, on the other hand, in addressing the technology training needs of the staff "train for an hour, after school, in the cafeteria" (p. 420).

Kingston, Morgan, and Wagstaff (1992) also supported the concept of increased development in new technologies for teachers. This development is necessary to assist the school planning staff in making judgments about the purchase, implementation, and use of new technologies, for example, in determining when to dispense with a particular technology and when to continue with its use. Kingston et al., claimed there are many cases in which developments have been technology-led without sufficient strategic school-district planning. According to these authors, implementation of a strategic planning approach for new technologies will be a major challenge for schools. This planning is characterized by establishing needs, determining priorities, and communicating both to product providers. The authors suggested that an on-going investment in staff development is critical for these planning efforts to materialize.

The need for teachers to become more familiar with computer and telecommunications technologies has also been stressed by Friedman (1994). As technology is so pervasive in business and industry, according to the author, it will "inevitably become more widely deployed in schools" (p. 89). According to Friedman, the integration of technology should be an educational issue. Friedman further noted that teachers must be involved with technology and that additional training efforts are needed. This author claimed "a coordinated strategy for utilization of the technology should be laid out to ensure the technology is not limited to small areas. Teachers must be on the forefront of technology" (p. 89).

Although computer and telecommunications technologies in general were considered critical for consideration by school district planners, Dyrli and Kinnaman (1994e) cited the convergence of computer, telephone, and television as "perhaps the most significant trend in the evolution of technology" (p. 94). They continued by stating "there is no trend more important to the future of technology - and to education - than networking" (p. 96). The two key areas of impact provided by this technology are (1) global telecommunications, the ability to be connected to any information resource anywhere, and (2) real-time multimedia. In a later article, Dyrli and Kinnaman (1995) suggested that in the future, education will cease being location-dependent and that learning at home will become prominent through home-school-community network connections.

The importance of networking has also been stressed by Eberlee (1994). This author stated that this technology is underdeveloped in the education sector. The capability of broadband networks to provide multimedia and distance learning in real time underscores its importance.

Further support for the importance of increased use of advanced telecommunications capabilities in schools was provided by West (1995). This author credited the Director of the U.S. Office of Technology study, mentioned previously, in stating a key capability of this technology is its ability to allow teachers to "break the isolation of the classroom and share ideas and techniques and to learn from colleagues collaboratively" (p. 11).

Finally, Mageau (1994b), in discussing the technology development needs of school principals, stated telecommunications "is the number one technology for principals (teachers and kids too)" (p. 17). As Mageau pointed out, online networks will provide a means by which innovators in education can find one another and share ideas in a supportive environment.

Statement of the Problem

ATM in Education

Networking and telecommunications have been cited by several authors as the most critical emerging technology for the educational environment (Eberlee, 1994; Mageau, 1994b; West, 1995). Dyrli and Kinnaman (1994e) have taken this position one step further in stating the integration of voice, data, and video may be the most significant trend today in the technological evolution of networks. ATM is at the heart of this integration (Chen & Liu, 1994; International Telecommunication Union, 1992d).

According to the literature, there are a number of ATM/broadband networking pilot projects and implementations currently underway in educational environments (Aaron, 1995; Bernier, 1993; Chavkin et al., 1994; Feldman, 1995; Grovenstein et al., 1994; Heinanen, 1994; "Iowa taps", 1994; Littman, 1996; O'Shea, 1994a, 1994b; Patterson & Smith, 1994). Pickelsimer (1994) and Kinnaman (1994) have both pointed out that not all of these broadband projects are as successful as they should have been. These authors suggested that a lack of staff involvement contributed in a major way to the problems encountered in the projects.

Staff Involvement in Installation and Implementation

For a successful migration to broadband technologies, the literature suggests school district staff become more involved and actively participate in the decision process (Branscum, 1992; Dyrli & Kinnaman, 1994d; Friedman, 1994; Kaman, 1993; Kinnaman, 1994; VanSciver, 1994, 1995). This involvement would include decisions surrounding the selection, implementation, and use of computer and telecommunications technologies in the school environment. Hindering this involvement, however, is a knowledge gap on the part of school district staff members in this area as suggested by several authors (Dyrli & Kinnaman, 1994a; Friedman, 1994; Gross-Peck & Beyda, 1993; Killian, 1994; Pickelsimer, 1994; Van Horn, 1995a; West, 1995).

To close this knowledge gap, there is broad support for increased training on the role and significance of computer and telecommunications technologies for school district teachers and technology planners (Branscum, 1992; Dyrli & Kinnaman, 1994c, 1994d; Friedman, 1994; Grosse-Peck & Beyda, 1993; Killian, 1994; Kingston et al., 1992; Mageau, 1994a; Van Horn, 1995a, 1995b; West, 1995). Branscum (1992) emphasized that any training in the area of technology should be based on comprehensive research.

Relevance and Significance

The purpose of this dissertation investigation was to determine an effective approach by which teachers, school district technology planners, and other staff could increase their knowledge of ATM and its relationship to broadband networking concepts. A hypertext-based tutorial/guide for use by educators was proposed as a solution to this problem. A case study approach for measuring the effectiveness of the ATM tutorial/guide was suggested as a means by which the proposed solution could be evaluated.

The objectives of the dissertation did not include research into how to successfully implement broadband technologies into school environments. Instead, the purpose was to demonstrate that hypertext-delivered training would offer a solution to closing the knowledge gap demonstrated in school district staff that has created a barrier hindering their increased involvement in the migration process; selection, implementation, and use of these new technologies. Through increased use of effective training, and hence more involvement, it is suggested that broadband projects in school environments will be more successful.

Barriers

A major issue addressed by this study was sample selection. An appropriate sample size was suggested in the research, as further discussed in Chapter 3, Methodology. However, there were unknown potential barriers related to whether the school district staff would (or could) participate in the study. This barrier did not manifest itself in a lack of participants, however, as an adequate number of school district staff members were available for sample selection.

Second, an authoring system to produce the hypertext-based ATM tutorial/guide was selected based on an analysis discussed in Chapter 3 (see the *Select an Authoring System* section). While a tutorial was included with the system as shipped, the actual time necessary to become proficient with the selected package was unknown.

Research Issues to be Investigated

With a goal of investigating a means by which knowledge on ATM could be increased on the part of school district educators and technology planners, the key issues addressed in this dissertation included:

- Effective adult learning. This inquiry investigated parameters that enhance adult learning. For example, it was demonstrated that self-paced training is more effective than an instructor-led course for adults since adults prefer to approach training at their own pace and sequence. In addition, the literature suggested the use of a computer in self-paced training further increases its effectiveness.
- Whether interactive multimedia/hypertext training adequately addresses the

specific needs of adult learners. Multimedia, and hypertext in particular, offer features that increase the learning potential of adults. Hypertext, for example, allows branching to the desired sections of the training materials as opposed to requiring a sequential review. This capability supports the adult learning preference described in the previous bullet.

- A structured methodology by which an interactive multimedia/hypertext tutorial/guide could be developed. A structured model was suggested for the development of training materials based on a review of several different models.

The development of hypertext-based training, however, requires additional steps to be performed during the effort, for example, the creation of storyboards. The proposed model was enhanced to include these additional hypertext-based steps.

- A detailed review of ATM and its major components and functions. This review included topics such as ATM background, factors that have driven its development, features and benefits, a description of the ATM cell, standards, a comparison with related technologies, current issues, and projected applications and services.

Limitations, Delimitations, Assumptions, and Resources

Limitations

There were several limitations foreseen prior to beginning this study. First, a research study based on the total population of all school district staff members across the United States was beyond the scope of this dissertation effort. Therefore, a case study approach was proposed. In this case study, professional staff members from a specific school district from the state of Florida, specifically the Seminole County Public Schools, were selected. A second limitation was that it was not possible to oversee all subjects as they responded to the pretests and posttests of the study. Finally, as all subjects chosen for the sample were volunteers, it is possible that only those with a positive attitude toward computers and their use in training agreed to participate in the study. The letters sent to each of the schools in the school district detailed the use of a computer in this training effort, hence it is unlikely that someone with a negative view toward its use would have agreed to participate.

Delimitations

It was not the purpose of this study to attempt to predict the success of the educators and technology planners in their efforts to use the information in developing plans to migrate to ATM. Rather, the scope was limited to developing the proposed multimedia/hypertext-based tutorial and evaluating its (1) learning effectiveness and (2) preferences toward its use.

Assumptions

In addition to the above limitations and delimitations, the following assumptions were basic to the proposed study:

- Educators and staff to be involved with this study of ATM and its potential use within a school district were to have access to the appropriate hardware to use the interactive multimedia/hypertext training tool. The subjects would respond to the pretests, posttests, and preference surveys honestly, truthfully, and without the assistance of others.

Resource Requirements

The resources used in support of this effort included:

- CBT Express, a multimedia/hypertext authoring system. This selected product is discussed in more detail in Chapter 3, Methodology.
- Hardware to support CBT Express in both a development and a delivery mode. This is also further discussed in Chapter 3, Methodology.
- The functional details surrounding ATM that provided the basis for the subsections of the tutorial/guide.
- A random sample of subjects. This random sample was determined from a group of participants sought from the participating school district.

Definition of Terms

ATM. A local and wide-area network technology for transfer of all types of information, which utilizes cell relay and scales well from small to large systems, from very low to very high transmission speeds, and from local-area through metropolitan-area to wide-area environments (Gartner Group, Inc., 1993).

B-ISDN. Broadband ISDN, or ISDN at rates in excess of 1.5 Mb/s in the U.S. (AT&T Bell Laboratories, 1992).

Cell. In ATM, a 53-byte unit of transfer consisting of a 5-byte header and a 48-byte data payload (Marks, 1994).

Cell relay. A transmission mode that utilizes fixed-length cells as the transfer mechanism (Gartner Group, Inc., 1993).

Coaxial cable. A transmission medium consisting of one or more central wire conductors surrounded by an insulator and encased in either a wire mesh or metal sheathing (Gartner Group, Inc., 1993).

FDDI. Fiber Distributed Data Interface. An ANSI standard for 100 Mb/s fiber-optic local-area networks that incorporates token processing and supports circuit-switched data (Gartner Group, Inc., 1993).

Fiber optics. A high bandwidth technology that uses light to carry digital information (Gartner Group, Inc., 1993).

Frame relay. An ITU recommendation and ANSI standard. An ISDN packet-mode service that provides bandwidth on demand and integrated access with speeds up to 2 Mb/s over permanent virtual circuits (Gartner Group, Inc., 1993).

Hypertext. Text, combined with a system, that provides the ability to select relevant information automatically and immediately. "This information is . . . connected in a network of paths and associations" (Bornman & von Solms, 1994, p. 259).

ISDN. Integrated Services Digital Network. A design philosophy according to which digital networks are designed. Provides high-speed, high-bandwidth channels to all network subscribers (Gartner Group, Inc., 1993).

Isochronous. Time critical (Heinanen, 1994).

Kb/s. Kilobits per second.

Local-area network (LAN). A user-owned and operated facility connecting various communicating devices such as computers, terminals, word processors, printers, and mass storage units within a single building or campus of buildings (Gartner Group, Inc., 1993).

Mb/s. Megabits per second.

Metropolitan-area networks. A network technology optimized for distances over 50 kilometers, speeds more than 100 Mb/s and diverse forms of information (Gartner Group, Inc., 1993).

Multimedia. The synthesis of different types of media to include audio, text, graphics, animation, and video, through digital computing (Givotovsky, 1994). Interactive multimedia would allow a user to interact with the training to select specific topics and/or control the timing by which the training is to be conducted.

NCIH. North Carolina Information Highway (Patterson & Smith, 1994).

N-ISDN. Narrowband ISDN, that is, ISDN service at rate of 64Kb/s (Taylor, 1993b).

OA&M. Operations, administration, and maintenance.

Outsourcing. An organizational use of external consultants and other experts.

Packet switching. A technique in which a message is broken into smaller units that are individually addressed and routed through a network (Gartner Group, Inc., 1993).

PATH. Partnership for Access to Higher Mathematics, a broadband project implemented by Southwest Texas State University (Chavkin et al., 1994).

SMSD. San Marcos School District (Chavkin et al., 1994).

SMTC. San Marcos Telephone Company (Chavkin et al., 1994).

Switched multimegabit data service. A Bellcore-originated standard providing high-speed, high-volume switched digital service to metropolitan-area networks (Gartner Group, Inc., 1993).

SWTSU. Southwest Texas State University (Chavkin et al., 1994).

Synchronous optical network (SONET). An emerging ITU standard for synchronous transmission up to multigigabit speeds that promises multivendor interoperability, improved troubleshooting, and network survivability (Gartner Group, Inc., 1993).

SS7. A signalling scheme used in the U.S., designed for digital networks, and is key to current ISDN implementation (Gartner Group, Inc., 1993).

T1. A 56 Kb/s facility that can handle 24 multiplexed voice channels (Tanenbaum, 1988).

Wide-area network (WAN). A data transmission facility that connects geographically dispersed sites using long-haul networking facilities (Gartner Group, Inc., 1993).

Summary

The purpose of this dissertation is to investigate the use of interactive multimedia/hypertext as a means of educating school district educators and technology planners on the various aspects of asynchronous transfer mode (ATM) technology. In support of this dissertation goal, the following was discussed in this chapter:

- There is a need for this knowledge on the part of this school district staff to increase their involvement and participation in selection, implementation, and use.
- Unfortunately, this knowledge is lacking.
- To close this gap, there is support in the literature for increased training and development for teachers, administrators, technology planners, and other staff.

This problem is particularly critical as a number of ATM pilot projects in educational environments are now under study. Several of these were also presented and discussed in this chapter.

Finally, barriers and issues, key research questions to be investigated, limitations, delimitations, assumptions, resource requirements, and definitions of key terms were provided.

Chapter 2

Review of Literature

Overview

The following review of literature is presented in several subsections. The first is a historical review of the theory and literature. In this section (1) adult learning concepts, (2) increasing the effectiveness of adult learning through the use of computers in learning activities, and (3) development models supporting the structured creation of traditional training materials are discussed. The second section addresses a review of theory and literature more specific to this dissertation topic. In particular, in this section, topics addressed include (1) concepts surrounding multimedia and hypertext, (2) authoring systems used for the creation of multimedia/hypertext products, and (3) training development methodologies specific to computer-related training. Next, a review of asynchronous transfer mode technology and its related features and components is presented. The fourth section of this chapter provides a discussion of topics known and unknown based on the review of literature. Finally, expected contributions to the field provided by this dissertation effort are discussed.

Historical Overview of the Theory and Research Literature

Introduction to the Historical Overview

This section addresses learning characteristics of adults. Also, the use of computers in effectively addressing these particular learning characteristics is discussed. Finally, a number of traditional development models providing guidance for the development of computer-based training materials are provided.

Adult Learning

Spille, Galloway, and Stewart (1985) suggested "a common flaw in programs of education or training for adult learners is the implicit assumption that methods and materials designed for use by children or youth are equally applicable to adults" (p. 40). They proposed several guidelines that are more appropriate for developing courseware for adult learners. They suggested that, while instructional topics should be introduced in a logical sequence, built-in flexibility should allow the learner to choose a non-linear sequence, if desired, or skip certain activities. In addition, user control is a major aspect of adult training. The adult learner, according to Spille et al., should be able to determine where to enter a learning module and also be able to control the rate of presentation. The authors further stated that, as adults present a wide variety of learning needs and styles, rigid courseware can impede or stop learning efforts. Courseware flexibility, therefore, according to the authors, should provide options to accommodate a variety of user needs and desires.

The concept that adult learning is different from children's learning was further supported by Ament (1991). This author stated, "By the time we reach adulthood, each of us has developed our own methods of learning. That is, adult learners each have a unique and well-established learning style" (p. 3.66). Ament also suggested that the learning styles developed by adults follow an individualized path leading to mastery of the material.

The American Society for Training and Development (ASTD) (1986b), in their booklet Alternatives to Lecture, quoted John S. Randall in his writings for the Training & Development Journal, "Adults learn by doing" (p. 1). This booklet presented learning as an active process. "It cannot be passive . . . it implies a change for the better, a modification of behavior . . . an active, positive process accomplished through the individual's own activity" (p. 1). The booklet continued by stating that studies have shown passive learning, such as reading or listening, has led to recipients forgetting 50% of the material within 48 hours and an additional 25% within two weeks. "Adults can learn by listening and watching . . . but they'll learn better if they are actively involved in the learning process" (p. 1).

Geisman (1992) also provided support to these claims of increased effectiveness in adult learning via self-paced, interactive methods. The author credited this method with a 50-60 percent reduction in learning time accompanied by an increase of 40-50 percent in learner retention. Geisman continued that "unlike classroom training, the user must make decisions, answer questions, evaluate situations, as well as participate in simulations in order for the program to continue moving forward. The user also has the opportunity to review a concept or skill application as often as needed in order to understand it" (p. 10.18).

Use of Computers to Address Adult Learning

The previous section suggested training materials created for use by adults should be flexible to allow individual learners (1) to select the sequence that satisfies their personal needs and (2) to control the rate of presentation. In addition, it was demonstrated that increased activity in training events on the part of adult learners increases the effectiveness of the learning. These guidelines were further supported by American Telephone & Telegraph (AT&T) (1987). AT&T provided a set of guidelines to increase the effectiveness of materials being developed for the training and education of adults. First, adult learners wish to assume "responsibility for their own learning through self-designed and self-directed inquiry" (p. 8). Adult learners should be given choices regarding pace of the course and topic or module sequencing. In addition, these guidelines suggested, "adults want the opportunity to participate at the right time - that is, when they have enough information to participate effectively" (p. 9). Finally, according to AT&T, "Adult learners want the easiest, cheapest, fastest way to learn what they have to" (p. 9). Each of these guidelines is satisfied by a computer-based training solution.

The use of computers as a delivery mechanism for adult training and education has also been supported by Dejoy and Mills (1989). These authors suggested a growing need for adult-level learning based on "innovative types of instructional delivery" (p. 39). They cited computer-assisted instruction as a recommended method of delivery because learning can be flexibly tailored to satisfy the learners' preferred time, location, and order of content presentation. Dejoy and Mills further suggested that this format can be used anywhere (assuming appropriate equipment is available) and can be operated by the individual learner in a self-directed manner, thereby allowing adults to meet their personal learning needs. Their observations indicated adults want to first select the specific materials they need to learn or review from the larger content. Once the topic is selected, according to these authors, adults continue to impose their own learning styles on the material. They may require opportunities to back-up, adjust presentation speed and sequence, or skip around the material as their interests dictate. The authors stated that when this flexibility is not provided by the training materials, the learners become frustrated and the quality and effectiveness of the learning activity decrease.

Providing flexibility and activity in adult learning activities has also been supported by Amthor (1991). In addition, this author pointed out researchers have demonstrated that people retain 20 percent of what they hear, 40 percent of what they see and hear and 75 percent of what they hear, see, and do. Amthor further credited a Department of Defense study that concluded computer-based, interactive training improves training achievement by an average of 38 percent over traditional instructor-led methods while reducing the time required to reach competency by 31 percent.

An examination of independent studies of computer learning applications conducted by Khalili and Shashaani (1994) further supported the effectiveness cited above. In this analysis, thirty-six studies conducted between 1988 and 1992 were selected. These studies represented efforts to evaluate computer applications in educational settings at different grade levels. An overall average effect size (ES) of .38 was determined from these thirty-six studies that indicated the use of the computer applications "raised students' examination scores by .38 standard deviation" (p. 48). The analysis further demonstrated higher effect sizes among those students approaching adulthood. High school students demonstrated an effect size of .62 and college students an ES of .45. This is compared to .34 and .11 for elementary and middle school students respectively. The authors concluded; "The instructional use of the computer increases students' academic achievement" (p. 57).

Traditional Development Models for Structured Creation of Training Materials

Dean (1994) addressed several key questions regarding the use of an instructional design model for training development in adult education. First, why use an instructional design model? According to Dean, a lack of a formal development methodology can lead to instructional materials that do not meet the needs of the user. Second, who will benefit from the use of an instructional design process? Dean responded that anyone involved with development of learning activities, regardless of experience, can increase the quality of instructional materials through the use of an instructional design model. A third issue discussed by Dean (1994) was, when and where should instructional design be used? Dean claimed that, although typically associated with technical training and curriculum development in school systems, the application of instructional design can be broadened to include recreational adult education, professional development, occupational training, personal development, and graduate education. This author stated, "Instructional design is a tool to be employed whenever systematic planning for learning activities is desired" (p. 5).

A typical methodology is the structured Instructional Design Methodology as developed by AT&T for addressing adult learning. As described in AT&T's The Trainer's

Library: Techniques of Instructional Development (1987), there are six steps to be followed in this methodology: needs analysis, development of objectives and tests, instructional design, materials development, implementation, and evaluation.

In needs analysis, the first phase of the AT&T model, training deficiencies are identified, critical skills and knowledge (S/K) to be addressed by the training are listed, and the importance of each is determined. S/K statements are sentences that describe the skill or skill level required to perform the task or activity and what the performer must know to perform that task or activity. These become the basis for developing both objectives and tests. The American Society for Training and Development (ASTD), in its 1988 booklet Basics of Instructional Systems Development, stated the developer also needs to determine learner characteristics during this analysis phase. Examples of learner characteristics include education, experience, physical needs, cultural differences and language skills.

In the second, or objectives and tests, phase of the AT&T model, performance objectives are determined and tests constructed to measure the success in meeting the stated objectives. The third phase of this model focuses on instructional design where the performance objectives determined in the previous phase are sequenced and the lesson content outlined. In the fourth phase of the AT&T model, materials development, the key activity is the creation of materials covering the content areas. In the fifth, or implementation phase, content is validated and pilot sessions are conducted. In the sixth and final phase, evaluation, the training is evaluated for effectiveness.

This six-phase methodology is similar to the Instructional Systems Development (ISD) Model delineated in the American Society for Training and Development's booklet Basics of Instructional Systems Development (1988). The single difference is that ASTD proposes five steps (instead of six) with AT&T's Phase 2, Objectives and Tests, combined with Phase 3, Design, as opposed to being treated as a separate phases.

Summary

This section of Chapter 2, the Review of Literature, provided a historical overview of literature related to this investigation. This review of literature provided several key finding. First, adult learning is different from that of children. Adults prefer flexibility be built into their learning media to provide the ability to (1) choose their own sequence to review the material and (2) control the rate of presentation. Next, the use of computers in adult learning was shown in the literature to be an effective delivery mechanism. The use of a computer provides the flexibility desired by adults. Finally, traditional structured training development models were discussed. These models provide a framework by which training materials can be developed to better meet the needs of the learners. A model found to be frequently supported in the literature consists of five phases: analysis, design, materials development, implementation, and evaluation.

Theory and Research Literature Specific to the Topic

Introduction

This section provides a discussion of multimedia concepts, and in particular the hypertext subset of multimedia. Authoring systems used to develop multimedia-based training materials are also discussed. Next, a discussion of instructional design methodologies used for the creation of computer-based training products is presented. These methodologies provide a structured approach for the development of training materials. Finally, an in-depth discussion of asynchronous transfer mode technology is offered.

Multimedia Concepts

The review of literature addressing adult training and education suggested structured learning should support an interactive, non-linear sequence to approach the various topics as well as offer the user control over the speed of material presentation (Ament, 1991; American Society for Training and Development, 1986b; Geisman, 1992; Spille, Galloway, & Stewart, 1985). These parameters include the ability to return to various topics for review should the user desire as well as the capability of skipping material. The literature addressing training via computer suggested its use as an effective medium by which these needs can be addressed (American Telephone & Telegraph, 1987; Amthor, 1991; Dejoy & Mills, 1989; Khalili & Shashaani, 1994). This section provides support for the choice of multimedia, and in particular hypertext, as a particularly viable means by which training via computer can be offered.

There are several definitions of multimedia. Dahmer (1993) defined multimedia as a "computer system capable of seamlessly manipulating data in several formats (such as text, graphics, sound, and still or motion video) and of allowing nonlinear navigation (branching) and presentation of the data formats based on real-time user input" (p. 46). Campbell (1994) described multimedia as "presentation of two or more types of digitally encoded information, at least one of which is time based" (p. 3). These definitions simply suggest that multimedia uses a computer to integrate different media, for example, multimedia may employ voice with graphics, use full-motion video with voice or text overlays, or provide a search mechanism to locate additional details on a topic of particular interest to the learner.

As this concept of interactivity is a capability offered by multimedia, it became a viable candidate for a solution to the stated objective of this dissertation inquiry. This was supported by Weisburgh (1991) in his article promoting the use of interactive solutions for adult learners. According to Weisburgh, "Historically, adult educators model their programs after the classroom lectures they remember from their childhoods. We now know that this lecture approach is unsuitable for adults. It takes too long, is too costly, and for a large percentage of potential trainees, is just not effective. A more interactive approach is called for" (p. 649).

Corporations are currently planning substantial moves into multimedia technologies as an avenue for adult training within the next year or two (Jerram, 1994). Hewlett-Packard, AT&T, Arthur Anderson Consulting, U.S. West, Northern Telecom, Federal Express, and Apple are a few examples of major corporations that are currently re-engineering their training departments with moves toward technology-based training (Geber, 1994). While training organizations are looking toward videotape training and distance learning via video- and audioconferencing to solve high cost and resource issues, they "are also turning to self-paced multimedia courseware, which offers the relative low cost and visual enhancement of videotape, the depth and random access of a book, and some of the interaction and feedback of a live teacher" (p. 52). Jerram, in quoting analyst

Bob Abraham of Freeman Associates, stated "Multimedia training is not just another way of doing it; it's the ultimate way to teach" (p. 53).

Multimedia allows trainers to tailor training to fit the needs of the individual learners. According to Ed Schroer, Vice President of New Business Development for the American Society for Training and Development (ASTD), "The idea that you can bring everyone into a classroom and give them the same thing at the same pace is outmoded. Computer-based multimedia training can be more realistic and immediate" (Jerram, 1994, p. 53).

This position was further supported by Luther (1992). According to this author, training is more effective when students can actually interact with the subject, in addition to simply reading or hearing about it. With multimedia training, students are in a one-on-one environment working by themselves at their own speed. Luther stated, "The result is more effective, lower-cost training" (p. 6).

This continued growth in self-paced, interactive learning technologies on the part of corporations and other learning institutions was explained by the numerous advantages provided by Geisman (1992, p. 10.18). These advantages include the following.

- Learning efficiency and effectiveness are increased.
- Learning can become competency-based.
- Learner performance reports are immediately available.
- Incremental or systematic learning is possible if desired.
- Simulations are possible to reinforce learning.
- Review of skills and concepts is available at will.

Staninger (1994) also supported the position of increased learning effectiveness through the use of multimedia training. According to this author, knowledge transfer is improved, thus increasing learning effectiveness, as this method of learning offers the potential of focusing on the critical relationships between conceptual/abstract knowledge and specific knowledge. Furthermore, Staninger claimed, the learner in encouraged to (1) create a personalized strategy for accessing the information, thereby increasing the chances for successful retrieval of desired information and (2) develop new ways to organize the information.

There are also a number of disadvantages to this method of learning. These are discussed in more detail in the following section, The Hypertext Subset.

The Hypertext Subset

Eugenio and Habelow (1994) differentiated between four different types of multimedia, Type 0 through Type 3. Type 0 multimedia is commonly called hypertext/hypermedia. These authors claimed the goals of this category are electronic access to information and information dissemination. The instructional objective of Type 0 multimedia is to allow the learner to access information for job task performance or reference. An example of Type 0 multimedia is online help.

Eugenio and Habelow's (1994) second category, Type I multimedia, is often referred to as interactive hypertext/hypermedia. The objective of this category is mastery of knowledge based on simple procedural objectives. The authors suggested training via Type I multimedia will allow the learner to "be able to define, identify, list, match, recall, select, recognize, generalize, state, calculate, complete, select, compile, describe, summarize, paraphrase, detect, differentiate, distinguish, and observe" (p. 22). Informational overviews and fundamental courses are examples of Type I multimedia.

According to Eugenio and Habelow (1994), the third category of multimedia, Type II is commonly known as interactive multimedia. This category, however, is more oriented toward performance-based training for complex intellectual tasks. The instructional objectives include the goals of Type I. In addition, however, the learner will also be able to apply the knowledge gained to specific tasks. Type II multimedia typically includes technical or computer systems training not requiring simulation.

Type III multimedia, the fourth and final category according to Eugenio and Habelow (1994), is also referred to as interactive multimedia and also has a goal of performance-based training. In addition to the characteristics and functions provided by Type II multimedia, however, Type III provides simulations of physical tasks. Examples of Type III multimedia include equipment or mechanical repair simulators and military weapons simulators.

Tolhurst (1995) provided a more definitive discussion on the distinction between multimedia, hypertext, and hypermedia. This author claimed the multimedia area, found in Figure 2, represents all applications that offer multiple media formats, such as text, still or animated graphics, movie segments, video, and audio information. Hypermedia can be considered a <u>proper</u> subset of multimedia, that is, all hypermedia can be considered to be multimedia as multiple media formats are also used. However, Tolhurst provided the distinction that hypermedia allows a user an added opportunity to interactively traverse the information non-linearly.

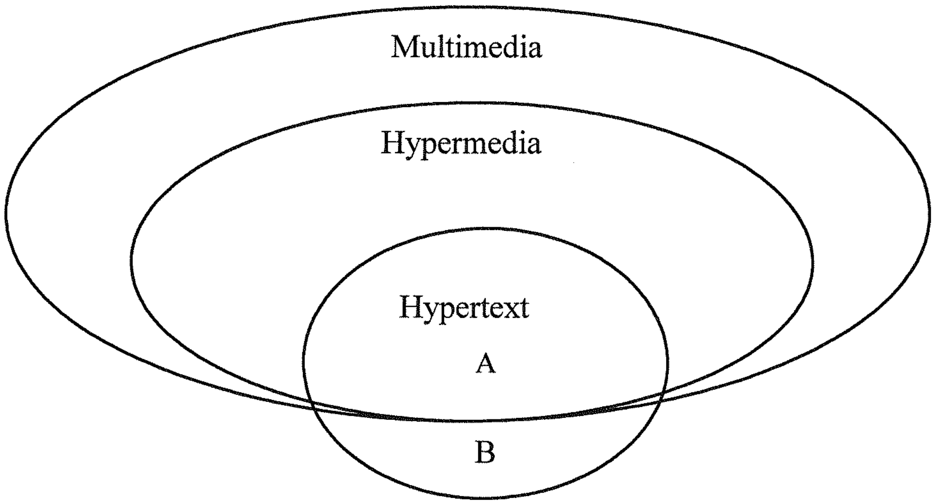

Figure 2. Multimedia, Hypermedia, and Hypertext

Hypertext, on the other hand, is composed of two subsets; one that falls within the multimedia/hypermedia area, as shown by area A in Figure 2, and a second subset that falls outside Tolhurst's (1995) definition of multimedia. This is portrayed by area B in Figure 2. The distinction between area A and area B is determined by whether multiple media types are used (area A) or a single medium type is used (area B). According to Tolhurst, hypertext that utilizes only one medium, for example text only, does not fit the pure definition of multimedia and hence, must exist outside the realm of multimedia.

Kearsley (1990) supported the above distinction between hypermedia and hypertext. This author referred to hypertext as a method for organizing online databases that allows the learners to selectively choose the topics and information they wish to review via navigational links generated during the creation of the database. When audio or video sequences are used, however, Kearsley referred to the databases as hypermedia.

Nielsen (1995), on the other hand, took a slightly broader view of the distinction between hypermedia and hypertext. According to this author, traditional definitions of hypertext imply an application that displays plain text. Hypermedia, on the other hand, has been accepted to stress the multimedia aspects of the applications. However, as systems today almost universally include the capability of including graphics with the text, Nielsen preferred to not distinguish between these two concepts as "there does not seem to be any reason to reserve a special term for text-only systems" (p. 5).

Nielsen (1990a, 1995) defined hypertext as non-sequential writing. It can be viewed graphically as several nodes, each containing some amount of text or other information, connected by directed links. Navigation within this network is accomplished via these links. Nielsen (1990a) supported a concept of true hypertext where "users *feel* that they can move freely through the information according to their own needs" (p. 297). The author stated that hypertext is a popular approach to delivering "on-line presentation of large amounts of loosely structured information such as on-line documentation or computer-aided learning" (p. 296). In addition, hypertext is a more natural basis of learning as it allows the readers to investigate ideas as they choose in contrast to the sequential choice presented by the author of the material. According to Nielsen:

> All traditional text, whether in printed form or in computer files, is *sequential*, meaning that there is a single linear sequence defining the order in which the text is to be read. First you read page one. Then you read page two. Then you read page three . . . Hypertext is *nonsequential*; there is no single order that determines the sequence in which the text is to be read. (1995, p. 1)

This concept was supported by Bornman and von Solms (1993). They also stated the concept of hypertext suggests non-sequential writing of information that allows learners to connect bits of information together via paths, or links. The example provided by these authors was that of a user accessing information in a book via the table of contents. Desired information can be found "instantly and without problems and without making use of a sequential search" (p. 260). They further suggested that there are no limiting searches or any sequential routes that are required to find the desired information.

Craver (1991) provided an example describing how the node-link relationship can be used to implement non-sequential hypertext. A word or phrase in the document might be highlighted to indicate the existence of a link to a node containing additional information, such as the definition of the highlighted word. If the user selects the highlighted area, the additional information, in this example the word's definition, would be retrieved by the computer and displayed to the user. This concept can be expanded beyond simple text to include other types of information accessible by the computer such as images, animation, audio, or full-motion video.

There are disadvantages to this method of training, however. Dillon (1991) suggested that "people still prefer paper, find it easier to use, and read faster or more accurately with it" (p. 1244). Bornman and von Solms (1994) offered three other disadvantages. First, these authors suggested the learner may have a tendency to become disoriented. This occurs when learners seek information via the navigational links and lose their sense of direction within the application. The second disadvantage is related to cognitive overhead. This problem occurs as learners begin to search for information. They may find their attention is diverted from the nature of the information, and they begin to "concentrate more on the way the information can be reached and the variety of information structures that exist" (p. 263). The authors stated that cognitive problems result. The third possible problem is the potential for insufficient access to the information. This is usually more of a problem, according to Bornman and von Solms, for learners who are not familiar with the navigation methods being employed in the application.

Disorientation was also cited as an issue by Staninger (1994). Individuals unaccustomed to using hypertext may not be prepared to choose their own path toward the desired information. The learner may require a period of adjustment and a change in attitude toward the method of information acquisition. Staninger continued that this unfamiliarity can lead to the learner becoming "lost" or disoriented in the application. The author claimed, however, that this is a misconception on the part of the learner since, in hypertext, there is no one correct place to begin a search and no one correct path to follow. To resolve this issue, the author suggested an introduction to the hypertext environment is necessary to educate learners about the capabilities and possibilities of this self-directed method of learning.

An orientation to the hypertext environment was also cited by Nielsen (1995) for inclusion as a design element to assist the learner in maintaining a sense of location. An example of a hypertext system offered in this book included a diagram, easily accessible by the learner, that served as a two-dimensional table of contents. The various information nodes, or chapters, were displayed in this diagram as well as available links that graphically demonstrated the relationship of the chapters. Independent nodes (that is, those with no specific incoming links) could also be displayed in this diagram. These nodes might include, for example, information about the author or a glossary.

Nielsen (1995) reinforced this orientation to the hypertext environment in his example by continuing to display this diagram to the learner in a separate window as the various informational nodes are accessed. In addition, in a further window, the author provides the learner with a more detailed diagram of the specific chapter currently selected which displays related subnodes and links. This allows the learners to read the information selected, note their position in the chapter selected, and note the position of the chapter in the overall scheme of the application all on one screen. In addition, Nielsen offered several additional tips for aiding the user. First, as the nodes are accessed, a checkmark was added to the diagrams indicating to the learner that this informational node has already been accessed. Next, Nielsen's example provided a timestamp indicating the time elapsed since this particular node was accessed. This assisted the learners in recognizing that they may have already seen the information. Third, his example provided a history list indicating all nodes accessed, the sequence in which they were reviewed, and the time elapsed since they were visited. Finally, a feature was also available in Nielsen's system to allow learners to annotate their thoughts as they accessed the different chapters.

Nielsen (1995) offered five categories of hypertext applications. These are (1) computer applications such as online documentation, user assistance, software engineering, and operating systems; (2) business applications such as interactive repair manuals, dictionaries and reference books, auditing tools, and trade show support; (3) intellectual applications such as collaborative brainstorming support, journalism, and research; (4) entertainment and leisure applications such as tours of foreign cities, library visits, and interactive fiction; and (5) educational applications such as learning a foreign language, education in the classics, and museum visits.

According to Nielsen (1995), "Hypertext is well suited for open learning applications where the student is allowed freedom of action and encouraged to take the initiative" (p. 101). Kearsley (1990), claimed "students seem to learn more about the subject area when they use hypertext databases to study with" (p. 45) and that hypertext capabilities will have a significant impact on learning via computers in the future. These positions support the use of hypertext as a medium for training of adults who, according to a number of authors (Ament, 1991; Dejoy & Mills, 1989; Spille, Galloway, & Stewart, 1985), prefer to interact with training material in an individualized manner.

Multimedia/Hypertext Authoring Systems

Authoring systems are typically used to create multimedia applications (Luther, 1992). These systems are tools for multimedia authors to create the structure; collect, create, and organize the content; and test the authored application. The author further stated that authoring systems may employ a special language, similar to a programming language, to accomplish this task. Alternatively, a graphical interface may be used in which the author manipulates a mouse or other device to create an application description and sequence. In this second case, the authoring system translates this description into actual computer instructions without the assistance of the system user. Luther added that these systems may include features associated with the supported media. For example, there may be tools available in the authoring system to perform audio, video, or image capture from live input signals; edit these captured files; manage all media resources; and maintain the associated storyboards.

Luther (1992) also discussed several issues to be addressed in choosing an authoring system. First, the authoring system must support the targeted computer platform and hardware configuration. Next, Luther suggested that if programming skills are lacking, the authoring package chosen should not be one that uses only a language-based interface. Instead, the selection of a package utilizing a graphical point-and-click interface is warranted. A further issue to address in choosing an authoring system is to insure that features to be included in the authored package are supported by the tool. For example, if full-motion video is to be included, it must be supported by the authoring tool. Next, the scale of the proposed effort should be supported by the system. Systems intended for use by large organizations involved with multiple projects, for example, may offer features unnecessary to an individual user. Finally, the style of the authoring system should match the style of the author, otherwise its use may be awkward.

Instructional Design Methodologies for Creating Computer-Based Solutions

The review of historical literature reinforced the need for a structured design model for training materials development (Dean, 1994). Dean suggested that the lack of guidance proposed by a formal methodology may lead to training that does not satisfy the learning needs of the user. This section reviews structured design models that apply specifically to training offered via computers.

The Teachers' College of the Air Force (Atkins, 1994) uses a five-step instructional design methodology for structuring their training material creation whether these materials are used for instructor-led courses or computer-based delivery. An analysis of the Air Force Instructional Systems Development model, presented by Atkins, suggests it is the same approach as offered by ASTD (1988) and AT&T (1987) as discussed previously in this chapter. This author stated, "Whether we are developing multimedia, distance learning, or other types of structured learning, we use the ISD model to ensure our instruction is valid and meets the needs of our customers" (p. 4).

This same five-step methodology was selected by Gleason (1991) in her development of the Yearbook Advisor CBT. This effort, a computer-based hypertext training program for new yearbook advisers who lack a journalism background, was developed for her dissertation in Computer-Based Training and Learning at Nova Southeastern University. The author credited ISD with delivering a systematic approach to the design and development of the training materials.

Finally, Orr, Golas, and Yao (1993) also supported this five-step model for the development of multimedia applications. According to these authors, "Training applications using interactive multimedia capabilities are growing in number. The approach followed to produce these multimedia applications is essentially the same (analysis, design, development, implementation, and evaluation) regardless of the instructional delivery system" (p. 1).

Dean (1994) proposed a methodology that closely parallels the ones described above. The first step is to gather data related to learner needs and characteristics. The author claimed that "learning needs are internally or externally identified discrepancies between an ideal and real state, and motivation is the force that drives a learner to participate in learning to reduce that discrepancy" (p. 36). Dean further presented a partial list of learner characteristics which may be assessed. This list included traits such as intellectual abilities, study habits, life experiences, motivation to learning, and the learner's developmental stage.

The second step in Dean's (1994) model is to address the learning context. According to this author, context is the environment of the learner. It can include social, political, economic, or other factors that may impact learning. This context may provide suggestions as to (1) the goals and objectives of the instructional programs, (2) the type of learning that may be most appropriate for the students, (3) the overall format, including length and overall design, (4) the methods of learning to which the students are already accustomed, (5) the means of evaluation, and (6) the criteria for judging the overall success of the learning.

The third step, according to Dean (1994), is to develop goals and objectives. These should be based on the desired learning outcomes, certification requirements, the learning context, the instructor's strengths, and the learners' needs. Dean claimed this step "is the most important part of the entire instructional design process" (p. 81). Appropriate goals will aid in development and learning activities; inappropriate ones will result in activities which do not meet the needs of the learner.

The fourth step in Dean's (1994) model is to develop the learning activities. This includes selection of activities appropriate for the learners, the content, and the context in which the activities will be presented. Each activity should meet a specific objective.

Evaluating the learners is the next step of Dean's (1994) model. This evaluation can be conducted before, during, and after the learning activity and can include the learners' reactions to participation in the activity.

Dean's (1994) final step is to evaluate the instructional plan. This includes addressing questions such as:

- Are the goals and objectives appropriate for the learners and their context?
- Are the activities appropriate for the learners and their context?
- Are the evaluation procedures appropriate for the learners and their context?

Givotovsky (1994) proposed a variation of the above models that addresses the planning and design phases specifically for interactive multimedia applications. There are eight steps in Givotovsky's model: user profiling, functional element mapping, establishment of goals, evaluation and prioritization, design visualization, ideal world design draft, design document, and finally, functional specification. These are addressed below.

- User profiling. The activities of this phase determine the audience traits and requirements. The result is a user-base definition.
- Functional element mapping. This phase defines the range of information and interaction. A general purpose for the application is established.
- Establishing goals. In this step, the basic functions of the application are determined and the required media elements defined.
- Evaluation and prioritization. This phase distinguishes between desired and required features of the application. In addition, other elements are defined.
- Design visualization. This phase provides a mapping of the required features

in a basic schematic. The required media elements are illustrated.

- Ideal world design draft. This step adds all desired features to the basic schematic to produce an enhanced schematic. The desired media elements for this phase are then illustrated.
- Design document. This phase reviews and refines the enhanced schematic to produce a design document.
- Functional Specification. From this design document, a functional specification is produced from which the application can be developed.

An instructional design methodology developed and refined by Adams (1994) is more complete than Givotovsky's and more specific to the development of multimedia applications than the other models discussed. Adams has used this methodology in the development of commercial multimedia applications since 1990. There are six phases proposed by this author: planning, design, development, distribution, evaluation and maintenance. These are discussed below in more detail.

The first phase of Adams' (1994) model is planning. This step consists of seven subphases.

- Organize the project. The scope is determined and the risks identified.
- Develop a resource plan where people, facilities, and equipment resource needs are determined.
- Determine a curriculum plan. This includes planning that relates to the audience (who, where, how many, and base knowledge), the content (the modules to be developed and prerequisites), the integrated media (graphics,

audio, video, and animation to be used), assessment (exercises, practices, and tests to be used), and evaluation (student feedback to be gathered and follow-up reviews to be conducted.)

- Develop the technical plan. This includes identifying the development environment (hardware and software) and the delivery environment (hardware, software, and location).
- Plan the distribution and implementation. This includes determining what media will be used in distribution and how delivery will be accomplished (LAN distribution and/or delivery, for example).
- Design the maintenance plan. This includes identifying how maintenance of the product is to be accomplished.
- Determine the team work plan. This applies to situations where several developers are working on a single project.

The second phase of Adams' (1994) methodology is to design the course. There are six steps included in this design phase.

- Conduct a course analysis. This includes determining the length of the course, identifying the audience (what prerequisites are necessary), and developing the goals and objectives for the course.
- Design the interface. This includes determining the details surrounding screen layout and navigational methods, as well as establishing the functions and features to be included (glossary, index, table of contents, and help, for example).

- Prototype the design. This is typically used to allow the customer/client to evaluate the design.
- Identify screen guidelines. This includes developing the rules to be followed in screen development such as determining fonts and the use of color and menu bars.
- Develop a course outline providing several layers of detail from the major learning areas. As units in multimedia/hypertext courses can be accessed nonlinearly, care must be taken in this stage to ensure standalone learning is possible.
- Create storyboards. These documentation tools provide screen-by-screen details of the content, exercises, tests, and proposed graphics. How the graphics are to be invoked and where audio is to be used are also defined.

The third phase of Adams' (1994) methodology is to begin actual development. This phase also includes several steps which are discussed below.

- Develop or accumulate the multimedia assets to be used. These include graphics, animation, audio and video.
- Author the screens. This includes adding the content, linking the multimedia assets, providing hyperlinks and navigation, and addressing other functions and features such as table of contents, references, help, and a glossary.
- Program any remaining aspects of the application. This includes items such as buttons and navigational aids. Also included in this phase is the development of student registration, test tracking, and installation programs.

- Test the developed materials extensively. Adams proposes three phases of testing. The first testing phase is to examine each unit in a linear fashion. This includes testing each module, function, and feature in an attempt to "break" the system. The next testing phase allows selected learners to access each unit and provide comments. This includes assessing the user interface, content, structure, and tests and exercises. Finally, a system test should be accomplished. This step is required if multiple courses are being developed and inter-course links are provided. Also included in this phase is the testing of other functions and features such as student registration, test tracking, and installation procedures.

Adams' (1994) fourth phase is to address distribution of the multimedia product. This step applies specifically to commercial packaging, however, the development of software documentation is also included. Software documentation addresses issues such as how to install the package, how students are to register, how to use the system, and how to upload files for test tracking and student feedback. In addition, in this phase the runtime environment is prepared as determined by the authoring package in use.

The fifth phase of the model proposed by Adams (1994) is to evaluate the effectiveness of the multimedia application. This includes a review of learner test scores, feedback sheets, and comments.

Maintenance is the sixth and final phase of the Adams' (1994) methodology. This phase addresses how maintenance changes and releases are to be managed.

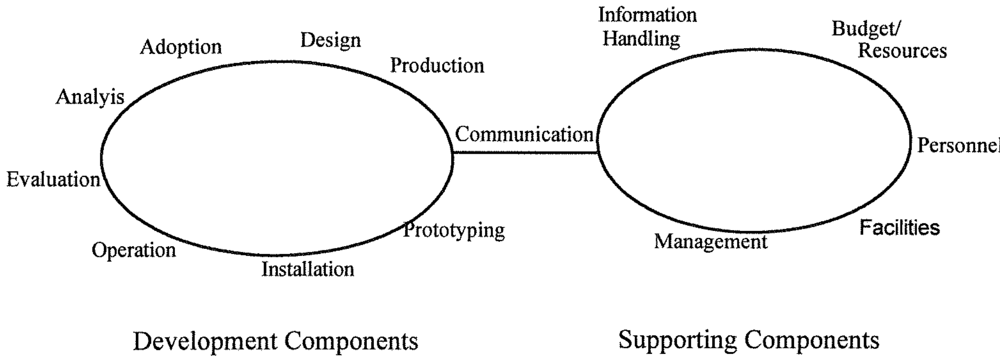

Figure 3. Gentry's ID Model

A final model reviewed which lends itself to the design of computer-based multimedia/hypertext applications, is the Instructional Development (ID) model as proposed by Gentry (1994). A graphic display of this model is found in Figure 3. As demonstrated in the figure, Gentry added several supporting components to the model: information handling, budget and resource allocation, personnel, facilities, management, and communication. This author provided several justifications for the use of this particular model. First, the model is more dynamic than the more traditional models that propose a linear approach to the development process. Second, an equal emphasis is placed on the support and development components. According to the author, "Most models either give short shrift to how development and support components are related or may not show any relationship" (p. 4). The final reason supporting the use of this model is that it draws attention to the importance of information sharing.

A summary of each development component of Gentry's (1994) model follows:

- Needs analysis - establish the needs and goals for the proposed instruction and assign appropriate priorities to these needs.

- Adoption - address acceptance by decision makers and obtain a commitment of resources.
- Design - determine and specify objectives, strategies, techniques and media for meeting the instructional needs.
- Production - construct the elements of the projects based on the design.
- Prototyping - assemble, pilot test, respecify, validate, and finalize an intructional unit.
- Installation - establish the necessary conditions for effective operation of a new product when initially placed on the target system.
- Operation - maintain the continuing application of an instructional product.
- Evaluation - collect and analyze data about an instructional unit for enabling decisions on maintenance and revision.

The supporting components of Gentry's (1994) model are as follows:

- Management - control, coordination, integration, and allocation of resources.
- Information handling - select, collect/generate, organize, store, retrieve, distribute, and assess information.
- Budget and resource allocation - determine resource needs, formalize budget, and acquire and distribute resources.
- Personnel - determine staffing needs and support.
- Facilities - organize and renovate space for design, implementation, and testing of instructional elements.

Connecting the development and supporting components of Gentry's model is the communication process. This component provides information distribution and circulation among those involved in the project.

Summary

This section of Chapter 2, the Review of Literature, provided a review of literature that is specific to this investigation. First, a review of multimedia was presented with special emphasis on the hypertext subset. According to the literature, hypertext provides a means by which adult learning issues can be addressed. This includes flexibility in sequencing the topics and control over the rate of presentation. The literature further supported the use of the five-step development methodology (analysis, design, materials development, implementation, and evaluation) for the development of multimedia/hypertext-based learning tutorials. This model is in current use by several large training organizations and multimedia developers. However, as this media requires the use of a computer, several unique tasks are required and should be included in the development model. These include efforts such as designing the topic screens, specifying the navigational techniques to be used, and creating storyboards.

Asynchronous Transfer Mode Technology

ATM has been in the laboratories since 1987 (Briscoe, 1993). In Chapter 1, a number of implementations of broadband technologies based on ATM use in the educational environment were discussed (Bernier, 1993; Feldman, 1995; Heinanen, 1994; "Iowa taps," 1994; O'Shea, 1994a, 1994b; Patterson & Smith, 1994). Also in Chapter 1, an overall lack of knowledge of computer and telecommunications technologies on the part of educators was further identified (Dyrli & Kinnaman, 1994a; Friedman, 1994; Gross-Peck & Beyda, 1993; Killian, 1994; Pickelsimer, 1994; Van Horn, 1995a; West, 1995). Increased training for educators and school district technology planners was suggested as a potential resolution to this problem by several authors (Branscum, 1992; Dyrli & Kinnaman, 1994c, 1994d; Friedman, 1994; Grosse-Peck & Beyda, 1993; Killian, 1994; Kingston et al., 1992; Mageau, 1994a; Van Horn, 1995a, 1995b; West, 1995). This section addresses specific key topics surrounding asynchronous transfer mode technology. A background is provided. Key factors influencing ATM development, ATM features and benefits, the ATM cell structure and transfer protocol, emerging standards, related technologies, ATM LANs, and outstanding issues are also examined.

Background

There has been a struggle between the computer and telephone industries as to which would lead the effort toward a unifying communications network. Transmission evolution in the computer industry has progressed through circuit switching and message switching to packet switching (Tanenbaum, 1988). Frame relay and finally cell relay, the basis of ATM (Davidson, 1994), are the major concepts that follow. More efficient transfer of data has accompanied each step of this evolution. For example, according to Tanenbaum, message switching eliminated the circuit switch need for an end-to-end physical copper path to be established between the sender and receiver in advance of any data transfer. Instead, these store-and-forward networks pass data between switching stations storing a complete block of data and checking each block for transmission errors before forwarding it to the next station where the reception, error checking, and forwarding is again conducted. According to Tanenbaum, packet switching networks, such as X.25 networks, offer increased efficiency in that these allow the passing of portions, or packets, of data. These networks, when transmitting a multipacket message, allow the first packet to be checked for errors and forwarded to the next station before the second packet has fully arrived. Transmission delay has been reduced and overall throughput improved.

Frame relay continued to improve on this concept by reducing the overhead previously required for error checking and correction, allowing for still greater throughput (Davidson, 1994). Finally, cell relay, as described by Davidson, allows for even higher transmission rates than frame relay as a fixed-size cell is used which (1) allows for more efficient switching and (2) reduces the reassembly processing time by receiving switches.

On the telephony side, Signaling System Number 7 (SS#7), was a 1970s CCITT (now ITU) effort to align the protocol controlling telephone switching equipment with the OSI reference model (Tanenbaum, 1988). Tanenbaum cited the Integrated Service Digital Network (ISDN) as the next major step forward in voice/data integration. ISDN, according to Tanenbaum, was the effort to replace the analog telephone system with a digital solution that is suitable for transport of both voice and nonvoice traffic. Broadband ISDN (B-ISDN) is the next step in this evolution. With B-ISDN, transmission rates are dramatically increased.

Each of the technologies described above, whether from the computer or telephony industries, has provided a step in the evolution toward a medium that can handle all communications requirements, such as the simultaneous transport of data and full-motion video. B-ISDN has been recognized by both industries as this unifying solution (Stewart, 1992). ISDN is typically viewed as a service providing transport at a rate of 64 kb/s (Taylor, 1993b). B-ISDN, on the other hand, offers much higher speeds with transfer rates in the range of 1.5 Mb/s (AT&T Bell Laboratories, 1992) to 622 Mb/s and above (Kaman, 1993; Salo, Cavanaugh, Spengler, & Thomas, 1992). Broadband rates as high as 2.4 Gb/s have been cited by Newman (1994) and Heinanen (1995).

International Telecommunication Union's (ITU) Recommendation I.121 provided a description of the basic principles of B-ISDN (International Telecommunication Union, 1991d). According to this recommendation, "asynchronous transfer mode (ATM) is the transfer mode for implementing B-ISDN" (p. 1). Several underlying characteristics of ATM were also presented in this ITU recommendation. The first characteristic presented was ATM's ability to provide a high degree of flexibility due to its cell transport concept. The small, fixed cell size (53 bytes) has been cited by Kwok (1992) as one of ATM's major advantages. ATM's cell transport concept can enable the simultaneous transport of voice, video, and text.

According to this ITU recommendation (1991d), the second underlying characteristic of ATM is its ability to provide dynamic bandwidth on demand. This allows for establishing bandwidth allocation at the time of call set-up as well as the ability to modify the allocation after the call is underway. For example, one can initiate a file transfer at any time during a call without having to reestablish the connection with new parameters necessary to transfer the file. Another example, provided by van der Veen (1993) is the ability to allow teleconference attendees to initiate a video transfer among those on the call without disrupting the current conversations.

A third characteristic of ATM, as presented by the International Telecommunications Union (1991d), is the virtual path concept which allows for simpler network management. For example, it is possible to bundle all virtual channels belonging to a specific customer within a single virtual path (Davidson, 1994).

The final characteristic presented by the ITU is ATM's independence from the physical layer. This independence allows ATM network implementations to use twisted-pair, coaxial cable, or fiber-optic cable.

B-ISDN, utilizing ATM, provides two classifications of user applications, interactive and distributive (Law, 1992). Interactive applications provide a two-way exchange of data and are typically classified as conversational, messaging, and retrieval. Examples are telephony, videoconferencing, electronic mail, and video-on-demand. Distributive applications provide a unidirectional flow of data from a source to one or more destinations. Examples of distributive applications are video rental and high-speed file transfer.

Standards for ATM and B-ISDN are currently being addressed and formalized by the standards organizations, primarily the International Telecommunications Union (ITU). In addition, organizations with commercial interests are beginning to venture into this technology with the availability of key products and services such as multimedia terminals, ATM switches and routers, and terminal adapter cards. These companies have banded together to form the ATM Forum (Clyne, 1994). The goal of this international organization is to accelerate the availability of ATM products and services through the development of interoperability specifications and to promote cooperation throughout the industry (Sammartino, 1993).

Factors Driving Broadband Technologies

Broadband ISDN, according to Kaman (1993), is "true ISDN in that it can handle services that require guaranteed bandwidth (e.g., audio, video), bursty data traffic, interactive communications between groups of persons (multicast) or person-to-person, and distributive services (i.e., broadcasting)" (p. 12). It differs from narrowband ISDN in that an optical fiber infrastructure is used as well as a fast packet-switched protocol. There are a number of factors that are driving the implementation of this technology. These factors include business requirements, residential demands, and developments in enabling technologies.

Walters, Burpee and Dobrowski (1993) discussed several business requirements that have guided the development of this technology. These include the need for teleconferencing, LAN interconnection, WAN consolidation, distance learning, cooperative work, merchandising, and corporate broadcasting. The importance of these business demands was supported by Briscoe (1993) as he claimed that the demand for high bandwidth LAN interconnection and the spreading of multimedia communications to the desktop represent key market demands leading to ATM development.

From a residential point-of-view, Walters et al. (1993) cited the demand for video services as a key factor guiding the development of these broadband technologies. Miller (1993) further specified "bandwidth-hungry applications like multimedia and the high-speed networks needed to accommodate them" (p. 23) as key technology factors. Armbruster (1995) also noted the demand for multimedia applications as a key factor leading to the development and implementation of broadband technologies. He stated that there will be fewer and fewer applications using a single information type. Instead, according to this author, applications with multiple information types will be dominant.

Developments in other enabling technologies have also aided in implementing ATM and broadband technologies in general. Davidson (1994), for example, pointed out that fiber-optic cable has lowered network noise allowing for streamlined protocols that reduce the amount of header space necessary for error checking, thereby reducing the total amount of overhead required for transmitting a message. This author also pointed out that silicon integrated circuits continue to double in density every nine months. He noted that this growth in integrated-circuit technology "is now fueling broadband LANs and WANs, providing network elements that operate at ultrahigh data rates" (p. 2).

Application Data Characteristics

Applications place different demands on the information they process. For example, application information can typically be classified as either time-based or non-time-based (Kwok, 1992). Time-based information is dependent upon delivery at specific instances to maintain its meaning. Examples of this type information are video and audio. Non-time-based information is not dependent upon this delivery constraint. Graphics, text, and still images can maintain their context and meaning without these timing considerations.

Kwok (1992) continued by categorizing delivery requirements as real-time and non-real-time. Real-time delivery is defined by Kwok as that consumed immediately. In contrast, non-real-time may be stored for later use. A phone conversation is an example of a real-time application while, leaving a voice message on an answering machine is a non-real-time application. The distinction drawn is that real-time application parties participate at the same time while non-real-time parties may participate at different times.

As the goal of B-ISDN is the transfer of all types of communication via the same physical medium (Le Boudec, 1992), ATM must be successful in the integration and transport of data regardless of whether time-based or non-time- based or whether the delivery is required in real-time.

Features and Benefits of ATM

According to Le Boudec (1992), implementing B-ISDN will provide users with high-bandwidth service capabilities for all communications types over a single physical medium. ATM's selection as the transport mechanism for B-ISDN allows for these broad capabilities.

More specifically, Briscoe (1993) presented a list of features and benefits that can be attributed to the use of ATM. These include the following:

- ATM has the ability to handle all perceived types of communications. Heinanen (1994) expanded on this benefit in crediting the chosen cell size, 53 bytes including a 5-byte header, with being able to combine the best features of circuit switching (high speed and small delay) with those of packet switching (addressability and flexible bandwidth allocation). This allows for the accommodation of a variety of services using various data types and requirements, for example, time-critical voice and video applications as contrasted to simple data file transfers.
- The simplicity found in ATM promises lower costs and easier interworking

between users.

- Emerging standards promise an open philosophy to allow for many vendors and higher competition ultimately leading to lower costs for users.
- ATM can scale from low bandwidth to gigabits per second to allow for continued evolution.
- ATM has experienced wide acceptance throughout the communications industry. This acceptance is clearly demonstrated by the large number of product announcements as well as by the strength of the ATM Forum (Sammartino, 1994).

Several other authors have supported the advantages discussed above as well as delineating additional benefits. Sammartino (1994) and Kwok (1992), for example, discussed ATM's ability to dynamically establish, maintain, and clear circuit connections in a multivendor environment allowing users greater flexibility as a major advantage. Kwok further cited other advantages. These include ATM's ability to handle integrated voice, data, and video; its ability to integrate multiple applications with diverse transmission characteristics; and its use of statistical multiplexing for sharing bandwidth, thus leading to increased network efficiency. Van der Veen (1993), Bemmel and Ilyas (1993), and Eneborg and Lagerstedt (1993) have also supported ATM's ability to provide users with dynamic bandwidth on demand, freeing up idle resources, as a key advantage. Bemmel and Illyas further stated this idle bandwidth can then be offered to more demanding users. Eneborg and Lagerstedt claimed that the flexibility to transport variable bit rates dynamically, with no limits on bandwidth fluctuations, will promote ATM as the most likely "enabling technology for multimedia communication" (p. S9).

Shimada (1995) summarized a key benefit of ATM as the ability to provide "very low latency transport of data, voice, and LAN communications over local-area, metropolitan-area, and wide-area networks" (p. 2). This author continued with a second major benefit of ATM: its ability to provide bandwidth-on-demand at a guaranteed rate for a specific connection. Other benefits offered by Shimada include ATM's (1) ability to integrate Ethernet and Token Ring legacy LANs and (2) support for many cabling types, including two- and four-pair unshielded twisted pair and multimode fiber.

Anderson, Doshi, Dravida, and Harshavardhana (1994) cited improved network restoration as a key advantage of ATM networks. A reduction in the number of network connections is a further advantage presented by Dziatkiewicz (1994). This author claimed that this advantage results from ATM's use of virtual circuits (VCs), which eliminate the user's need for separate dedicated connections leading to an overall reduction in the required number of network connections.

Finally, Armbruster (1995) further delineated a number of additional benefits that can be provided users of B-ISDN via ATM. These benefits include:

- Fewer uncertainties and mistakes on the part of users as necessary information will be available just in time and just in place;
- Improved telesurveillance, telecontrol, security, and risk minimization;
- Flexibility concerning hours, location, and the organization of work;
- Reduced travel costs;

- Improved customer relations and quicker time to market;
- Common utilization of information;
- Better support through three-dimensional visualization and demonstration; and
- Immediate advice from central experts.

<u>The ATM Cell</u>

ATM is intended to transport all communication services with the same cell format (Le Boudec, 1992). The cell used to transfer data is 53 bytes in length. It contains a 5-byte header and a 48-byte information field. Figure 4 details the structure of the cell header at the user-to-network interface, that is, as seen by devices accessing an ATM network.

The 48-byte data area was chosen as a compromise to support the voice traffic demand for quick access to the network and the data traffic demand for large data units

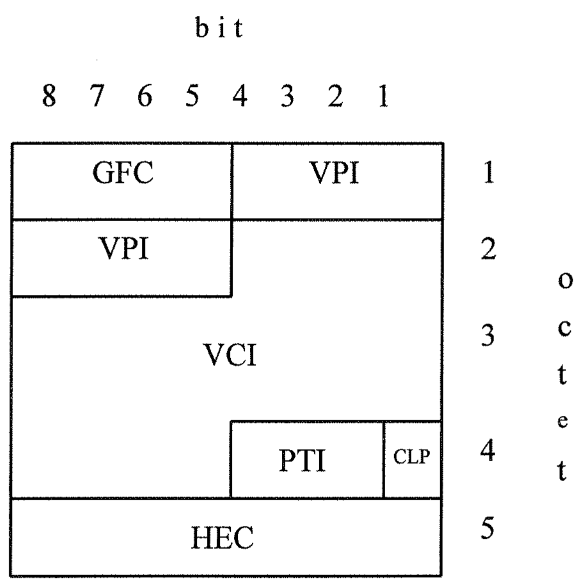

Figure 4. The ATM Header

(Salo et al., 1992). Should the full 48 bytes not be used for transporting data, padding is used to fill the cell.

Salo, Cavanaugh, Spengler, and Thomas (1992) presented the following explanation for each of the fields in the ATM header.

GFC - Generic flow control. This field is found in the first four bits of the first byte. It is used as the end-to-end flow control mechanism at the user-to-network interface. Flow control is the concept employed by a transfer mode to insure the sender sends data no faster than can be handled by the receiver (Tanenbaum, 1988).

VPI - Virtual path identifier. This is an 8-bit field found in the second half of the first byte continuing into the first half of the second byte. It is used for directing cells within the ATM network. The VPI, along with the following VCI field, is discussed in more detail below.

VCI - Virtual channel identifier. This is a 16-bit field spanning the second, third, and fourth byte of the ATM header. Along with the VPI, it is used to direct cells within the ATM network.

PTI - Payload type indicator. This 3-bit field identifies the type of data being carried by the cell. These data types include user data (in the form 0XX) or operation and maintenance data (types 100 and 101). This final type indicates the data is related to operation and maintenance of the virtual circuit that carries the cells.

CLP - Cell loss priority. This final bit of the fourth byte, if set to 1, indicates the cell has a low priority and is subject to being discarded when the network is under stress. If set to 0, the cell is of higher priority and is less likely to be discarded.

HEC - Header error correction. This final byte of the ATM header serves as a checksum for the first 4 bytes. It can correct a single-bit error and can detect some multiple-bit errors.

International Telecommunication Union Recommendation I.150 (1993a) presented a discussion of the relationship between virtual channels and virtual paths. According to this recommendation, ATM cells flow along a virtual channel, identified by their virtual channel identifiers (VCI). All cells in a given channel follow the same route across the network and are delivered in the same order as sent. Virtual channels are transported within a virtual path identified by the virtual path identifier (VPI). These virtual paths are used to aggregate the virtual channels. This relationship is shown in Figure 5.

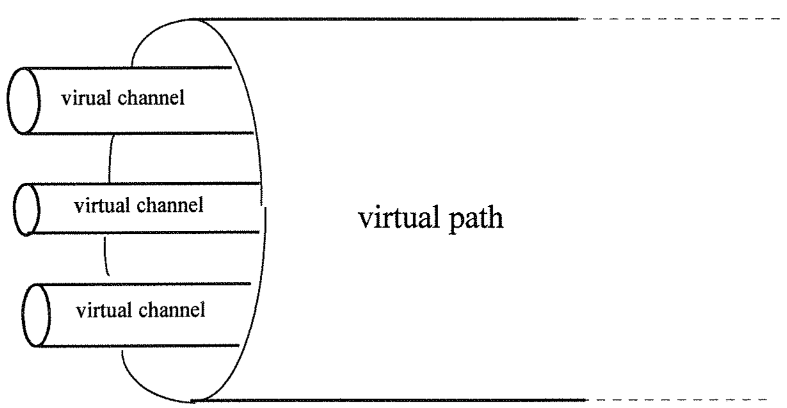

Figure 5. Virtual Channel/Path Relationship

Both virtual circuits and virtual paths are subject to being switched, via VP or VC switches, as they are transmitted through the network (Le Boudec, 1992; Salo et al., 1992). A VP switch can redirect a virtual path, but all VCs within this path remain intact. A VC switch terminates virtual paths and can switch the channels within a virtual path. Figures 6 and 7 depict these switches.

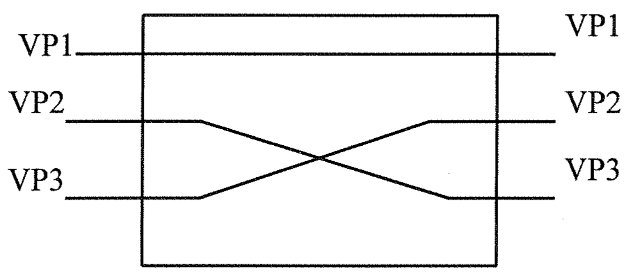

Figure 6. Virtual Path Switch

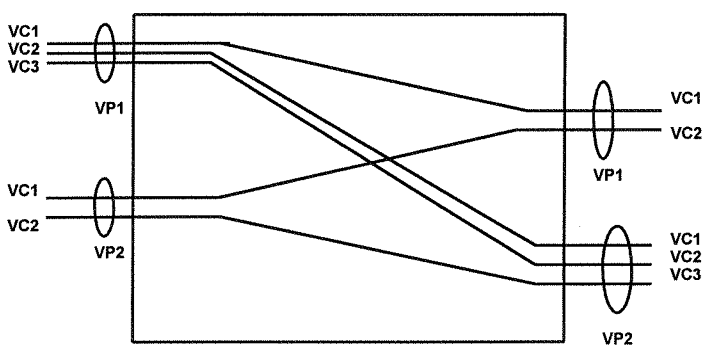

Figure 7. Virtual Channel Switch

<u>ATM Standards</u>

In 1990, CCITT (now the International Telecommunication Union - ITU) approved its first set of recommendations on B-ISDN (International Telecommunication

Union, 1991b). Following is a list of ITU recommendations that currently address the details surrounding B-ISDN and, in particular, asynchronous transfer mode technology.

I.113 - Vocabulary of terms of broadband aspects of ISDN.

I.121 - Broadband Aspects of ISDN. This recommendation listed the basic principles of B-ISDN and provided a list of developments necessary to support more advanced services and applications. This recommendation specifically stated that ATM is to be the transfer mode for B-ISDN implementation.

I.150 - B-ISDN Asynchronous Transfer Mode Functional Characteristics. The functions of the ATM layer of the protocol stack were specifically addressed in this recommendation. Virtual paths and channels were discussed in detail along with quality of service (QoS) and generic flow control (GFC).

I.211 - B-ISDN Service Aspects. This recommendation provided a classification of B-ISDN services. These services were categorized hierarchically by service class (conversational, messaging, retrieval, and distribution) and by the type of information and data within each service class. Examples of potential services and applications were further provided.

I.311 - B-ISDN General Network Aspects. This recommendation described networking techniques, signalling principles, traffic control, and resource management for B-ISDN.

I.321 - B-ISDN Protocol Reference Model and Its Application. The ATM protocol was discussed in detail in this recommendation.

I.327 - B-ISDN Functional Architecture. This recommendation provided the basic functional architecture of B-ISDN.

I.361 - B-ISDN ATM Layer Specification. The basic principles of the ATM layer and its functions were provided by this recommendation.

I.362 - B-ISDN ATM Adaptation Layer (AAL) Functional Description. The basic principles of the AAL, functions performed in the AAL, and a classification of services that may require AAL capabilities were provided by this recommendation.

I.363 - B-ISDN ATM Adaptation Layer (AAL) Specification. This recommendation addressed service and network-related issues as well as the fundamental characteristics of ATM.

I.364 - Support of Broadband Connectionless Data Service on B-ISDN. This recommendation described how connectionless data services could be supported via B-ISDN. Although considered to be connection-oriented, the provision for a connectionless service can be realized through ATM switches supporting connectionless data units between functional groups. The general protocol structure to address this service was discussed in the recommendation.

I.371 - Traffic Control and Congestion Control in B-ISDN. This recommendation discussed network congestion. Congestion is the situation in which the network is not able to meet the performance objectives. This is typically caused by unpredictable traffic fluctuations or by fault conditions in the network. Traffic control mechanisms were also described.

I.413 - B-ISDN User-Network Interface. This recommendation provided the configuration for the user-to-network interface and examples of different physical alternatives.

I.414 - Overview of Recommendations of Layer 1 for ISDN and B-ISDN Customer Accesses. Configurations for customer access to ISDN and B-ISDN were described in this recommendation.

I.432 - B-ISDN User-Network Interface - Physical Layer Specification. This recommendation provided details surrounding the user interface to the B-ISDN network.

I.580 - General Arrangements for Interworking Between B-ISDN and 64 kb/s Based ISDN. Evolutionary phases of B-ISDN implementation necessitate a variety of ways to interconnect these networks. These were discussed in this recommendation.

I.610 - OAM Principles of the B-ISDN Access. This recommendation primarily discussed the considerations of the operation and maintenance (OAM) functions.

The ATM Protocol Structure

There are three layers comprising the ATM protocol stack: the physical layer, the ATM layer, and the ATM adaptation layer (AAL) (AT&T Bell Laboratories, 1992; International Telecommunication Union, 1991e; Le Boudec, 1992). Figure 8 provides an example of an ATM channel connection displaying the hierarchy of these protocol layers.

The purpose of the physical layer is to provide transport of valid cells and to deliver timing information (Le Boudec, 1992). There are two sublayers of the physical

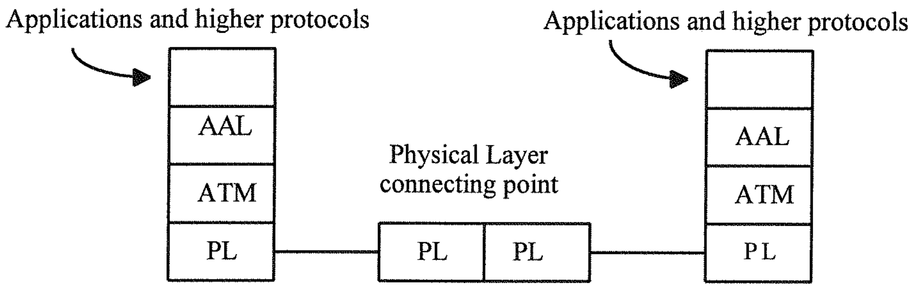

FIgure 8. The ATM Protocol Hierarchy

layer: the physical media sublayer, which provides the bit transmission and physical access to the media, and the transmission convergence sublayer, which receives the cells from the ATM layer and packs them into the proper format for transmission over the physical media sublayer.

Within the ATM layer, information is transported in the 53-byte packets (48 bytes of data and a 5-byte header) described previously (Le Boudec, 1992). Le Boudec described cell routing within the ATM layer as a function of two fields found in this header, the virtual channel identifier (VCI) and the virtual path identifier (VPI), discussed previously. International Telecommunication Union Recommendation I.150 (1993a) provided four additional functions of the ATM layer: cell multiplexing and switching, quality of service (QoS), cell loss priority, and generic flow control at the user interface. These functions were also discussed previously in the section detailing the cell header.

The ATM adaptation layer (AAL) provides the services needed when the data to be passed will span multiple ATM 48-byte cells (Salo et al., 1992; International Telecommunication Union, 1991a). To accomplish this task, ITU-T Recommendation I.362 (1993b) has proposed two sublayers of the AAL. First is the segmentation and reassembly (SAR) sublayer. which segments higher layer application data into a size suitable for an ATM cell and reassembles the ATM cell information into higher layer application information. The second is the convergence sublayer. which provides services such as cell loss detection, timing recovery, and multiplexing.

The AAL also provides a variety of services to user applications based on the type of information being passed (Le Boudec, 1992). These services are based on (1) whether a timing relationship between source and destination applications is required or not, (2) whether constant or variable bit rate applies, and (3) whether the service is connection-oriented or connectionless. Following are the different adaptation layer types that have been defined by the ITU-T:

- AAL1. This service involves the transfer of data with a constant bit rate that requires timing of information between source and destination (International Telecommunications Union, 1991a; Salo et al., 1992). Traditional voice transport is an example of an application requiring AAL1 service (Kawarasaki & Jabbari, 1991).
- AAL2. This service involves the transfer of data with variable bit rates that requires timing of information between source and destination (International Telecommunications Union, 1991a; Salo et al., 1992). Kawarasaki & Jabbari (1991) cite video and audio information as data transferred via AAL2 service.
- AAL3/4. Adaptation layer 3 was originally meant for connection-oriented, variable-bit-rate data services without a required timing relationship (Kawarasaki & Jabbari, 1991; Salo et al., 1992), while, according to

Kawarasaki & Jabbari, adaptation layer 4 was meant to support connectionless data service. Salo et al. stated these two adaptation layers have now been merged.

- AAL5. This service attempts to reduce the complexity of AAL3/4 by eliminating most of the protocol overhead. It is also meant for connectionless service (Salo et al., 1992).

The Role of SONET

The synchronous optical network (SONET) was initially developed to facilitate connecting multivendor fiber-optic networks ("The SONET success," 1994). SONET's goal was to provide simplicity for the fiber network environment as it addresses the complex problems that accompany higher bandwidth. For major ATM implementations, SONET provides the infrastructure over which ATM cells are transmitted (Christensen & Hughes, 1994).

SONET is capable of delivering bandwidth-on-demand at very high rates ranging from 51.84 Mb/s to over 13 Gb/s (Davidson & Muller, 1992). A major advantage, according to Davidson and Muller, is its ability to remain independent of the specific services and applications it supports. These authors continued that because of these capabilities, SONET is expected to displace dedicated circuits and will "one day make videoconferencing as convenient to use as *plain old telephone service*" (p. 287).

Naegle, Gossage, Testi, Vahle, and Maestas (1995), in their discussion of the ATM/SONET implementation at Sandia National Laboratories, presented seven key benefits of SONET use. These are:

- It is highly reliable.
- It is very efficient in its use of optical fiber conductors.
- It offers very high bandwidth capacity.
- National and international telecommunications standards exist.
- It supports interfaces for all types of information - voice, video, and data.
- It offers "essentially unlimited loss budget and distance range" (p. 663).
- Integrated operations, administration, management, and provisioning support are available.

SONET's role is to provide the transmitters, receivers, and amplifiers (Christensen & Hughes, 1994). It also provides the framing and control signals to insure the information streams are synchronized. This synchronization insures the integrity of the data streams, that is, the data will be received in the same order as sent regardless of how it is passed through the network.

ATM LANs

ATM was first defined by the CCITT for application in public networks (Fischer, Wallmeier, Worster, Davis, & Hayter, 1994). Fisher et al. continued that since its introduction, the advantages of the ATM concept have become more appreciated by manufacturers of computer systems and LANs as a flexible technique for a wider variety of applications. They cited the ATM Forum's efforts in defining the role of ATM LANs as evidence of this trend. This was further supported by Armbruster (1995) and Heinanen (1995) as they stated that the interconnection of LANs and WANs will be an important application for the initial phase of ATM network implementations.

Fischer et al. (1994) and Kavak (1995) pointed out a primary difference in the ATM and traditional LAN concepts. Conventional LANs and metropolitan-area networks (MANs) operate in a connectionless manner. ATM LANs, on the other hand, are connection-oriented. Because of this, before any data can be transferred, a connection must be established between two ATM hosts (Chao, Ghosal, Saha, & Tripathi, 1994). Once this connection is established, data are transferred between these nodes in the 53-byte ATM cells. The goal of ATM LAN emulation is to use this connection-oriented concept to emulate the connectionless nature of existing LANs (Jeffries, 1994). Jeffries stated that this will provide a service where users on an existing LAN can connect to both users on the same LAN as well as users on other LANs via ATM servers, routers, bridges, and other connection devices. According to Jeffries, this service should be provided without any modifications to the existing legacy LANs. To accomplish this, the conversion of LAN data packets "into ATM cells (and vice versa) without generating too much overhead at the ATM-attached devices" (p. 95) is required.

The importance of providing ATM LAN support without any modification to the existing legacy LANs was further supported by Newman (1994). Newman stated that for ATM to succeed as a LAN technology, it must interconnect installed-base LANs by supporting the existing protocol stacks without modification.

Figure 9 illustrates an example of an ATM-emulated LAN as proposed by Kavak (1995). Three ATM LAN emulation services are depicted as a part of the network; an LE Server (LES), a broadcast and unknown server (BUS), and a LE Configuration Server (LECS). According to Kavak, the LES provides for registration and address translation

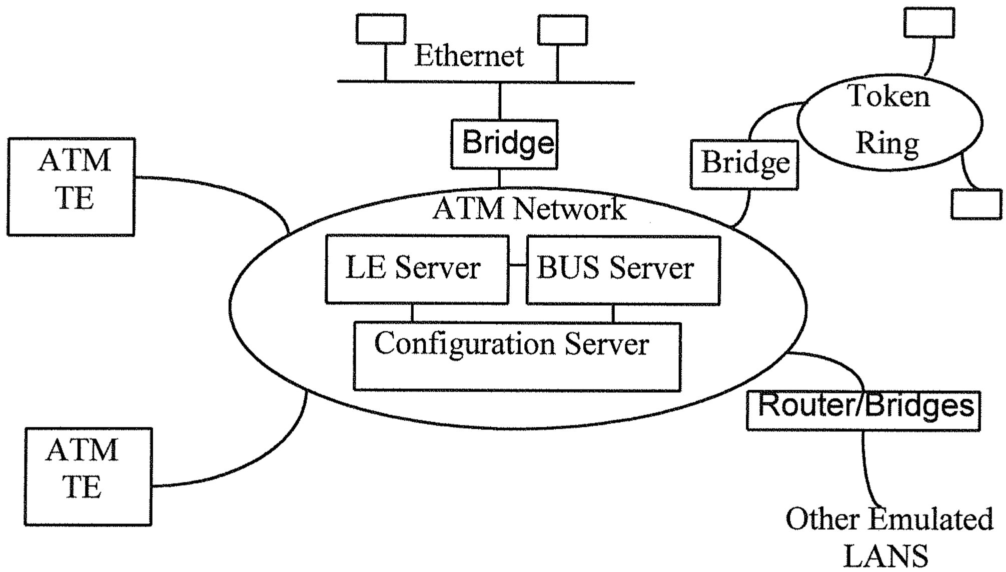

Figure 9. An Example of an Emulated LAN

into ATM addresses, the LECS is used for locating the LES and obtaining information about the configuration for each ATM segment, and the BUS is used for passing multicast/broadcast and also for passing data to unregistered LANs for which addresses cannot be resolved.

One advantage of LAN emulation, as pointed out by Chao et al. (1994), is the possibility of removing potential traffic bottlenecks found in busy existing LANs. These authors stated local area networks are "primarily based on shared media interconnects" (p. 52). These interconnects are likely to lead to bottlenecks because of the emerging multi-media applications contending for bandwidth resources and because of other rapidly growing services that offer simple data transfers. ATM's ability to provide switching and multiplexing to allow for increased bandwidth and greater flexibility, the authors claimed, offers the potential of relief from this bottleneck. Jeffries (1994) also supported this advantage. According to Jeffries, since most traffic will be "carried on independent point-to-point connections . . . , there's far more capacity available" (p. 99).

A second advantage of ATM LAN emulation has been pointed out by Jeffries (1994). Users on existing LANs currently reside at the same geographic locations. This limitation has been removed through the LAN connections to ATM networks. Users of ATM LAN emulation are geographically restricted only by the scope of the ATM LAN, which may be global in nature.

Jeffries (1994) stated that all of the activity on an ATM-emulated LAN follows five steps. These are:

- Initialization. The first necessary activity is to establish an ATM connection. This is accomplished by the LAN emulation client finding the address of the ATM server so it can join the emulated LAN. This address is available from a table in the ATM switch.
- Configuration. Once the ATM server address is established, the maximum acceptable frame size is determined from the ATM server.
- Joining. A join request is then sent to the LAN emulation server. This request contains the ATM address, LAN type, and maximum frame size.
- Registration and BUS initialization. Once the join is complete by registering with the LAN emulation server, a data connection is established with the BUS, or the broadcast MAC (media access control) address, and the client is added to the ATM's virtual connection.
- Data Transfer. The LAN emulation client is now ready to transfer data.

ATM Migration

Armbruster (1994) cited four phases in the migration to ATM networks.

- Interconnection of LANs and WANs. This step is currently underway. Fisher, Goeldner, and Huang (1992) also supported this interconnection as a first phase of ATM migration. Armbruster further stated that the continued use of LANs "is a given" (p. 41) due to the investment and projected development.
- Introduction of ATM networks or the upgrading of existing networks by ATM crossconnects and switches. Armbruster projected this phase beginning in 1995.
- Access to narrowband networks via ATM interfaces, which should begin in 1996.
- Integration of narrowband services into the universal ATM network. Armbruster claimed this phase may begin toward the end of the 1990s.

A slightly different approach to ATM migration has been proposed by Briscoe (1993). This author agreed that the implementation of wide area networks is the first opportunity for ATM. This opportunity is based on a growing demand for high bandwidth communications across widely distributed locations. This demand for high bandwidth communications will lead to private network solutions and interconnecting LANs via ATM. Briscoe cited access at the premises (direct user access) as the second major evolutionary opportunity for ATM. This approach has also been supported by Handel and Huber (1994).

Fukuda, Kodama, and Katsube (1993) provided support to the above, but offered a slightly different view of the evolution. They stated that ATM as a leased line, public network service will be the first phase, or the introductory stage. This stage will allow users to subscribe to a service allowing the interconnection of LANs and/or PBXs located at geographically separated sites. Phase 2, or the expansion stage, is based on the emergence of ATM terminals. These terminals will allow direct connections to ATM switches by users. The final, or the diffusion stage, will be characterized by the replacement of ordinary voice telephones by "some type of multimedia terminals" (p. 214). During this phase, multimedia terminals, high resolution color displays, and multimedia/hypermedia databases will be widely used. In addition, high definition TV will become more important.

Duke-Woolley (1993) presented a slightly different approach to ATM migration. This author claimed large corporations are currently moving toward ATM in two phases. The first step involves the implementation of frame relay. This migration allows the corporations to take advantage of frame relay's high-speed data transfer capabilities. As ATM becomes more available and economically more practical, it will gradually replace frame relay in the backbone network. Kapoor (1991) also supported this initial migration to frame relay and stated that, due to the overlap in user requirements and in timeframes of availability of these services, there will be a period of coexistence for the two technologies.

A Comparison With Related Transfer Modes

A broadband technology related to ATM is frame relay. The concept behind frame relay is simple, namely eliminate protocol overhead and associated processing at each network node to allow for a more efficient transmission of data (Davidson & Muller, 1992). The frame, the basic unit of transfer in this technology, is variable in length, but cannot exceed 8,189 bytes. Davidson and Muller continued that, through the use of this lowered protocol overhead, frame relay typically transmits at a rate of 1.544 Mb/s. However, increased rates are possible utilizing SONET and the fiber distributed data interface (FDDI), a fiber-based networking standard.

Davidson (1994) cited advantages of frame relay as (1) efficient transport of bursty applications that require high-speed data transfer, (2) a cost-effective alternative to leased lines, and (3) support for LAN interconnections. As this author pointed out, however, although frame relay provides efficient high-speed transport of data, its transfer rates are not fast enough to effectively support voice or video. In addition, the variable length nature of its data unit is not suitable for providing integrated video services (Taylor, 1993a).

Another transfer service related to ATM and offered by telephone companies is the Switched Multi-Megabit Data Service (SMDS) (Davidson & Muller, 1992). Davidson and Muller, as well as Salo et al. (1992), described SMDS as a connectionless technology that is being tested at the 1.5 Mb/s and 45 Mb/s level and is anticipated to reach 150 Mb/s as compared to ATM, which is expected to reach 622Mb/s and beyond (Kaman, 1993).

Davidson and Muller (1992) offered several advantages of SMDS over other alternatives. With its bandwidth-on-demand service, SMDS can provide a low cost, high speed network for distributed locations that need occasional remote connections. Next, SMDS offers more simplified routing via its connectionless network as compared to the connection-oriented frame relay. SMDS provides fault tolerance, high survivability, and increased reliability due to its dual-bus architecture. Additionally, SMDS supports voice and video traffic via fixed-size packets, each with a payload of up to 9,188 bytes and a header (Grovenstein, Pittman, Simpson & Spears, 1994), which are further segmented into 53 byte cells (Davidson, 1994; Kapoor, 1991) for transport across the network. Finally, SMDS is compatible with other emerging networks, such as ATM, providing a natural migration path.

One further transfer mode, for which standards are being defined and developed for broadband ISDN service, is the SynchronousTransfer Mode (STM) (Davidson & Muller, 1992). While ATM employs a statistically multiplexed method of transport, STM relies on time-division multiplexing. Davidson and Muller further described STM as (1) being circuit-switched and (2) providing dedicated bandwidth while ATM allows bandwidth-on-demand over virtual circuits.

Bemmel and Ilyas (1993) claimed that ATM's main advantages over the more traditional STM technology are (1) higher bit flexibility and (2) a greater degree of integration both in transmission and switching functions. Anderson, Doshi, Dravida and Harshavardhana (1994) further claimed that ATM will offer more efficient network restoration over STM based on (1) its cell level error detection that allows for an enhanced ability to detect failures, (2) its rate adaptation ability that allows for increased capacity utilization which can yield faster and more flexible network reconfiguration, and (3) its nonhierarchical multiplexing which allows for more flexible interface structures and eliminates multiplexing stages within the network.

<u>ATM Issues</u>

According to Sammartino (1994), congestion control is probably ATM's major unsolved technical issue. This author stated that there are no inherent flow control mechanisms in ATM. These must be built on top of ATM protocol stacks so data flow can be controlled by reducing the traffic when necessary to avoid congestion. Sammartino stated that this solution should be available in 1996.

Chang and Su (1992) also cited congestion control as a major ATM architectural issue along with traffic control. The distinction between these two concepts, as offered by these authors, is that congestion control deals with situations where total traffic has exceeded the capacity of the network while traffic control manages the data flow so congestion is prevented. Their 1992 study presented a general overview of these issues as well as a survey of techniques and algorithms that offer potential resolution to the congestion control problem. These potential solutions include:

- All cells share a common buffer. Lower priority cells are allowed to be pushed out and lost when congestion occurs.
- Buffers do not allow lower priority cells to enter unless adequate space is available.
- Different buffers exist for cells of different priorities.

Traffic control solutions presented by Chang and Su include preventive actions such as flow control, restrictive actions like admission control, and reactive actions like early congestion notifications. After summarizing and analyzing various algorithms and schemes that attempt to resolve these issues, the authors concluded that "more sophisticated control procedures and resource management need to be developed in a timely manner and have to be seriously considered for standardization" (p. 29).

Stallings (1995) claimed the complexity of the congestion control problem is compounded by the limited availability of overhead bits to be used to exert flow control of user cells. One possible solution to this issue has been proposed by Bemmel and Ilyas (1993). They suggested expanding the 1-bit cell loss priority (CLP) field to two bits which would allow for a new priority strategy based on four classes rather than two. Their research suggested that this strategy offers significant improvement in the overall traffic flow. However, further study of the scheme is required in a multiple-node environment.

Simcoe and Roberts (1994) discussed two other potential solutions to the congestion control problem, specifically credit-based flow control and rate-based flow control. In a credit-based flow control implementation, each virtual circuit on an ATM network is assigned a specific amount of buffer space and a corresponding number of credits that indicate the amount of data that can be accommodated by the downstream ATM switch. When transmission occurs over the circuit, the downstream switch returns a notification as to whether the data was forwarded or buffered. If buffered, no credit is issued so the sending node stops transmitting. If the data are forwarded, a credit is returned telling the source node to continue transmitting. These authors claimed that this concept allows a balance across the network on a node-by node basis.

The rate-based paradigm, according to Simcoe and Roberts (1994), relies on cell transmission between source and destination nodes to control traffic rates. This is accomplished by having the sending node interleave its data cells with resource management (RM) cells that indicate the source's current transmission rate and desired rate. Each RM cell received is returned by the destination node. Along the circuit back to the source, each node along the way reads and stamps the returning cell indicating whether the present transmission speed is acceptable, whether the source can increase the speed, or whether a slower rate is desired. This method, according to the authors, allows the source to always use a current snapshot of the entire network's condition to adjust its rate of transmission.

The ATM Forum had originally considered both the rate-based and the credit-based schemes (Kavak, 1995). The rate-based paradigm was adopted in October 1994 (Stallings, 1995).

Federline (1995), Hodges (1995), Lang (1995), and Miller (1993) felt that ATM costs are another major issue facing potential customers. Lang stated that "it's not yet economically feasible to extend ATM all the way to most desktops" (p. 31). Federline further supported this position. This author claimed that ATM services at a 45 Mb/s rate are too expensive, and as the services grow to 155 Mbps, the costs become prohibitive.

Tariffs are having a substantial impact on the ATM cost issue. According to Miller (1993), over a five year period, WAN tariffs are likely to represent more than 80% of the internetworking expense. This author further claimed multimedia usage is likely to drive those costs even higher. Hodges (1995) felt these broadband tariffs must be addressed if ATM "is to grow beyond the experimental stage" (p. 25).

Hodges (1995) further claimed that if ATM is to "become as ubiquitous as predicted" (p. 25), the overall costs of its network services must be reduced. This author believed that this is more important than the introduction of new and distinct broadband network services. Hodges, stated "ATM offers an exceptional revenue opportunity for [ATM providers] if users can be motivated to experiment with applications and develop a business case for aggressive ATM consumption. This is possible only if ATM threshold costs are low" (p. 26).

With respect to the above cost issue, following are several examples of ATM equipment prices:

- ATM Switches.

  A 4-port switch from UB Networks - $9,990 (Data Communications, 1994a).
  A 16-port switch from UB Networks - $15,920 (Data Communications, 1994a).
  A 24-port switch from Fore Systems - $35,880 (Data Communications, 1994c).
  A 29-port switch from Alcatel - $40,000-120,000 (Data Communications, 1994d).
  An ATM WAN switch from Fore Systems - $88,000-200,000 (Data Communications, 1994c).
  A high-capacity ATM switch from AT&T - $50,000-400,000+ (Data Communications, 1994d).

- Adapters and Concentrators.

  A 24-port multimedia access concentrator from General Datacomm - $20,000 (Data Communications, 1994b).
  A 25 Mb/s ATM adapter from Turboways - $405 (Data Communications, 1994d)

- Routers.

  An ATM router from Netedge Systems - $24,250-52,750. (Data Communications, 1994d).

- Diagnostic and Test Equipment

  A one-port ATM analyzer from Siemens AG - $44,160 (Data Communications, 1994a).

A multi-port ATM analyzer from Adtech - $30,700 (Data Communications, 1994e)

These equipment prices can translate into individual user-interface ATM connection costs of between $1,000 and $3,000 (Prabhakar, 1995). This can be compared to LAN user-interface connections that range in cost from $100 to $200.

A further issue facing potential users of ATM is the growing complexity of network management complicated by the virtual networking capabilities associated with ATM (Federline, 1995). Federline claimed the entire network must be perceived as one entity, not individual physical networks. Troubleshooting of the ATM-based network cannot be conducted as it is today, for example, by simply attaching a protocol analyzer and analyzing the carried traffic. Management of the network is made more complex by the high volume of network management and control data as well as the connection-oriented environment. The author claimed decentralized network management solutions must be developed to address this increased complexity.

Several other issues warrant mention. Federline (1995) claims the ATM protocol at the adaptation layer, as it packetizes the input, adds additional cell overhead and delay in addition to potential cell loss. Sammartino (1994) felt a further issue to be addressed is multivendor interoperability as more vendors begin to ship their products.

Projected Applications and Services

ITU-T Recommendation I.211 (International Telecommunication Union, 1993d) presented a list of potential services and applications based on two categories, interactive and distribution. According to this recommendation, there are three different services making up the interactive category: conversational, messaging, and retrieval.

Distribution services include distribution without presentation control and distribution with presentation control. The following paragraphs summarize the potential available services and applications as presented by Verma and Kapoor (1990) based on these service categories.

1. Interactive-conversational class. There are four different types of information found in this service class: video/sound, sound, data, and document transfer. Potential applications include movies, tele-education, building security, multilingual complementary channels, and high-speed transfer of data and images.

2. Interactive-messaging service. Two different types of information are found in this service class: video mail and document transfer. Applications include transfer of moving pictures and an electronic mailbox for mixed-media documents

3. Interactive-retrieval. This service class includes the retrieval of infor- mation such as text, data, graphics, sound, still images, and moving pictures. Applications include entertainment, remote education, image communication, mixed-document retrieval, and telesoftware.

4. Distribution without presentation control. This service class includes the following four different information types: (1) video; (2) text, graphics, and still images; (3) data; and (4) moving pictures and sound. Applications include distribution of television programs, electronic newsletters, and distribution of unrestricted data.

5. Distribution with presentation control. This service class includes text, graphics, sound, and still image information types. Applications of this service include tele-education and news retrieval.

Summary

In this section of Chapter 2, the Review of Literature, asynchronous transfer mode technology was discussed in detail. In this regard, the following topics were presented: a background of ATM, factors driving broadband technologies, characteristics of application data, features and benefits of ATM, the ATM cell, ATM standards, the protocol structure, the role of SONET, ATM LANs, migration to ATM, a comparison with related transfer modes, issues, and projected applications and services.

Summary of What is Known and Unknown About the Topic

Based on the literature review presented in this chapter, the following was learned.

- With respect to emerging broadband technologies:

    1. Emerging telecommunications technologies, particularly broadband communications, are being implemented in educational environments (Aaron, 1995; Bernier, 1993; Chavkin et al., 1994; Feldman, 1995; Grovenstein et al., 1994; Heinanen, 1994; "Iowa taps," 1994; Littman, 1996; O'Shea, 1994a, 1994b; Patterson & Smith, 1994).

    2. There is a need for school district educators and staff to become more actively involved in the planning for purchase, implementation, and

continued use (Branscum, 1992; Dyrli & Kinnaman, 1994d; Friedman, 1994; Kaman, 1993; Kinnaman, 1994; VanSciver, 1994, 1995).

3. Within this school district staff, there is an overall gap in knowledge of these technologies, specifically broadband technologies, hindering this involvement (Dyrli & Kinnaman, 1994a; Friedman, 1994; Gross-Peck & Beyda, 1993; Killian, 1994; Pickelsimer, 1994; Van Horn, 1995a; West, 1995).

4. Training is a means by which this gap can be narrowed (Branscum, 1992; Dyrli & Kinnaman, 1994c, 1994d; Friedman, 1994; Grosse-Peck & Beyda, 1993; Killian, 1994; Kingston et al., 1992; Mageau, 1994a; Van Horn, 1995a, 1995b; West, 1995).

5. Networking and telecommunications have been cited as the most critical of the emerging technologies for educational environments (Dyrli and Kinnaman, 1994e; Eberlee, 1994; Mageau, 1994b; West, 1995).

- There are specific training approaches that enhance and increase the effectiveness for adult learners (Ament, 1991; American Society for Training and Development, 1986b; American Telephone and Telegraph, 1987; Amthor, 1991; Dejoy & Mills, 1989; Geisman, 1992; Khalili & Shashaani, 1994; Spille et al., 1985).
- Multimedia and its hypertext subset are an effective means by which to address these particular training needs desired in adult training (Geisman, 1992; Jerram, 1994; Luther, 1992; Staninger, 1994; Weisburgh, 1991).

- There are structured models that aid the development of computer-based training, such as hypertext (Adams, 1994; Analysis and Technology, Inc., 1995; Atkins, 1994; Dean, 1994; Gentry, 1994; Givotovsky, 1994; Gleason, 1991; Orr et al., 1993).

The Contribution This Study Will Make to the Field

The purpose of this study was to investigate the effectiveness of a hyper- text-based training solution for increasing the knowledge of ATM on the part of educators and school district technology planners. A secondary goal was to measure this population's attitudes and opinions toward this method of learning. Based on the results of the study, well-researched guidance on training internal staff can be provided to school districts as they plan their purchase, migration to, and implementation of broadband technologies.

Summary

This review of literature addressed several areas. First, as the problem to be addressed indicated a lack of background and training in computer and telecommunications technologies, particularly in B-ISDN topics, on the part of school district staff, adult learning was explored. This literature indicated that adults should be given the opportunity to navigate training media at their own pace and sequence based on their personal training needs. Attention was then given to multimedia, and hypertext in particular, as a potential solution in addressing training needs of these adults. As multimedia/hypertext allows for flexibility on the part of the participant in structuring the pace and sequence of the learning, it provided a solution for the learning requirements of this population. Multimedia/hypertext authoring systems were discussed next. A number of structured instructional design and development models were then detailed. Finally, asynchronous transfer mode technology was discussed in detail.

Chapter 3

Methodology

Introduction

In this section, the method used for developing and testing the interactive hypertext tutorial/guide on asynchronous transfer mode technology will be discussed. In particular, the methodology used included (1) selection of the authoring system and (2) development of the tutorial/guide on asynchronous transfer mode technology following a structured methodology for the development of training materials. As a part of this development, the learning objectives of the tutorial and the tests used to measure its effectiveness were reviewed and validated by a panel of experts.

Following its development, the ATM tutorial/guide was administered to the selected sample. Finally, the guide/tutorial was evaluated. This evaluation included (1) an analysis of learning effectiveness and (2) an analysis of the sample's attitudes and opinions toward this method of learning.

Restatement of the Problem

The importance of the involvement and participation by educators in the selection process, implementation, and use of broadband technologies was demonstrated in the review of literature (Branscum, 1992; Dyrli & Kinnaman, 1994d; Friedman, 1994; Kaman, 1993; Kinnaman, 1994; VanSciver, 1994, 1995). A knowledge gap hindering this involvement was also determined through this review (Dyrli & Kinnaman, 1994a; Friedman, 1994; Gross-Peck & Beyda, 1993; Killian, 1994; Pickelsimer, 1994; Van Horn, 1995a; West, 1995). To close this gap, a number of authors have supported increased training for school district staff and technology planners (Branscum, 1992; Dyrli & Kinnaman, 1994c, 1994d; Friedman, 1994; Grosse-Peck & Beyda, 1993; Killian, 1994; Kingston et al., 1992; Mageau, 1994a; Maule, 1993; Van Horn, 1995a, 1995b; West, 1995). Reducing this knowledge gap soon via training is critical as pilot projects are currently being implemented testing the capabilities of this technology in the school environment (Aaron, 1995; Bernier, 1993; Chavkin et al., 1994; Feldman, 1995; Grovenstein et al., 1994; Heinanen, 1994; "Iowa taps," 1994; Littman, 1996; O'Shea, 1994a, 1994b; Patterson & Smith, 1994).

Restatement of Major Issues and Research Questions

The first issue to be researched was learning effectiveness for adults. It was demonstrated that learning effectiveness differs between adults and children (Ament, 1991; Spille et al., 1985). Adults prefer flexibility in training, that is, they specifically prefer flexibility in (1) choosing their own sequence for accessing and reviewing training materials (AT&T, 1987; Dejoy & Mills, 1989; Spille et al., 1985), (2) controlling the rate of presentation (AT&T, 1987; Dejoy & Mills, 1989; Spille et al., 1985), and (3) in selecting the time of participation (AT&T, 1987). Furthermore, it was shown that adults learn more effectively if actively involved (Amthor, 1991; ASTD, 1986b; Geisman, 1992).

The second major issue addressed in solving the problem was to determine the appropriate method or media to be used in development of the tutorial for use by adults.

Kearsley (1987) proposed use of a checklist for determining the applicability of a computer-based alternative to traditional training methods. The results of applying this checklist to the proposed ATM tutorial can be found in Appendix A. These results suggested that the choice of computer-based instruction was an appropriate vehicle for this tutorial on ATM. The results were consistent with the review of literature addressing the use of a computer to deliver training to adults as delineated in Chapter 1.

The second part of this issue was whether this topic, an educator's guide to asynchronous transfer mode technology, if offered via computer-based instruction/training, lent itself to a multimedia/hypertext solution. As discussed earlier, Eugenio and Habelow (1994) differentiated between 4 different types of multimedia. Type 0 is the electronic access and dissemination of information such as an online help function. Type I is the mastery of knowledge. Type II and Type III are both performance-based training of complex tasks, such as troubleshooting and diagnosis, the difference being Type III includes simulation. The objectives of the hypertext-based tutorial suggested a Type I alternative, as the goal was more than simply accessing and disseminating information as suggested by Type 0 multimedia. However, the performance-based training goals of Type II and Type III were beyond the scope of this dissertation. Rather, the goal of the tutorial was to assist school district staff members in defining, identifying, listing, describing, and summarizing key aspects of the ATM as these apply to an educational environment. Eugenio and Habelow referred to Type I multimedia as interactive hypertext/hypermedia.

Eugenio and Habelow (1994) stated that a hypertext application should include hyperlinked presentations using text-based content with simple graphics. These authors further stated the application should also contain a level of interactivity that includes user responses to system prompts, simple branching, feedback, and remediation. The hardware and software that may be utilized, according to these authors, could include a DOS, MPC, or UNIX computer with suitable hard drives and an authoring system. Finally, the authors suggested that the user interface be simple and should provide basic information regarding student presentation controls such as quit and page forward and back.

Eugenio and Habelow (1994) continued that no simulations are necessary to implement Type I multimedia. However, appropriate media elements may include "nonprofessional narration; purchased sound effects and music clips; un-retouched 8-bit low-color photos; clip art, flow charts and line drawings" (p. 24). The authors further suggested 2-D and 3-D models, as well as video, are not necessary for this level of multimedia.

Hypertext, as described above, supports the characteristics of learning materials that make adult learning more effective. First, learners can access, via hypertext, the topics in the sequence they prefer (Bornman & von Solms, 1993; Craver, 1991; Kearsley, 1990; Nielsen, 1990a, 1995; Staninger, 1994). In addition, hypertext, as a form of computer training, offers by its very nature the ability to allow adults to control the rate of presentation and to access the materials according to their own schedule.

The third area of research was to investigate and select a structured method by which the application could be designed and developed. Eugenio and Habelow (1994) stated the instructional design of a hypertext application should focus on "content and simple task analysis . . . Also, a systematic approach to instructional design (i.e. ISD-type model)" should be employed (p. 22). This use of a structure model was further supported by a number of authors (Atkins, 1994; Dean, 1994; Gleason, 1991; Orr et al., 1993).

A number of such models were analyzed and presented in Chapter 2, the Review of Literature. However, several authors (Adams, 1994; Analysis and Technology, Inc., 1995; Gentry, 1994; Givotovsky, 1994) pointed out differences in multimedia development that necessitate modifications to the models to increase their effectiveness. For example, the development of storyboards prior to course authoring is an effort not typically required of traditional instructor-led training; however these are necessary in multimedia development.

The final area of investigation surrounded the topic of ATM. This effort was made easier by the wealth of information available on all aspects of this emerging technology.

Restatement of Assumptions and Limitations

Two limitations were noteworthy with respect to this investigation. First, a truly random sample of all school district technology planners and teaching staff throughout the United States was not expected. Hence a case-study research approach was proposed and employed. The professional staff from a single school district was selected and a random sample chosen from this group of educators. This is discussed in more detail in a following section.

The second limitation was that it was not possible to oversee all subjects as they responded to the pretests and posttests.

In addition to the above limitations, the following assumptions were basic to the proposed study:

- Educators and staff involved with this study of ATM and its potential use within a school district were to have access to the appropriate hardware to use the proposed interactive multimedia/hypertext training tool.
- The individuals would respond to the pretests, posttests, and questionnaires honestly, truthfully, and without the assistance of others.

Restatement of Goals and Objectives

The goal of the tutorial was to offer a training alternative by which educators and other school technologists could improve their knowledge of asynchronous transfer mode technology. This goal included an evaluation of the tutorial/guide in terms of (1) learning effectiveness and (2) preferences, attitudes, and opinions toward the training medium. The measure of learning effectiveness was based on a comparison of pretests and post-tests designed and validated during the development phase. Preferences toward this hypertext-based training solution were measured via a comparison of the precourse and postcourse surveys found in Appendices C and D.

Research Methods Employed

A case-study approach was used to investigate the effectiveness of the ATM tutorial/guide for educators and technology planners. The following subsections provide further explanation for this choice of research method.

Case-Study Justification

Yin (1994) presented a comparison between five types of research strategies: experiments, surveys, archival analyses, history, and case-studies. This comparison was based on the form of the research questions being investigated. This author has claimed that the appropriate strategies for researching how questions and why questions are experimental research, historical research, or case-studies. Surveys and archival analyses are appropriate techniques to investigate who, what, where, how many, and how much questions. As this dissertation effort focused on how educators and technology planners can increase their knowledge of ATM, surveys and archival analyses were not appropriate. Historical research does not focus on contemporary events, such as the administration and analysis of the tutorial/guide on ATM for educators. Hence this technique was eliminated as a potential research method. As experimental research requires control over behavioral events, such as the control found "in a laboratory setting" where the researcher "can manipulate behavior directly, precisely, and systematically" (p. 8), this method was also eliminated as a technique by which this investigation could be conducted. Based on this analysis, a case-study was found to be the appropriate research technique for this dissertation.

The selection of a case-study approach for this dissertation was also consistent with the description of case-study research as provided by Gay (1992). According to this author, "a case-study is the in-depth investigation of an individual, group, or institution" (p. 235). For this research effort, the group selected for investigation were personnel from a single school district.

Case-Study Design Considerations

Yin (1994) claimed there are five components to be considered in the design of a case-study. First, the case-study's questions must be developed. As previously stated, the focus of this investigation was to investigate *how* educators and technology planners can increase their knowledge of ATM. A hypertext-based tutorial was proposed and employed for this investigation as supported by the review of literature related to (1) adult training and education, (2) use of computers for adult training, and (3) multimedia/hypertext capabilities and limitations.

The second component of case-study design, according to Yin (1994), is to determine the study's proposition(s). These propositions direct attention to specifically what will be examined within the scope of the study. In this dissertation's effort, the proposition under investigation was (1) learning based on the hypertext-based ATM tutorial/guide as well as (2) preferences toward this method of training.

Yin's (1994) third design component is the unit of analysis. This unit may take several forms. For example, the unit of analysis of a case-study may be an individual, a larger entity such as a defined group or organization, an event such as a specific decision, or a specific state such as the economy of a nation. A school district served as the unit of analysis for this particular study. The choice of a single, specific school district was consistent with Yin's approach to case-study design as he stated a single case or multiple cases are both appropriate for this research technique. Seminole County Public Schools in central Florida specifically served as the case to be investigated in this study. This particular school district was chosen as an interest in focusing on the use of technology in a school setting had been displayed through establishing and staffing (1) technology planning positions at the school district level as well as (2) technology facilitators at the individual schools (Pickelsimer, 1994).

Yin's (1994) fourth component in the design of a case-study was to link data to the propositions. The propositions for this particular study were specified earlier in this section as (1) the learning achieved from the hypertext-based ATM tutorial/guide as well as (2) preferences, opinions, and attitudes toward this method of training. The data used for interpreting these topics of investigation were (1) the results of precourse and postcourse topic mastery tests and (2) the shift in preferences, attitudes, and opinions based on a differences found between the precourse and postcourse surveys.

Yin's (1994) final step in designing a case-study was to determine criteria for interpreting the findings. Statistical analyses of the comparison of (1) the precourse and postcourse topic mastery tests and (2) the precourse and postcourse attitudinal surveys, described previously in this section, were determined to provide the statistical data. Specifically, a *t*-test for nonindependent samples, discussed in more detail in a later section of this chapter (Format for Presenting Results), provided the quantitative data for analysis and evaluation.

<u>Case-Study Significance</u>

Yin (1994) stated that case-study significance can be determined by those studies where:

- An individual case or cases are unusual and of general public interest.
- The underlying issues are of national importance in either theoretical or

practical terms.

- Both of the above apply.

It could not be argued that the case selected, that is the professional staff from the Seminole County Public Schools, was unusual or of general public interest except within its immediate locale. However, as shown in Chapter 1, broadband applications and pilot projects incorporating ATM were underway in school environments across the United States (Aaron, 1995; Bernier, 1993; Chavkin et al., 1994; Feldman, 1995; Grovenstein et al., 1994; Heinanen, 1994; "Iowa taps," 1994; Littman, 1996; O'Shea, 1994a, 1994b; Patterson & Smith, 1994). The significance of training educators and technology planners in preparation for further efforts similar to these was supported by the literature discussed in Chapter 1 (Branscum, 1992; Dyrli & Kinnaman, 1994c, 1994d; Friedman, 1994; Grosse-Peck & Beyda, 1993; Killian, 1994; Kingston et al., 1992; Mageau, 1994a; Maule, 1993; Van Horn, 1995a, 1995b; West, 1995). Hence, it was claimed that this issue was of national importance in school district environments.

Specific Procedures Employed

There were four primary steps followed in implementing this project. The first step was to design and author the ATM tutorial/guide using the selected authoring system and following the structured development model described later in this chapter. Next, the population sample was selected from the professional staff of the Seminole County Public Schools. Third, training via the authored ATM tutorial/guide was administered to the selected sample. Finally, the results of administering the ATM tutorial/guide to the selected sample were evaluated to determine (1) the learning effectiveness and (2) the preferences toward the use of this medium for training. Following is a more detailed explanation of each of these specific procedures.

Select an Authoring System

There were several multimedia authoring systems evaluated for potential use. Eric Brown (1994) presented an evaluation of 57 different multimedia authoring products from 47 different companies. Of these 57 products, 53 ran on a personal computer platform, either DOS, Windows, or Mac. These 53 authoring products ranged in price from $100 to $8,000 and offered considerable differences in functionality.

The selection of an authoring system for this investigation was based on a comparison of the products' features and functionality, price, availability, ease of use, distribution platform, file types supported, authoring tools (editing, menu creation, training and testing, debugging), runtime requirements, system support, and applicability to the project. The key feature required of the multimedia authoring system was support for the development of a hypertext application.

Based on this selection criteria, CBT Express, from Aimtech Corporation, was chosen as the authoring system for this dissertation effort. This product was chosen for the following reasons

1. Hypertext support was provided according to Nielsen's (1995) definition of hypertext as non-sequential, interlinked nodes of text and graphics. In addition, support for animation, audio, and video in a wide variety of file formats was provided by CBT Express (Aimtech, 1994a).

2. One of the key features desired in adult education and training products is flexibility in topic selection and navigational abilities (Ament, 1991; Dejoy & Mills, 1989; Geisman, 1992; Spille et al., 1985). Menus and a variety of button types in CBT Express allowed this for free-form navigation (Aimtech, 1994c). According to Aimtech, these allow the learners to pursue paths based on their individual training needs.

3. Disorientation, or becoming lost in a training course, was a major issue according to several authors (Bornman & von Solms, 1994; Nielsen, 1995; Staninger, 1994). To provide a means of overcoming this problem of disorientation, course maps could be developed with the CBT Express product. These maps "show the user an overview of the structure of the course and lets the user move quickly and easily from one part of the course to another" (Aimtech, 1994b, p. 10-3). Once constructed, these maps were available via an options button present on each lesson screen.

4. CBT Express provided hot-word and hot-graphic support allowing a learner to select highlighted words or graphics and branch to, for example, a glossary where the definition of the selected hot-word was provided (Aimtech, 1994b).

5. Individual student registration and bookmarking to a built-in database were supported by CBT Express (Aimtech, 1994b). Student registration and logging in to the course were accomplished via the student's first name, last name, identification number, or any combination of these three fields as identified in the authoring

phase. Bookmarking allowed a learner to return to the point of exit from a previous session.

6. Cross-platform support for Windows, Windows NT, OS/2, UNIX via motif, and Macintosh was available via CBT Express (Aimtech, 1994c). This allowed delivery on these platforms through one development effort.

7. A number of preconstructed templates were available with the CBT Express authoring system (Aimtech, 1994b). These included templates for student registration and login, course objectives, menus, text blocks, summaries, course maps, and glossaries. In addition, true/false, matching, multiple-choice, and fill-in-the-blank templates were provided for exercise and testing activities.

8. No run-time licensing fees were required (Aimtech, 1994a). This allowed for the deployment of any number of copies of the authored courseware with no additional fees.

<u>Development Design Model for the ATM Tutorial/Guide</u>

Each of the design and development models presented in the previous chapter provided a methodology by which training materials could be effectively designed and implemented. The AT&T six-step model and the ISD five-step model, for example, provided such a framework. Although the literature suggested these particular models could be used for development of multimedia applications (Atkins, 1994), additional design considerations needed to be specified as multimedia products contain features not necessarily found in the more traditional instructor-led training. For example, in the traditional ISD model, the goals of the third phase, instruction design, focus on sequencing objectives and outlining content (American Society for Training and Development, 1988). However, as suggested by Adams (1994), the design phase should also include an interface design that focuses on screen layout and how navigation is to be accomplished; the identification of screen guidelines that include fonts, use of color, and the design of menu bars; and the creation of storyboards that detail the text content and proposed graphics.

There were also several limitations to the other development models discussed in the review of literature. The Givotovsky (1994) model presented only the planning and design phases and did not address material development, implementation, and evaluation. The Adams (1994) model focused on the development of commercial products in a multi-author environment. As commercial distribution of the tutorial and sharing of authoring responsibilities did not apply to this dissertation effort, this model contained several steps that were unnecessary.

The methodology employed in this dissertation was based on the ISD and similar models as proposed by American Telephone & Telegraph (1987), American Society for Training and Development (1988), Gleason (1991), Atkins (1994), and Dean (1994), but contained details specific to the design and development of a computer-based multimedia/hypertext product. The choice of this 5-step design model specifically for the creation of multimedia/hypertext training applications was supported by Orr et al. (1993), Gleason (1991), and Atkins (1994). Orr et al., in their paper describing the development of storyboards, stated "training applications using interactive multimedia capabilities are growing in number. The approach followed to produce these multimedia applications is essentially the same (analysis, design, development, implementation, and evaluation) regardless of the instructional delivery system" (p. 1).

Details of the development model applied in producing the multimedia/ hypertext-based ATM tutorial for this dissertation are addressed in the following subsections. These development phases include analysis, design, materials development, implementation, and evaluation.

Analysis. In this first phase, three steps were completed. The first step was to develop instructional objectives for each unit. According to American Telephone and Telegraph (1987), these are statements that describe "expected learning outcomes to be achieved by a learner upon completion of a training program" (p. 17). Instructional objectives have two primary functions: to provide a focus for the training and to provide a measurement tool. There are three basic characteristics shared by instructional objectives: they are specific, they are measurable, and they describe an outcome that is observable to others. The authors continued that instructional objectives have three parts: performance, conditions, and criteria.

The above description was also supported by Nowack (1992). He stated that each objective should have (1) a description of what the trainee should know after the training, (2) the conditions under which the knowledge is demonstrated, and (3) the criteria for identifying success of the training.

The above concept was more recently supported by Analysis and Technology, Inc. (1995). Analysis and Technology similarly defined an objective as a goal that the student is expected to reach by the end of the instructional unit. Analysis and

Technology supported the ABCD method of developing an objective. Instructional objectives developed using this methodology have four parts. The first item to be specified in the objective is the audience, or more specifically, the learner. Behavior, or as stated above, the performance to be accomplished by the learner, is the next part the objective. The third aspect(s) included in an instructional objective are any conditions under which this behavior or performance is to be accomplished. Finally, the degree, or the acceptable level of performance, is specified. An example of an objective following these guidelines is as follows:

A: A student completing this ATM tutorial will be able to

B: list the three layers of the ATM protocol stack

C: without assistance

D: with 100% accuracy.

The objectives for this ATM tutorial can be found in Appendix E. To insure the various topics related to asynchronous transfer mode technology were appropriately covered in the tutorial, the validity of these instructional objectives was confirmed by a panel of experts in conjunction with the validation of the pretests and posttests. This panel was composed of three individuals currently involved with ATM implementation and planning. As such, these individuals were able to provide the necessary recommendations and guidance with respect to coverage of key ATM topics. Additional details surrounding this validation are provided later in this section.

The second step in this analysis phase was to develop the pretests and posttests based on the instructional objectives. A multiple-choice format offering at least four possible answers was used as a basis for these tests. American Telephone & Telegraph, in the book Developing Training Tests (1987) offered the following advantages supporting the use of multiple-choice questions:

- They are generally more objective than essay tests or short answers.
- They are easy to administer and students can usually answer quickly.
- Scoring is easy.
- Statistics are easily handled.
- Reliability is generally good (a student would choose the same answer again if asked twice).
- Several levels of learning are generally measurable because the "incorrect" answers can be preselected to attract students with varying degrees of understanding.

Dean (1994) also supported several of the above advantages. He cited ease in scoring and the capability of evaluating information acquisition by the learners as key advantages of multiple-choice tests.

American Telephone & Telegraph (1987) also, however, identified two disadvantages to this manner of testing. First, guessing is easy. However, this is somewhat measurable. "If four alternative responses are provided, for instance, about one-fourth of the guesses will be correct" (p. 73). The second disadvantage is that it is sometimes difficult to develop good "incorrect" answers to attract selection by students with an unsatisfactory grasp of the material. Dean (1994) cited two further disadvantages: (1) the tests are often time consuming to develop and (2) some learners experience difficulty with the multiple-choice format.

Dean (1994) presented several rules for writing multiple-choice test questions. First, each problem should address a single issue. Next, brief statements should be used, not complex sentences. Third, positive statements should be used, not negative statements. Next, problem statements should make sense without reading the alternatives. Finally, concrete terms rather than abstract terms should be used. This author continued with some further rules for determining alternative answers. First, correct answers should be unquestionably correct. Next, wrong answers should represent common mistakes made by the learners. Third, the answers should be brief. Next, the position of the correct answer should vary. Fifth, numerical answers should be presented numerically. Next, words unfamiliar to the learners should be avoided. Seventh, "all of the above" and "none of the above" should be used sparingly. Finally, irrelevant clues, such as grammatical inconsistencies that point out the right or wrong answers, should be avoided.

A set of guidelines for the development of multiple-choice questions was also provided in the 1987 American Telegraph & Telegraph document. These guidelines also suggested the avoidance of "all of the above" because if a learner recognizes that two of the alternatives are correct, "all of the above" would be the obvious choice. "None of the above" should also be avoided as it does not suggest the learner knows the correct answer, only that the alternatives given are incorrect. Questions can be started with either a full question or an incomplete sentence if that stem is immediately clear without reading the choices. Four to five alternative responses are adequate. Fewer choices lead to scores that are too affected by guessing. Six or more confuse the learner as it is difficult to keep all of the choices in mind simultaneously. This book also advised that there be only one correct answer and that the incorrect alternatives be plausible. The book supported Dean (1994) in that (1) the incorrect alternatives should be ones that would be chosen by learners who have a partial understanding of the material and (2) a random order of answers was suggested so no pattern can be discerned. Alphabetizing answers by the first letter of the first word should provide this randomization, according to this book. The pretest can be found in Appendix F and the posttest in Appendix G.

The third and final step in the analysis phase is to validate the pretests and posttests according to the judgment of a panel of experts. According to Gay (1992), this is the method by which content validity is to be determined. Gay stated:

> There is no formula by which it can be computed and there is no way to express it quantitatively. Usually experts in the area covered by the test are asked to assess its content validity. These experts carefully review the process used in developing the test as well as the test itself and make a judgement concerning how well items represent the intended content area. This judgement is based on whether all subareas have been included, and in the correct proportions. In other words, a comparison is made between what ought to be included in the test, given its intended purpose, and what is actually included. (p. 157)

American Telephone & Telegraph (1987) also supported the determination of content validity to insure the questions are content-valid. A content-valid test, according to this book, can identify those learners who have gained the skills and knowledge presented in an instructional unit.

To accomplish this portion of the analysis phase, the electronic mail request found in Attachment H was forwarded to 20 experts in the field of ATM. These experts were identified by a list of ATM subject-matter experts provided by AT&T Bell Laboratories.

Six of the twenty responded that they were willing to assist with the validation of the tests and the objectives. Although all six were provided the list of objectives and the pretests/posttests, three experts eventually provided feedback.

Qualifications of the three experts responding to the request for test validity assistance are as follows:

1. Kenneth C. Glossbrenner is a supervisor in the Cross-Services Data Performance Group of AT&T Bell Laboratories. He holds bachelor's degrees in Mathematics and Music and a master's degree in Applied Mathematics from Virginia Polytechnic Institute. Mr. Glossbrenner is the chair (Rapporteur) of the ITU-T Study Group 13, the team addressing recommendations for B-ISDN/ATM performance. This group's products are Recommendations I.350, I.353, and I.356. His response can be found in Appendix I.
2. Dr. Vijay Bhagavath holds a Ph.D. in Electrical Engineering from the University of Texas. He also works for AT&T Bell Laboratories in a group planning for future AT&T broadband products. Dr. Bhagavath's response was gathered via a phone conversation.
3. Judith Mcgoogan holds a bachelor's degree in Mathematics and a master's degree in Information and Computer Science from the University of Oklahoma. She is currently a Systems Architect with Lucent Technology Bell Laboratories in the Network Systems organization. Her group plans for the evolution of Service Node products, such as the 5ESS-2000, GlobeView-2000, DACS, and 4ESS products. Her response can be found in Appendix J.

The findings of these experts are discussed in the Reliability and Validity Section found later in this Chapter.

Design. American Telephone and Telegraph (1987) described the design phase as having several steps. The first step is to sequence the learning objectives and outline the learning units so each objective is addressed in an organized manner. Next, an instructional plan is developed to control how each unit will be presented, reinforced, and tested for mastery of the material. Next, an audit is conducted to evaluate the plan to insure the budget, time constraints, and staff resources are adequate. Finally, lesson plans are developed based on classroom and physical considerations.

The multimedia authoring training manual used by Analysis and Technology, Inc. (1995) has more recently supported this approach to design but, in addition, provided steps that are more specific to the development of multimedia courseware. The steps that apply to the design of multimedia learning start with the specification of the instructional modes, in this case a hypertext learning application. Next, the instructional flow is determined based on the established instructional goals. The third phase is to identify design strategies, such as screen design, navigation, and menu specifications. The fourth step is to define how learner performance is to be monitored and evaluated. Finally, the support materials are identified. These materials include graphics, sound, and video resources to be used.

Based on the above recommendations, this phase led to the completion of three major steps. The first step of the design phase was to sequence the validated learning objectives and outline the units of learning. The following units were selected for development based on the review of literature. The following topics were also validated by the panel of experts for completeness with respect to topic coverage.

- ATM background;
- Factors driving the technology;
- Data characteristics of potential broadband applications;
- Features, benefits, and limitations of ATM;
- ATM applications and services;
- The ATM cell;
- The ATM protocol;
- The role of SONET in ATM implementations;
- ATM LANs;
- Strategies for ATM migration;
- Related transfer modes; and
- Outstanding ATM issues.

The literature surrounding ATM and broadband technologies abounded with acronyms and terminology potentially unfamiliar to educators. Therefore, in addition to the above list of ATM topics, a glossary containing a list of key definitions was provided to assist the learners as needed. Also, a help section was provided to assist the learners in the use of the hypertext-based tutorial, as recommended by Nielsen (1990b) and Staninger (1994).

Guidelines were then established, as the second step of the design phase, for defining screen criteria such as use of colors, fonts, and inter-screen navigation. The basis for these guidelines were the suggestions for development of multimedia applications as provided by Layberger (1994). This article presented recommendations for creation of effective visuals, use of color, creation of text and titles, and presentation of shadows and edges. The author suggested that each visual convey one main idea and that unneeded detail be omitted as this detracts from the learners' ability to concentrate on the message. Regarding color, the author recommended limited or no use of red, purple, magenta, orange, hot colors (such as hot pink), brown, and pure white. Rather, the author suggested the use of black, white, blue, green, and gray. He further recommended the use of a gray or blue background. He continued in providing several rules for text and titling: short words and messages should be used, text should be kept in the center part of the screen, and a large, simple, easy-to-read font should be used. This author further suggested shadows that completely surround text be avoided. If shadows are used, gray, black, or a color that is one or two shades darker than the predominant background color should be used.

Based on the above recommendations, gray was chosen for the background color for all screens with the use of blue fonts for the content and burgundy for titles. Arial was the primary font used for text content with the Benguit Frisky font for titles. No text shadows were used. Furthermore, the bulleted items were centered both horizontally and vertically and kept as short as possible, so as to make the messages readable.

Dejoy & Mills (1989) presented several other suggestions that were incorporated into the overall screen design guidelines. They stated that instructions should be clear, easy to understand, and accessible throughout the program. Furthermore, any choices presented to the learner should be clear and easy to follow. In presenting the materials, these authors recommended that objectives be clearly stated, feedback be provided following testing of the learner, and the user be able to return to previously presented material for review. Finally, these authors advised that learners be able to exit the program at any time and restart at the same place.

Based on these recommendations from Dejoy and Mills (1989), the unit objectives were presented at the beginning of each unit on a specific-objectives screen. The learning objectives for the tutorial can be found in Appendix E. At the end of each unit and subunit, testing was presented to the learner on the key topics with feedback provided for wrong answers. In addition, at any time the learner could return to previously presented materials for review. Exiting the tutorial was also available through an options button provided on all screens except the main menu and testing screens. Bookmarks were provided to allow the learner to return to the point of exit if desired.

The third and final step of the design phase was the creation of storyboards. A storyboard, according to Orr et al. (1993), is the documentation for an interactive multimedia application. The authors stated that it contains instructions for programming, the audio scripts, and a detailed descriptions of the visual elements to be used such as text, video, and graphics. These storyboards were used to define each screen layout and the interaction between screens using the unit content established in first step above and according to the guidelines developed in the second step of this design phase. Analysis and Technology, Inc. (1995), presented five areas to be captured on each storyboard. First, video images are to be described. As none were planned in this hypertext application, this area was not required. The second part of a storyboard, according to this book, is the design of the graphics to be used on the screen. The third area of a storyboard is the narrative script. The next area to be detailed on the storyboard is a description of the interaction between the screen and the learner. Finally, any special programming necessary for the screen under design is detailed to include navigation between the screens.

The storyboards for the screens of the hypertext tutorial included the screen layout; screen timeout, if applicable; background color; graphics files used; text files used; and information required for the type of frame used. Storyboards for exercise frames, for example, included information such as number of tries allowed, feedback text files, and colors to be used to indicate the correct response. Storyboards for lesson frames included navigation information such as screens for forward, exit, previous, glossary, help, and course map buttons/options. In addition, an options button allowed for branching to other key topics found in the tutorial. This branching information is also included on the storyboard. Other types of storyboards developed for the hypertext tutorial included a copyright screen, a title screen, a main menu, a login screen, a glossary, a help screen, and the final certificate screen. Fonts, font sizes, and color information for the text (except titles and subtitles) were defined in the text files, and hence not found on the storyboards themselves.

Materials development. In this phase, the screens and interfaces were developed according to the storyboards. In addition, extensive testing was conducted to insure the tutorial functioned as planned and designed. For example, did the navigational buttons function correctly? did branching occur as expected?, and were there no unplanned exits from the tutorial?

Implementation. In the implementation phase, pilot sessions were conducted to validate the instructional design. Two individuals were asked to install the tutorial, proceed through the tutorial and test all available options to insure that novice users could traverse all topics based on their individual preferences, and validate that the flow of the unit screens was consistent, for example, objectives could always be found following the unit title screen. Based on the results of the pilot sessions, minor modifications were made to the tutorial. The simple installation and user instructions were found to be adequate.

Evaluation. This is the critical fifth phase of the methodology used to develop the multimedia tutorial. However, as this evaluative effort is major in its scope and importance to this dissertation, it is specified in more detail in the following section.

Sample Selection.

According to Gay (1992), there are three primary steps in determining a sample to be tested. The first involves identifying the population. As the goal of this dissertation was to increase ATM awareness among educators and those involved with school-district technology planning, the targeted population were those adults (teachers, administrators, or technology staff) currently employed by the Seminole County Public Schools.

The second step in sampling is to determine the required sample size. According to Gay (1992), a study of this type should involve a sample of at least 30 subjects.

Gay's third step is the selection of a sample. Participation in the study included a willingness to complete the pretest, the posttest, the precourse preference survey, and postcourse preference survey as well as completing the tutorial. Care was taken to insure anyone employed as a teacher, administrator, or a technology planner from each of the schools within the school district would have an opportunity to participate. In this manner, bias as a result of sampling, as described by Gay, was avoided. From the list of interested participants, a sample of at least 30 subjects was to be selected in a random manner.

Following Gay's (1992) procedures outlined above, a letter was sent to all principals, media specialists, and technology coordinators in the Seminole County Public Schools seeking assistance in identifying those interested in participating in the study. In addition, a letter was sent to the school district's Director of Instructional Media and Technology Services and the Director of Computing Services requesting their assistance in seeking participants as well. A sample letter can be found in Appendix L.

From the respondents, 35 were chosen at random and were contacted. All agreed to participate fully, that is, to complete the pretest and posttest, complete the precourse and postcourse preference surveys, and complete the tutorial. Of the original thirty-five, thirty-two actually completed all aspects of the study. The results found in the following chapters represent the efforts of these sample participants.

<u>Evaluation of the ATM Tutorial/Guide</u>

Two phases were proposed for evaluating the effectiveness of the tutorial. The first phase was to evaluate the product in terms of learning effectiveness. Next, the product was evaluated to determine the learners' attitudes, opinions, and preferences toward this method of training and learning.

The first evaluative phase was based on the administration of precourse and postcourse topic mastery tests to determine whether the hypertext-based ATM tutorial was effective in increasing the users' knowledge of asynchronous transfer mode technology. The test questions were multiple-choice based on the goals and objectives of the modules. The pretests and posttests can be found in Appendices F and G respectively. A panel of experts provided validation for the questions found on the tests, as discussed previously.

In addition to measuring the learning effectiveness of the tutorial, a precourse and postcourse survey were used to evaluate the preferences of the tested population toward the use of this computer-based medium. According to Best & Kahn (1986):

> Even though there is no sure method of describing and measuring attitude, the description and measurement of opinion may, in many instances, be closely related to people's feelings and attitudes . . . several methods have been employed to collect data of people's expressed opinions, such as asking people directly how they feel about a subject. This technique may employ a questionnaire. (p. 180)

The surveys used for this proposed dissertation can be found in Appendix C (precourse) and Appendix D (postcourse). The questions found on the proposed survey are of the closed form, that is, permitting only selected responses as opposed to the open form which allows any response. "Generally it is desirable to design the questions in closed form so that quantification and analysis of the results can be carried out efficiently" (Borg, 1987, p. 109). The responses were based on a Likert scale, the most widely used ordinal scale (Leedy, 1989). According to Leedy, the Likert scale allows respondents to select one of several categories that best describe the answer to the question.

Except for changes in verb tense, the two questionnaires found in Appendices C and D are identical. The design of these surveys was based on the 1991 Gleason dissertation because (1) the intent to measure preferences, attitudes, and opinions toward a computer-based learning alternative was similar to the goals of this proposed dissertation, (2) the design of the questions was supported by literature addressing sound instrument design-principles, (3) validity was established by questionnaire-formation experts, and (4) adequate reliability was demonstrated (internal consistency of .94 and the postcourse survey indicated a .96 on Cronbach's coefficient alpha).

The hypertext tutorial on ATM is, by design, somewhat different from a linear computer-based training application as, by its very nature, hypertext is non-sequential (Bornman & von Solms, 1993; Craver, 1991; Nielsen, 1990a, 1990b; Tolhurst, 1995). This non-sequential aspect of hypertext is preferable for adult learning as this audience would rather have the flexibility of traversing topics according to their specific needs (Ament, 1991; Dejoy & Mills, 1989; Spille, Galloway, & Stewart, 1985). The opinion/attititude surveys used by Gleason, therefore, required some modification to more adequately address learners' preferences.

Nielsen (1990b) presented five usability parameters for hypertext. First, the application should be easy to learn. When learners enter the application, they should be able to quickly grasp the basic structure of the material and determine where and how to look for specific information. Question 3 on the questionnaire was modified slightly to include *learning*, as well as simply *understanding*, the application. Question 5 further addressed this area of usability as it questioned the learner about the effectiveness of screen presentations, which would include navigational choices and other options.

Next, the application should be efficient to use. According to Nielsen (1990b), this means that learners can quickly find the information they desire and not have to learn or traverse non-relevant material more than necessary. While Question 7 somewhat addressed this issue, Question 13 was added to more specifically measure the learners' opinion of this area of usability.

Third, Nielsen (1990b) suggested the use of the system should be easy to remember. Question 14 was added as re-entry of the application was not measured in the original questionnaire.

Next, according to Nielsen (1990b), there should be few errors on the part of the learners in locating information. Question 7 addressed this issue to some extent as it questioned the learner as to the ease of use of the environment; however, errors encountered by the learners were not questioned. Question 15 was, therefore, added to query the learners about their experience in choosing incorrect links.

Nielsen's (1990b) final usage parameter is that the system should be pleasant to use and learners should prefer this method versus the more traditional solutions such as paper, lectures, or seminars. Question 12 was expanded slightly ("Other methods of training" instead of "Seminars and lectures" found on the original question) to address this issue.

Formats for Presenting Results

A one-group, pretest-posttest design, as described by Gay (1992), was chosen for evaluation of (1) learning effectiveness as well as (2) preferences, attitudes, and opinions toward learning via this medium. In this design, according to Gay, one group is pretested; exposed to a treatment, in this case administered the ATM tutorial guide; and finally posttested. Success of the treatment is determined by comparing the pretest and posttest scores.

To evaluate the results, *t*-tests were calculated for the instruments, learning mastery pretests and posttests, and precourse and postcourse preference surveys. According to Gay (1992), this statistic is used to determine if two mean scores are significantly different at a selected probability level. More specifically, the *t*-test for nonindependent samples was calculated. This test is more appropriate for use when one sample is pretested before a treatment, then posttested. Gay states, "the *t* test for nonindependent samples is used to determine whether there is probably a significant difference between the means . . . for one sample at two different times" (p. 437). A .05 level of significance was used. This, according to Gay, is "a reasonable probability level" (p. 432) for most studies. This level would suggest that significant differences in mean scores would occur by chance only 5 times out of 100. The SPSS/PC+ Studentware software package was used to determine evaluation results.

Projected Outcomes

Statement of the Hypotheses

The literature (Branscum, 1992; Dyrli & Kinnaman, 1994c, 1994d; Friedman, 1994; Grosse-Peck & Beyda, 1993; Killian, 1994; Kingston et al., 1992; Mageau, 1994a; Maule, 1993; Van Horn, 1995a, 1995b; West, 1995) suggested a need for additional training in computer and telecommunications technologies on the part of school-district educators and technology planners. This training will assist in closing a knowledge gap in this area to allow for increased participation and involvement in decisions surrounding selection, implementation, and use of these new products and services. The use of interactive multimedia, or hypertext in particular, as a solution to address training on ATM and its related technologies for school-district educators and technology planners was chosen to investigate this effort. Hypertext was chosen because:

1. A review of how adults learn indicated a need for training courses and programs that focus on flexibility in topic-selection and pacing as well as an ability to interact with the training materials (Ament, 1991; American Society for Training and Development, 1986b; Dejoy & Mills, 1989; Geisman, 1992; Spille et al., 1985).
2. An analysis of interactive multimedia and hypertext indicated this medium will accommodate these parameters (Campbell, 1994; Dahmer, 1993; Eugenio & Habelow, 1994; Geisman, 1992; Jerram, 1994; Nielsen, 1990a, 1990b; Luther, 1992; Weisburgh, 1991).

Based on the above reviews and the methodology proposed in this chapter, the hypotheses to be tested were:

H(1): There will be no statistically significant difference in the mean test scores on a knowledge-based test on asynchronous transfer mode technology achieved prior to the use of an interactive hypertext tutorial/guide and the mean test scores achieved by the same subjects after using the tutorial/guide. A .05 level of significance will be used to test this hypothesis.

and

H(2): Data gained from precourse and postcourse surveys on the subjects' preferences toward the use of hypertext in the learning of asynchronous transfer mode technology will indicate no statistically significant differences based on the use of the tutorial/guide. A .05 level of significance will also be used for this hypothesis.

Alternate Hypotheses

The related alternate hypotheses were:

$H_a(1)$: The mean scores on the postcourse multiple-choice test will be significantly higher than on the pretest.

and:

$H_a(2)$: The subjects will respond significantly more favorably with respect to preferences toward this method of training as measured by precourse and postcourse preference surveys.

Resources Used

There were a number of hardware and software resources necessary for implementing the study proposed in this dissertation. First, a copy of the selected authoring system, CBT Express, was purchased. According to the Aimtech documentation (1994a), the following hardware and software were determined to be the minimum requirements necessary for development of the ATM tutorial/guide.

- A 486 PC;
- A 16-color VGA graphics board;
- 8 MB RAM;
- MS-DOS 5.0 or higher;
- Windows 3.1 or higher; and
- A dual-speed CD-ROM drive.

The tutorial was developed on a 75 MHz Pentium PC with a SVGA graphics board, 16 MB RAM, Windows 95, and a quad-speed CD-ROM drive. This particular PC was also used for extensive testing of the tutorial as well as a 486 laptop and a 386 PC, each equipped with a VGA graphics board, 8 MB RAM, and Windows 3.1. The developed tutorial required 6 MB of hard disk storage for installation.

A final resource used was a copy of the SPSS/PC+ Studentware Plus software package for statistical analysis.

Reliability and Validity

Test Reliability.

Reliability, according to Gay (1992), means dependability or trustworthiness. That is, reliability is the degree to which a test consistently measures whatever it intends to measure. One common measure of reliability is referred to as split-half reliability. This statistic was calculated as a part of this dissertation effort to determine its reliability.

This split-half reliability statistic was determined per the procedures outlined by Gay (1992, p. 165). These procedures are as follows:

- Administer the total test to a group.
- Divide the test into two comparable halves, or subtests. This was accomplished by including all odd items on one subtest and all even items on the other subtest.
- Compute each subject's score on the two subtests. Each subject consequently had two scores, a score for the odd items and a score for the even items. The computer commands used to calculate the results of this step can be found in Appendix M.
- Correlate the two sets of scores. The SPSS/PC+ Studentware Plus commands used to determine these results can also be found in Appendix M. According to this software, a Pearson *r* correlation coefficient of .5922 applies to the two subtests. The Pearson *r* results in the most reliable estimate of correlation and is preferred over other techniques, according to Gay (1992).
- Apply the Spearman-Brown correction formula. Reliability is related to the length of the test, and as the correlation coefficient stated above is based on

subtests half as long as the original test, a correction formula must be applied (Gay, 1992). The Spearman-Brown formula is:

$$R = \frac{2r}{1 + r}$$

where R is the reliability of the total test
and r is the split half reliability.

Applying this formula results in the following:

$$R = \frac{2(.5922)}{1 + .5922} = \frac{.1844}{1.5922} = \underline{.744}$$

According to Ravid (1994), there are several factors that affect the test reliability. These include:

1. Heterogeneity. According to this author, when the group used to derive the reliability estimate is heterogeneous with respect to the property being measured (in this case, knowledge of asynchronous transfer mode technology), the higher the resulting reliability coefficient.
2. Test Length. This author stated that, all things being equal, the longer the test, the more reliable. In this particular case, the split-half method of reliability calculation was used on a test of 26 questions. This method has the effect of reducing test size to 13 questions, half the size of original test.
3. Item Difficulty. Ravid claimed that tests which are too easy or too difficult tend to have lower reliability.
4. Quality of Items. Improved questions improve the reliability.

These parameters were supported by Herring (1990) in his recommendations for improving the reliability coefficients. To do so, this author suggested the following:

- Lengthen the test;

- Increase the homogeneity of the questions;
- Increase the number of discriminating questions;
- Increase the number of questions of moderate difficulty; and
- Seek participants with a broad range of ability (with respect to the topic under investigation).

In 1966, Hedges claimed that, although standardized tests should score in the .90s, reliability of about .60 is adequate for educator-made tests. He further stated that "if you ever get as high as .67 . . . be grateful" (p. 22). This was further confirmed by Herring (1990). This author stated that reliability coefficients of educators are typically in the range of .60 to .80. Tuijuman and Postlethwaite (1994) felt that reliability scores should be somewhat higher. They stated "as a rule, one should not use any test for individual measurement with a reliability coefficient below .70" (p. 127). Ravid (1994), on the other hand, felt that in "exploratory research, even a modest reliability of .50 to .60 is acceptable" (p. 252). This author felt that, for group decisions, reliability levels in the .60s may be acceptable.

Based on the recommendations presented above from Hedges (1966), Herring (1990), Ravid (1994), and Tuijuman and Postlethwaite (1994) with respect to the minimum satisfactory level of test reliability, the achieved and demonstrated .744 was determined to be adequate.

<u>Test Validity</u>.

Content validity, according to Gay (1992), is the "degree to which a test measures an intended content area" (p. 156). According to this author, this statistic requires both item validity and sampling validity. Item validity is a measure of how well the test questions represent the intended content area, while sampling validity is concerned with how well the test measures the total content area. According to Gay:

> Content validity is determined by expert judgement. There is no formula by which it can be computed and there is no way to express it quantitatively. Usually experts in the area covered by the test are asked to assess its content validity. These experts carefully review the process used in developing the test as well as the test itself and make a judgement concerning how well items represent the intended content area. This judgement is based on whether all subareas have been included, and in the correct proportions. In other words, a comparison is made between what ought to be included in the test, given its intended purpose, and what is actually included. (p. 157)

A panel of experts was asked to evaluate this statistic prior to its administration to the selected sample. The composition and qualifications of this panel were discussed in an earlier section of this chapter. Their findings were as follows:

1. Glossbrenner (Appendix I) found the test to be balanced and overall a "fine" test. Recommendations were made as to the wording and the answers of several questions.

2. Bhagavath found the test to be complete and balanced. He had no further recommendations as to changes or additions to the instructional objectives or the testing instruments. These comments were based on the use of the tutorial as an overview to ATM. He had suggestions as to topic coverage should the training be used in other-than-overview situations.

3. Mcgoogan (Appendix J) felt the test covered all topics appropriately. She found no errors in the test materials but offered several suggestions to strengthen the wording of the questions and answers.

Summary

This chapter outlined the methodology used in authoring and evaluating the ATM tutorial for educators. CBT Express was selected as the authoring system to be employed for this dissertation effort. The reasons for this selection were outlined in this chapter. The five-step ISD model was chosen for developing the tutorial. However, to accommodate specific multimedia/hypertext issues, the five steps were broadened to include areas such as use of colors and shadows in the application screen design and the development of storyboards. Sample selection was discussed as were the evaluation criteria used. Evaluation was accomplished in two separate efforts. First, the learning effectiveness of the tutorial was evaluated via a pretest and posttest procedure. Next, the preferences of the participants toward this type of training were measured via a precourse and postcourse survey. Hypotheses tested were delineated. Finally, the resources required and used were presented as well as a discussion of the results of the calculation of the coefficient of reliability and the determination of test validity .

Chapter 4

Results

Introduction

Chapter 3, Methodology, offered two hypotheses and the methodology by which they were to be tested. Specifically, these hypotheses were:

H(1): There will be no statistically significant difference in the mean test scores on a knowledge-based test on asynchronous transfer mode technology achieved prior to the use of an interactive hypertext tutorial/guide and the mean test scores achieved by the same subjects after using the tutorial/guide. A .05 level of significance will be used to test this hypothesis.

and

H(2): Data gained from precourse and postcourse surveys on the subjects' preferences toward the use of hypertext in the learning of asynchronous transfer mode technology will indicate no statistically significant differences based on the use of the tutorial/guide. A .05 level of significance will also be used for this hypothesis.

Corresponding alternate hypotheses were also presented. These were:

$H_a(1)$: The mean scores on the postcourse multiple-choice test will be statistically significantly higher than on the pretest.

and:

$H_a(2)$: The subjects will respond statistically significantly more favorably with respect to preferences toward this method of training as measured by precourse and postcourse surveys.

To evaluate these hypotheses, this chapter will present the results of the precourse and postcourse ATM mastery tests and the results of the precourse and postcourse preference surveys. Descriptive and inferential statistics will be presented for both hypotheses. In addition, specific findings will be delineated as well as a summary of the results.

Data Analysis

Analysis of the Precourse and Postcourse Topic Mastery Tests.

Descriptive Statistics. There were 32 participants who took part in the study. The pretest portion of the study was composed of 26 multiple-choice questions, each worth one point. No partial points were given. The group's pretest mean score was 9.125 with a standard deviation of 2.575.

Table 1

Range and Frequency of Correct Pretest Answers

No. of correct answers	Frequency
6.0	5
7.0	5
8.0	6
9.0	3
10.0	5
11.0	3

(table continues)

No. of correct answers	Frequency
13.0	2
14.0	2
15.0	1

Table 1 presents the range of scores and frequency of correct answers for the pre-test results. As shown in the table, the scores ranged from 6 correct answers (23%) to 15 (58%).

There were also 26 questions on the posttest, each worth one point. Again, no partial points were given. The mean for this part of the study was 21.875 with a standard deviation of 1.963. These scores ranged from 18 (69%) correct answers to 25 (96%). The range of correct answers as well as frequencies for the posttest are found in Table 2.

Table 2

Range and Frequency of Correct Posttest Answers

No. of correct answers	Frequency
18.0	2
19.0	4
20.0	2
21.0	1
22.0	12
23.0	2
24.0	8
25.0	1

A comparison of measures of central tendency for both the pretest and posttest is found in Table 3. The substantial increase between the results of the pretest and posttest is evident from this table. The mean increased 12.75 while the median and mode increased 13.5 and 14 respectively.

Table 3

Measures of Central Tendency - Topic Mastery Tests

Statistical measure	Pretest	Posttest
Mean	9.125	21.875
Median	8.500	22.000
Mode	8.000	22.000
Standard Deviation	2.575	1.963

The SPSS/PC+ Studentware computer commands executed providing the descriptive statistics presented in Table 3 can be found in Appendix N.

Inferential Statistics. To compare the scores of the pretest and the posttest, a *t*-test for paired samples was conducted using the SPSS/PC+ Studentware software. The difference between the means was -12.7500 with a standard deviation of 3.183. A *t*-value of -22.66 and a 2-tail level of significance of .000 was provided by the SPSS/PC+ Studentware software. The difference between these scores was found to be statistically significant at the .05 level, the level of significance stated for the study. Table 4 provides the computer results. Appendix N provides a listing of the computer commands that generated the results found in this table.

Table 4

t-test Results - Precourse and Postcourse ATM Mastery Tests

Mean	SD	SE of mean	t-value	df	2-tail sig
-12.7500	3.183	.563	-22.66	31	.000

As the posttest scores were significantly different from the pretest scores, it is possible to reject this study's first null hypothesis that there would be no difference in scores, and accept the alternate hypothesis that educators score statistically significantly higher on the posttest than on the pretest when the hypertext-based tutorial on ATM is administered between the tests.

Analysis of the Precourse and Postcourse Preference Surveys.

Precourse and postcourse preference surveys were also used in this study. Aside from a change of verb tense, the surveys were identical (see Appendices C and D for these surveys). Each survey called for a response based on a Likert scale.

The precourse preference survey (Appendix C) was provided to each of the subjects with the course pretest (Appendix F). The survey dealt with the training preferences and the expectations of subjects as they completed the hypertext tutorial on ATM. After completing the tutorial, they were again asked to answer the survey questions via the postcourse preference survey (Appendix D).

The educators responded to 15 questions (question #10 had 5 separate responses) on these preference surveys. The computer commands that produced the statistical results, based on combining the responses to each question into a single score for each participant by adding the value of the response for each of the 15 questions, can be found in Appendix P. This was the procedure followed by Gleason (1991) in her dissertation employing the preference surveys upon which these were based. This procedure yields a maximum score of 95 for each survey.

Descriptive Statistics. The precourse preference survey had a mean score of 62.219 and a standard deviation of 7.807 based on the responses of the 32 participants. The individual scores ranged from 42 to 77. Table 5 lists the individual scores and frequencies. The computer commands used to determine these statistical results can be found in Appendix P.

Table 5

Precourse Preference Survey Statistics

Mean	Frequency	Mean	Frequency
42	1	63	3
50	2	64	1
53	1	66	1
54	1	67	1
55	1	68	3
57	3	71	3
60	3	72	1
61	2	76	1
62	3	77	1

The postcourse preference survey results produced a mean score of 70.125 with a standard deviation of 3.696 based on the responses of the 32 participants. The individual scores ranged from 64 to 81. Table 6 lists the individual scores and frequencies.

Table 6

Postcourse Preference Survey Statistics

Mean	Frequency
64	1
66	6
69	11
71	7
72	2
74	2
77	1
78	1
81	1

A comparison of measures of central tendency for the precourse and postcourse preference surveys is found in Table 7. As noted in this table, an increase in the mean scores of nearly 8 points was achieved with similar increases in the medians and modes (7 and 12 points respectively).

Table 7

Measures of Central Tendency - Preference Surveys

Statistical measure	Pretest	Posttest
Mean	62.219	70.125
Median	62.000	69.000
Mode	57.000	69.000
Standard Deviation	7.807	3.696

Inferential Statistics. To compare the scores of the precourse and postcourse preference surveys, a *t*-test for paired samples was again conducted using the SPSS/PC+ Studentware software. The difference between the means was -7.9063 with a standard deviation of 6.669. A *t*-value of -6.71 and a 2-tail level of significance of .000 was provided by the SPSS/PC+ Studentware software (the commands used can be found in Appendix P). The difference between these scores was found to be statistically significant at the .05 level, the level of significance stated for the study. Table 8 details the computer results.

Table 8

t-test Results - Precourse and Postcourse Preference Surveys

Mean	SD	SE of mean	*t*-value	df	2-tail sig
-7.9063	6.669	1.179	-6.71	31	.000

As the postcourse survey scores were significantly higher than the precourse survey scores, it is also possible to reject this study's second null hypothesis that there would be no difference in scores, and accept the alternate hypothesis that educators score statistically significantly higher on the postcourse preference survey than on the precourse preference survey when the hypertext-based tutorial on ATM is administered between the tests.

Findings

Hypothesis #1.

The statistics presented above show that the first null hypothesis can be rejected and the first alternate hypothesis, therefore, accepted. That is, the mean score of the postcourse multiple-choice topic mastery test, 21.875 with an SD of 1.947, is statistically significantly higher than the precourse mean test score, 9.125 with an SD of 2.575 at the .05 level of significance. It can be concluded, therefore, that the use of the hypertext-based tutorial is an effective means by which educators can increase their knowledge of ATM.

Pretest and Posttest Item Analysis. Each question on the pretest was analyzed based on the correct responses. Pretest scores indicated that no question was correctly answered by all participants, however, question #9 was answered correctly by 29 of the 32 participants. This question asked the participants to identify an example of an interactive application.

The most difficult questions found on the pretest appear to be #19 (3 correct responses), #23 (4 correct responses), and #17 (5 correct responses). These questions asked the participants to identify underlying characteristics of ATM (question #19), the five key steps of data transmission as followed by the computer industry (question #17), and the difference between ATM LANs and traditional LANs (question 23).

Posttest questions #1 (length of the ATM cell), #2 (two components of the ATM cell), #14 (major characteristic of Frame Relay), #15 (major characteristic of SMDS) and #21 (three layers of the ATM protocol stack) were answered correctly by all participants. Questions #3 (the header components that determine routing), #8 (time-based data example), and #20 (VCI and VPI relationship) were each missed by only one participant. Posttest question #19 (underlying characteristics of ATM) again proved to be the most difficult for participants to answer correctly as 22 of the 32 participants missed this question. Question #10 (an example of a distribution application) was the next most difficult with 15 participants incorrectly responding to this question. Appendix Q provides a complete listing of the number of correct answers for each question on the pretest and posttest.

Hypothesis #2.

While not the primary goal of this study, the preference surveys demonstrated several key elements of the preferences, attitudes, and opinions of the participants before and after completion of the ATM tutorial. Again, the inferential statistics presented earlier in this chapter show that null hypothesis #2 can be rejected, and hence the alternate hypothesis accepted indicating a statistically significant increase in the mean scores measuring the preference of educators toward the use of hypertext in learning ATM. The difference in mean scores (62.219 with an SD of 7.807 vs. 70.125 with a SD of 3.696) was significant at a .05 level of significance.

Precourse and Postcourse Item Analysis. Each question on the precourse and postcourse preference survey was analyzed based on the participants' responses. There were four questions where the mean score on the postcourse survey had increased by more than 1.0, on a scale of 1 to 5, from the mean score of the precourse preference survey.

Question #1 had an increase in mean scores of 2.5313. This question asked the participants how knowledgeable they considered themselves about ATM. It is not surprising that the participants felt more knowledgeable toward ATM as the precourse and postcourse ATM topic mastery tests indicated a significant increase in learning.

Question #2 had an increase in the mean scores of 2.0000 while question #9 showed an increase of 1.8125. Questions #2 and #9 asked how well prepared the participants considered themselves to advise others in the functions and applications of ATM. This may, again, be attributable to the significant increase in learning as measured by the topic mastery tests.

The mean scores of question #14 indicated an increase of 1.0938. This question dealt with the ease of navigation of the hypertext application. The postcourse preference survey also polled the participants as to whether they had exited and re-entered the tutorial. All indicated that they had done so. Their confidence in navigating the hypertext environment might be explained by the multiple methods by which topics could be chosen. Besides simply following the screens by choosing a topic from the main menu and linearly progressing through the screens, the participants could also:

- Branch to the course map where a link to each major topic was available;
- Branch to previous screen;
- Branch to the previous menu;
- Branch to the main menu;
- Branch through the options button to the participants' topic of choice;
- Branch through the options button to a help screen should the participant become confused or disoriented; and
- Branch to the glossary via the options button.

While many options were available for the participants' use in navigating through the tutorial, participant preferences were not measured. For example, whether anyone chose the course map as a means of linking to the various topics versus the forward-previous buttons was not recorded.

Very minimal or no changes in the mean scores were found in three questions of the preference survey. No change in the mean scores was found in question #6. This question asked the participants how well prepared they felt to employ skills learned from the ATM tutorial toward future tasks. As the tutorial stressed increasing the participant's *knowledge*, rather than building any skills, this lack of a significant increase was not unexpected.

A decrease of .0323 between the mean scores was found in question #10A. This question asked if the participants felt their knowledge of B-ISDN had been enhanced. As there was no unit dealing with B-ISDN as a specific topic, this is also not unexpected. The other topics addressed in the subparts of question #10 (ATM, SONET, standards, and migration) were presented in specific units; hence, perhaps, the participants could better relate to these topics.

A small decrease in the mean scores of .0938 was found in analyzing the results of question #12. This question asked if the participants felt that information sought was easily and quickly found in computer-based training environments. In addition, although no difference was found between the mean scores of question #6 on the precourse and postcourse preference surveys, the means were nearly 4 on a scale of 1 to 5 (3.9688 with a SD of .647). The lack of differences in the means of these two questions may indicate that the expectations of the participants, as measured by the precourse preference survey, were actually met, as measured by the postcourse preference survey.

The largest decrease in mean scores was found in analyzing question #15 (a decrease of .7813). This question asked the participants if they often chose the incorrect link in seeking specific information. This decrease would seem to be positive in nature as it would indicate that this tendency had been reduced following participation in this study. The actual survey questions can be found in Appendices C and D. Appendix R presents a complete listing of the mean scores of each question of the precourse and post-course preference survey.

Summary of Results

This chapter presented the results from (1) the administration of the precourse and postcourse topic mastery tests and (2) the precourse and postcourse preference surveys. Chapter 3, Methodology, offered the following hypotheses:

> H(1): There will be no statistically significant difference in the mean test scores on a knowledge-based test on asynchronous transfer mode technology achieved prior to the use of an interactive hypertext tutorial/guide and the mean test scores achieved by the same subjects after using the tutorial/guide. A .05 level of significance will be used to test this hypothesis.

and

> H(2): Data gained from precourse and postcourse surveys on the subjects' preferences toward the use of hypertext in the learning of asynchronous transfer mode technology will indicate no statistically significant differences based on the use of the tutorial/guide. A .05 level of significance will also be used for this hypothesis.

The corresponding alternate hypotheses follow:

> $H_a(1)$: The mean scores on the postcourse multiple-choice test will be statistically significantly higher than on the pretest.

and:

$H_a(2)$: The subjects will respond statistically significantly more favorably with respect to preferences toward this method of training as measured by precourse and postcourse surveys.

The 32 participants in the study had an overall mean score of 9.125 (out of 26 potentially correct responses) with a standard deviation of 2.575 on the precourse topic mastery test. The posttest results offered a mean of 21.875 with a standard deviation of 1.963. A *t*-test calculation comparing these means determined a t-value of -22.66 and a 2-tail significance of .000. These results are significant at a .05 level of confidence. Hence, hypothesis 1 was rejected and the alternate hypothesis accepted.

In addition to taking precourse and postcourse topic mastery tests, the participants were also questioned about their preferences, attitudes, and opinions via precourse and postcourse surveys. The results of the precourse survey indicated a mean score of 62.219 with a standard deviation of 7.807. A mean score of 70.125 with a standard deviation of 3.696 was determined for the participants' postcourse preference survey. A *t*-test of these values offered a t-value of -6.71 with a 2-tail significance of .000. At a .05 level of confidence, hypothesis #2 was also rejected and the alternate hypothesis accepted.

Hence, it is concluded that the difference in the mean scores of educators' precourse and postcourse topic mastery tests will be statistically significant if the participants are offered a hypertext-based tutorial on the topic of ATM between the administration of the two instruments. It is also concluded that preferences toward this training medium, as measured by precourse and postcourse course preference surveys, will be statistically significantly higher if the hypertext-based tutorial is offered between the administration of the two instruments.

Chapter 5

Conclusion

Conclusions

Following the review of issues leading toward this dissertation, a problem statement was formulated that indicated further investigation was needed to determine a means by which educators, school district technology planners, and other staff could increase their knowledge of ATM and its relationship to broadband networking concepts. A hypertext-based tutorial/guide for use by educators was proposed as a solution to this problem. Two hypotheses were offered for analysis.

> H(1): There will be no statistically significant difference in the mean test scores on a knowledge-based test on asynchronous transfer mode technology achieved prior to the use of an interactive hypertext tutorial/guide and the mean test scores achieved by the same subjects after using the tutorial/guide. A .05 level of significance will be used to test this hypothesis.

It was also hypothesized that:

> H(2): Data gained from precourse and postcourse surveys on the subjects' preferences toward the use of hypertext in the learning of asynchronous transfer mode technology will indicate no statistically significant differences based on the use of the tutorial/guide. A .05 level of significance will also be used for this hypothesis.

The corresponding alternate hypotheses to be tested were:

$H_a(1)$: The mean scores on the postcourse multiple-choice test will be statistically significantly higher than on the pretest.

and:

$H_a(2)$: The subjects will respond statistically significantly more favorably with respect to preferences toward this method of training as measured by precourse and postcourse preference surveys.

A hypertext-based training offering for educators was developed along with a methodology by which the two hypotheses stated above could be tested. This methodology included the development of a precourse and postcourse topic mastery test in ATM and a precourse and postcourse preference survey. Statistical analyses of the results of the administration of these instruments indicated that both hypotheses, H(1) and H(2), could be rejected and the corresponding alternate hypotheses accepted. It was concluded, therefore, that:

- Hypertext is an effective means by which to significantly increase the knowledge-level of ATM with school-district staff.
- Preferences toward this means of training significantly increase following the completion of a hypertext-based training course on ATM technology.

There were two limitations to this study that require discussion. First, this study attempted to measure the increase of knowledge of ATM on the part of educators through the use of hypertext-based training. To measure this learning, precourse and postcourse topic mastery tests were used. The posttest was taken by the participants following their completion of the training. It was demonstrated statistically, via these tests, that short-term knowledge was increased through the use of the hypertext-based training. However, potential success in ATM-related skills is not suggested nor is long-term knowledge retention predicted. For this type of training to be practical in terms of on-the-job value, these considerations should be evaluated in further research efforts.

Second, to make this dissertation manageable in the vast population under consideration, all educators throughout the United States, a case-study approach was selected. Additional studies may be necessary with larger, more diverse samples of this population. While there were no obvious reasons to consider staff from the selected school district distinct from others in terms of implications to the outcomes of this dissertation, a serious study of potential differences was not conducted.

Implications

There are several implications for school districts as they begin their migration to broadband networks. First, as demonstrated in the literature, knowledge of this technology within the school-district staff is currently inadequate (Dyrli & Kinnaman, 1994a; Friedman, 1994; Gross-Peck & Beyda, 1993; Killian, 1994; Pickelsimer, 1994; Van Horn, 1995a; West, 1995). In addition, the literature indicated that for these broadband implementations to succeed, it is necessary to involve this population as early in the planning phase as possible (Branscum, 1992; Dyrli & Kinnaman, 1994d; Friedman, 1994; Kaman, 1993; Kinnaman, 1994; VanSciver, 1994, 1995). Hence, training in this area is an important pursuit for school districts with plans to migrate toward broadband technologies (Branscum, 1992; Dyrli & Kinnaman, 1994c, 1994d; Friedman, 1994; Grosse-

Peck & Beyda, 1993; Killian, 1994; Kingston et al., 1992; Mageau, 1994a; Van Horn, 1995a, 1995b; West, 1995). This training should be a prime consideration as administrators consider staff development activities.

Second, training in broadband technologies should become available to school-district educators, administrators, and technology planners soon. Implementations and pilot projects of broadband networks are currently under way in school environments (Aaron, 1995; Bernier, 1993; Chavkin et al., 1994; Feldman, 1995; Grovenstein et al., 1994; Heinanen, 1994; "Iowa taps," 1994; Littman, 1996; O'Shea, 1994a, 1994b; Patterson & Smith, 1994). The potential offered by these networks is vast, for example in the integration of voice, data, and video; distributed education and training; video distribution; district-wide electronic mail; and LAN interconnection.

Finally, as school districts begin to investigate training for the staff in this area, computer-based hypertext training should be evaluated. This dissertation demonstrated two important aspects of this medium. First, it is effective in increasing the knowledge level of this population. Second, preferences toward computer-based hypertext training increase significantly following participation in a hypertext-based training offering.

Recommendations

This investigation brought forth several areas that would benefit from further research. These are detailed below.

First, as previously mentioned in this dissertation, while many methods of navigation were offered to the learners in this ATM tutorial, there was no attempt to measure the alternatives actually chosen even though the research suggested that this flexibility in topic selection is important to adult learners. For example, do most learners prefer to simply progress through the tutorial based on the forward-previous navigational buttons? Or, do they truly try to make use of the navigational capabilities of hypertext by actually traversing the application based upon the course map, via menus, or via the options button that allow for preferences in topic selection? It is recommended that additional research be conducted to better understand the navigational preferences of learners so as to lead to enhanced and more effective hypertext design.

Second, this dissertation focused on providing educators and school-district planners with a background in asynchronous transfer mode technology and related topics. The goal was an investigation into increasing the *knowledge* of this population. There are also a number of ATM-related skills that will be required of subsets of this population as their school districts begin their migration. These skills include design of the broadband networks, administration, performance tuning, and the actual use by all staff members and students. Hence it is recommended that additional research be conducted to investigate the effectiveness of hypertext to introduce and train educators in technology-based skills versus knowledge.

Next, research into the length of hypertext-based applications also appears to be worthy of further efforts. The tutorial produced through this dissertation took approximately 1 1/2 to 2 hours to complete depending upon the knowledge level of the learner. For example, the more heavily the glossary was used, the longer it took the learner to complete the tutorial. Is there a point where learning begins to decline based on the length of the tutorial? Also, is there an appropriate length (based on the number of screens) of units within a tutorial? Furthermore, is there an appropriate point to interject exercises, quizzes, and other learner interactivity, for example, after a specific number of lesson presentation screens? It is therefore recommended that additional research be conducted to determine the most effective ratio of (1) lesson screens, (2) summary/review screens, and (3) exercise and test screens. Additionally, it is recommended that further research be conducted to determine course-length effectiveness based on number of screens presented to the learner.

Finally, the research into hypertext conducted through this dissertation suggested text and graphics as the primary media elements. Further research into any potential increase in learning effectiveness and learner preferences through the use of sound and animation appears to be worthwhile, particularly as PCs are rapidly expanding in terms of memory, disk capacity, and speed. Do these additional media elements offer increased learning when used effectively, or do some learners lose their focus and concentrate more on the elements than on the message? Therefore it is recommended that research be conducted to measure any potential additional learning effectiveness offered through the use of sound and animation versus text and graphics alone.

Summary

A review of literature demonstrated several key facts relevant to this study. First, there is a wide range of broadband networking pilot projects and implementations currently underway in educational environments (Littman, 1996). Furthermore, a growing need was portrayed for increased involvement and active participation on the part of school-district staff members, particularly surrounding the selection, implementation, and use of computer and telecommunications technologies in the school environment. Unfortunately, a knowledge gap exists with this population in the area of broadband technologies, which hinders potential involvement. To close this gap, the literature offered support for increased training on the role and significance of computer and telecommunications technologies for school-district teachers and technology planners.

Networking and telecommunications were cited by several authors as the most critical emerging technology in the educational environment. It was further suggested that the integration of voice, data, and video may be the most significant trend today in the technological evolution of networks. Because ATM is at the heart of this integration, it was the focus of this dissertation.

The problem investigated by this study was an effective means by which teachers, school district technology planners, and other school-district staff could increase their knowledge of ATM and its relationship to broadband networking concepts.

As it would not be possible to select a truly random sample of school-district staff throughout the United States, a case-study approach was chosen. This method allowed for the professional staff of a single school district to be selected and evaluated as an alternative to attempting to test a sample of the entire population.

To begin the inquiry, several key areas of research were identified. First, parameters for effective adult learning were investigated. It was concluded, based on the literature, that adults prefer flexibility in terms of topic selection and timing of material presentation. In addition, it was shown that adults learn better if actively involved. An interactive, non-linear approach to the training, therefore, should be sought when educating adults. The potential delivery method should offer an alternative to traditional instructor-led events where the timing of the course delivery is dependent upon an instructor. Interactive computer-based approaches to training have the capability of delivering solutions to each of these preferences. Further investigation into multimedia, and in particular the hypertext subset, revealed that this medium of training allows for enhanced learner interaction. Hypertext not only allows learners to access the training at their convenience and at the delivery speed of choice, it also allows them to access the topics in the order of preference via links embedded in the application. Hence, as hypertext offers the capability of delivering training on ATM based on preferences of adult learners, it was chosen as the training medium.

The next step in this dissertation effort was to choose an authoring tool by which the application could be developed. This selection was based on a comparison of a number of authoring products in terms of features and functionality, price, availability, ease of use, distribution platform, file types supported, authoring tools (editing, menu creation, training and testing, debugging), runtime requirements, system support, and applicability to the project. The key factor required of this effort was support for the development of a hypertext application. CBT Express, from Aimtech Corporation, was chosen. This product was chosen because:

1. Hypertext support was provided. In addition, support for animation, audio, and video in a wide variety of file formats was available.
2. Flexibility in navigation was provided.
3. Course maps could be developed to aid in resolving learner disorientation.

4. Hot-word and hot-graphic support was available.

5. Individual student registration and bookmarking were supported.

6. Cross-platform support for Windows, Windows NT, OS/2, UNIX via motif, and Macintosh was available.

7. A number of preconstructed templates were available allowing for reduced development time

8. No run-time licensing fees were required.

The next area of investigation was to determine a methodology by which the hypertext-based tutorial could be developed. The 5-step ISD model was proposed as it had a broad base of support for its use. The 5 phases of development - analysis, design, material development, implementation, and evaluation - were augmented with steps specific to the needs of computer-based, multimedia applications. For example, screens needed to be designed, fonts selected, use of colors defined, and the use and types of navigation considered.

During the analysis phase of this development, a panel of ATM experts was asked to validate the course objectives and tests. The experts' analysis and recommendations led to modification to these goals and objectives and to changes in the precourse and postcourse topic mastery tests.

Development and testing of the tutorial followed this validation. Testing was accomplished not only by the author, but also by two volunteers who tested the computer-based product for ease of installation, proper navigation, ease of use, typographical errors, overall content flow, and for potential errors in terms of unexpected exits.

Letters were sent to all of the schools within the Seminole County School District and to key staff in the District office, seeking participants for the study. Of those who responded, a random sample was selected and contacted. Thirty-two of the thirty-five initially contacted actually completed all phases, that is, they completed the precourse and postcourse test, the precourse and postcourse preference survey, and the ATM tutorial. An evaluation of the results of these testing instruments indicated:

- There is a significant difference in the mean scores of a pretest and posttest on ATM if the participants complete the hypertext-based tutorial before administration of the posttest.
- There is a significant difference in the mean scores of a precourse and postcourse preference survey if participants complete the hypertext-based tutorial on ATM.

It was therefore concluded that (1) learning via a hypertext tutorial on ATM is effective for educators and school technology planners and that (2) preferences toward this type of training are enhanced through the use of this hypertext tutorial.

APPENDIX A

ATM CBT Feasibility Study

INSTRUCTIONAL FEASIBILITY	YES	NO
1. Is the training course or curriculum likely to be used long enough to be a good candidate for CBT?	X	
2. Does the total student volume or throughput (rate) justify CBT?	X	
3. Is the job performance so critical that a high degree of control over training effectiveness is needed?	X	
4. Are there pedagogical requirements for interactive instruction (e.g. dynamic graphics, immediate feedback)?	X	
5. Are there large differences in student entry levels that necessitate individualized instruction?	X	
6. Is the training environment an extension of the job environment (e.g. do both use computers)?	X	
7. Is there a strong need for standardized training (particularly at distributed training locations)?	X	
8. Is there a strong need for on-demand training (i.e. training available whenever and wherever needed)?	X	
9. Does the training involve expensive equipment or scarce experts?	X	

	YES	NO
10. Is the training relatively independent of human interaction?	X	
11. Are the present training program and materials competency-based?		X
12. Are there special aspects of the current training program that can be done well via CBT?		X

****

COMMENTS:

The divergent backgrounds of educators and school district technologists is a strong determining factor for the use of a computer-based instructional tool. Standardization of training will provide a basic foundation of knowledge surrounding the asynchronous transfer mode. The need for on-demand training provides for flexibility in training the school district staff.

****

ORGANIZATIONAL FEASIBILITY

	YES	NO
1. Are the systems personnel needed to design, develop, implement, operate, and maintain a CBT system available?	X	
2. Are the instructional designers/developers needed to create and maintain CBT materials available?	X	
3. Is the necessary instructional programming expertise available to implement, test, and debug CBT programs?	X	
4. Are necessary administrative personnel available to plan, supervise, and manage CBT activities. Do they have possess expertise?	X	

	YES	NO
5. Are the reactions of the training staff and students likely to be positive to CBT?	X	
6. Are the attitudes of the key decision-makers positive toward CBT?	X	
7. Is the application free of any organizational conflicts likely to jeopardize the success of CBT?	X	
8. Is interest in and support for the use of CBT widespread rather than limited to a few individuals?	X	
9. Are the expectations of the training staff or decision-makers regarding the benefits of CBT reasonable?	X	
10. Is the training system and organization flexible enough to accommodate disruption caused by the implementation and testing of CBT?	X	
11. Does a formal mechanism exist in the organization for the modification of procedures or policies needed to accommodate changes required for CBT?	X	
12. Is it clear which organization entity (or entities) will have responsibility and authority for implementing and operating the CBT system?	X	

****

COMMENTS:

Design and development of this proposed tutorial will be the responsibility of this author. As school districts are making extensive use of computers, indications are strong that the district staff users of the proposed tutorial, and their respective organizations, will be receptive to this computer- based solution to ATM training.

****

TECHNICAL FEASIBILITY	YES	NO
1. Do available systems/terminals provide the kind of display, input, and output capabilities required?	X	
2. Is the necessary processing capability available?	X	
3. Is the necessary off-line storage capacity (for lesson material and student records) available?	X	
4. Are the kinds of communications capabilities needed available?	X	
5. Is suitable software or courseware available?	X	
6. Can a system support the number of simultaneous users expected at peak loads?	X	
7. Will average system response time be acceptable?	X	
8. Has acceptable system reliability and service been demonstrated?		X
9. If the system is to be used concurrently for other applications, is CBT free of adverse effects on other applications or vice versa?	X	

	YES	NO
10. Have other technological alternatives that would have a lesser impact on resources needed been considered?	X	

****

COMMENTS:

There are several authoring packages that meet the needs of the proposed tutorial. CBT Express, from Aimtech, has been chosen to author this hypertext-based ATM guide based on its specific functions and features. No communications capabilities are necessary as it is anticipated that a standalone PC will be utilized to run the tutorial. It is further anticipated that the tutorial will be accessed by a single user.

****

ECONOMIC FEASIBILITY

	YES	NO
1. Are the total costs (including instructors, administration, facilities, materials, student travel, etc.) for the existing training program known?		X
2. Are the total development costs for the proposed CBT materials (including design, development, programming, evaluation) known?		X
3. Are the total delivery costs for the for the proposed CBT system (including hardware, acquisition, system operating and maintenance costs, instructors, administration, facilities, off-line materials, etc.) known?		X
4. Will the use of CBT result in annual or life cycle cost savings over the existing training?	X	

	YES	NO
5. Will the use of CBT result in value-added benefits over the existing training that can be quantified?	X	
6. Are assumptions underlying the cost analyses about the throughput or total utilization of CBT reasonable?	X	
7. Are the immediate or total costs of CBT tolerable costs for the organization?	X	
8. Will the organization fund the start-up costs at a level that is sufficient and necessary to assure a reasonable chance of success?	X	
9. Will the procurement process allow the CBT system or associated resources to be acquired in the timeframe needed?	X	

****

COMMENTS:

Financial obligations surrounding purchase of an authoring system and related software, development and delivery are the responsibility of the author.

****

APPENDIX B

Courseware Evaluation Checklist

Instructions

1. Are instructions incorporated in the courseware? y n na

2. Can the instructions be bypassed if not needed? y n na

3. Can the instructions be accessed without having to rerun the entire program? y n na

4. Are the instructions quick and simple? y n na

5. Is a complete and accurate index available? y n na

Sequencing

1. Are learning outcomes and objectives clear? y n na

2. Can a non-linear sequence be selected? y n na

3. Can unnecessary activities be skipped? y n na

4. Can an alternative sequence be selected by an instructor if appropriate and desirable? y n na

5. Does the material stimulate application of skills and knowledge previously learned? y n na

Role of Instructor

1. Can the learner summon an instructor via the keyboard? y n na

2. Can the learner reach an instructor via a toll-free telephone call? y n na

3. Can the learner effect two-way communication via the keyboard? y n na

4. Are name, address and phone number provided in the courseware? y n na

Feedback

1. Is feedback immediate? y n na

2. Is the feedback relevant for an adult learner? y n na

3. Is the language of the feedback consistent? y n na

4. Is a correct response not over-praised? y n na

5. Is the feedback nonthreatening? y n na

User Control

1. Can the learner determine where entry to the module, lesson or course begins? y n na

2. Can the learner specify the level of difficulty? y n na

3. Can the learner alter the rate of presentation of materials? y n na

4. Can the learner manipulate variables one at a time? y n na

Flexibility

1. Is the module, lesson, or course flexible enough to serve the intended range of users? y n na
2. Can content be altered by the instructor or learner? y n na

3. Can the program be used without moving from one workstation to another? y n na

4. Are options available to permit individuals or groups to work simultaneously? y n na

5. Can the courseware be revised or updated easily or quickly? y n na

6. Can the courseware be used in a variety of user environments? y n na

7. Is access to the system easy, not requiring elaborate and time-consuming protocol codes, sign-ons, or other complexities before courseware can be used? y n na

8. Can the learner obtain access to the system with minimum technological knowledge or skills? y n na

APPENDIX C

Pre-Course Preference Survey

Asynchronous Transfer Mode for Educators

DIRECTIONS: Circle the number of the appropriate answer using the following scale:

1 = STRONGLY DISAGREE
2 = DISAGREE
3 = NEITHER AGREE NOR DISAGREE
4 = AGREE
5 = STRONGLY AGREE

---

1. I consider myself knowledgeable about the asynchronous transfer mode.	1 2 3 4 5
2. I feel that I am prepared to advise in the asynchronous transfer mode functions and applications.	1 2 3 4 5
3. I find personal computer applications easy to learn and understand.	1 2 3 4 5
4. I think the skills I learn in this course will help me in technology planning.	1 2 3 4 5
5. Presentations (what comes up on the screen) on personal computers provide clear and concise information that I find easy to use.	1 2 3 4 5
6. I think skills I learned from this computer-based training program will allow me to perform better in future tasks.	1 2 3 4 5
7. I consider learning in the computer environment environment easier than in other forms (seminars, lectures, discussions, etc.).	1 2 3 4 5
8. I understand more clearly when I work at the computer rather than from reading or discussions.	1 2 3 4 5

9. I am confident about my ability to advise in the asynchronous transfer mode — 1 2 3 4 5

10. I think this computer-based training program will enhance my knowledge in the following areas:

A. Broadband ISDN. — 1 2 3 4 5

B. ATM. — 1 2 3 4 5

C. SONET. — 1 2 3 4 5

D. Broadband ISDN Standards. — 1 2 3 4 5

E. Migration to Broadband ISDN Technology. — 1 2 3 4 5

11. I am using this program to increase my knowledge of the asynchronous transfer mode. — 1 2 3 4 5

12. Other methods of training are easier than learning in computer-based training environment. — 1 2 3 4 5

13. Information I want to learn more about is easily and quickly found in a computer-based training environment. — 1 2 3 4 5

14. I easily remember how to use and navigate in a computer-based environment after re-entering the system. — 1 2 3 4 5

15. I often chose the incorrect link (or choice) in seeking specific information in a computer-based environment. — 1 2 3 4 5

Do you have any comments about this questionnaire, the computer program, or your own expectations?

Thank you for your assistance in gathering this information.

APPENDIX D

Post-Course Preference Survey

Asynchronous Transfer Mode for Educators

DIRECTIONS: Circle the number of the appropriate answer using the following scale:

1 = STRONGLY DISAGREE
2 = DISAGREE
3 = NEITHER AGREE NOR DISAGREE
4 = AGREE
5 = STRONGLY AGREE

---

1. I consider myself more knowledgeable about the asynchronous transfer mode.	1 2 3 4 5
2. I feel that I am better prepared to advise in the asynchronous transfer mode functions and applications.	1 2 3 4 5
3. I found this personal computer application easy to learn and understand.	1 2 3 4 5
4. I think the skills I learned in this course will help me in technology planning.	1 2 3 4 5
5. Presentations (what comes up on the screen) on personal computers provide more clear and concise information that I find easier to use.	1 2 3 4 5
6. I think skills learned from this computer-based training program will allow me to perform better in future tasks.	1 2 3 4 5
7. I consider learning in the computer environment environment easier than in other forms (seminars, lectures, discussions, etc.).	1 2 3 4 5
8. I understand more clearly when I work at the computer rather than from reading or discussions.	1 2 3 4 5

9. I am more confident about my ability to advise in the asynchronous transfer mode. 1 2 3 4 5

10. I think this computer-based training program has enhanced my knowledge in the following areas:

A. Broadband ISDN. 1 2 3 4 5

B. ATM. 1 2 3 4 5

C. SONET. 1 2 3 4 5

D. Broadband ISDN Standards. 1 2 3 4 5

E. Migration to Broadband ISDN Technology. 1 2 3 4 5

11. I used this program to increase my knowledge of the asynchronous transfer mode. 1 2 3 4 5

12. Other methods of training are easier to learn in than computer-based training. 1 2 3 4 5

13. Information I wanted to learn more about was easily and quickly found. 1 2 3 4 5

14. Did you quit and re-enter the tutorial? yes no

If yes, how well did you remember how to use and navigate the system. 1 2 3 4 5

15. I often chose the incorrect link (or choice) in seeking specific information. 1 2 3 4 5

Do you have any comments about this questionnaire, the computer program, or your own expectations?

Thank you for your assistance in gathering this information.

APPENDIX E

ATM Tutorial Objectives

Unit: Application Data Characteristics.

After successful completion of this module, the student will be able to:

- differentiate between time-based data and non-time-based data.

- differentiate between real-time delivery and non-real-time delivery.

Unit: Projected Applications and Services.

After successful completion of this module, the student will be able to:

- distinguish between interactive and distribution applications.

- provide at least one example of an application for each of the following categories
    - interactive conversational.
    - interactive messaging.
    - interactive retrieval.
    - distribution with presentation control.
    - distribution without presentation control.

Unit: ATM Cell Objectives.

After successful completion of this module, the student will be able to:

- list and describe the two major components of the ATM Cell.

- briefly describe the functions of each of the following:
    - generic flow control (gfc).
    - virtual path identifier (vpi).
    - virtual channel identifier (vci).
    - payload type indicator (pti).
    - cell loss priority (clp).
    - header error correction (hec).

Unit: Factors Driving Broadband Technologies.

After successful completion of this module, the student will be able to list three key factors that have driven the development of broadband technologies.

Unit: ATM Features and Benefits.

After successful completion of this module, the student will be able to:

- list and discuss five features and benefits achieved through the use of ATM.

- briefly describe the goal of the ATM Forum.

Unit: Standards and Issues.

After successful completion of this module, the student will be able to:

- identify the key organization involved with developing the merging ATM standards.

- list three issues related to ATM delivery.

Unit: Introduction and Background.

After successful completion of this module, the student will be able to:

- list the five steps in the evolution of data transmission as followed by the computer industry.

- list the three steps in the evolution of data transmission as followed by the telephone industry.

- provide four underlying characteristics of the asynchronous transfer mode.

- explain the relationship between virtual paths and virtual channels.

Unit: ATM LANs.

After successful completion of this module, the student will be able to:

- explain the difference between ATM LANs and conventional LANs.

- provide one advantage of ATM LANs.

Unit: Migration to ATM.

After successful completion of this module, the student will be able to list the first, and perhaps the key, phase in the migration to ATM networks.

Unit: ATM Protocol.

After successful completion of this module, the student will be able to:

- list three layers of the ATM protocol stack.

- briefly describe the function of each of the following:
  - Physical layer.
  - ATM layer.
  - ATM adaptation layer.

Unit: Related Transfer Modes.

After successful completion of this module, the student will be able to:

- distinguish between ATM and Frame Relay.

- distinguish between ATM and SMDS.

- distinguish between ATM and STM.

Unit: The Role of SONET.

After successful completion of this module, the student will be able to:

- explain the goal of SONET.

- explain the role of SONET in broadband networking.

- list four advantages gained through the use of SONET.

APPENDIX F

ATM For Educators - Pretest

Name: ____________________________

1. The length of the ATM cell is

    a. 5 bytes.
    b. 48 bytes.
    c. 53 bytes.
    d. Variable in length.

2. The two major components of the ATM cell are:

    a. The virtual channel identifier and the body.
    b. The cell and the payload area.
    c. The frame and the cell.
    d. The header and the payload area.

3. Routing in ATM is determined by which of the following, found in the ATM cell?

    a. The virtual channel identifier (VCI).
    b. The virtual path identifier (VPI).
    c. Either the VCI or VPI based on the type of cable used.
    d. The combination of the virtual channel identifier (VCI) and the virtual path identifier (VPI).

4. Key factors that have driven the development of broadband technologies are business demands, residential demands, and (list the **primary** answer):

    a. Advances in enabling technologies.
    b. Demand for a more sophisticated computer-based game environment.
    c. Demand for low cost data transfer.
    d. Educational demands.

5. Which is **not** a benefit achieved through the use of ATM?

    a. All types of data can be transferred via the same physical medium.
    b. Flexibility provided by the variable-length cell.
    c. The use of virtual channels.
    d. Wide-scale acceptance.

6. The goal of the ATM Forum is:

   a. Accelerated availability of ATM products and services.
   b. Development of ATM standards.
   c. Joint advertising and marketing efforts for ATM products and services.
   d. Joint development of ATM-based applications.

7. The first, and perhaps the **key**, phase in the migration to ATM is:

   a. Development of multimedia applications.
   b. Fiber-optic cable to the home.
   c. Growth of the ATM Forum.
   d. Interconnecting LANs.

8. Which of the following types of data is time-based?

   a. Electronic mail.
   b. Spreadsheet data.
   c. Transfer of financial data.
   d. Video.

9. An example of an interactive application is:

   a. Electronic mail between two correspondents.
   b. News retrieval.
   c. TV broadcast distribution.
   d. Video-conferencing.

10. An example of a distribution application is:
    a. Electronic mail between two correspondents.
    b. News retrieval
    c. Remote education between an instructor and multiple classrooms.
    d. Video-conferencing.

11. The goal of SONET, the synchronous optical network, is:

    a. Global interconnection of wide-area networks.
    b. Lowest cost network cabling.
    c. Replacement of coaxial cable in the LAN/WAN environment.
    d. Standard signalling rates and formats as well as simplicity for the fiber network environment.

12. The primary role of SONET is to:

    a. Provide equipment and signaling for network synchronization.
    b. Provide international access for wide-area networks.
    c. Provide an method of integrating local-area and wide-area networks.
    d. Provide a vehicle for efficient transfer of electronic mail.

13. Which is **not** an advantage gained through the use of SONET?

    a. High bandwidth capacity.
    b. More efficient use of satellite transmission facilities.
    c. More reliable and efficient.
    d. Telecommunications standards exist.

14. Which of the following **best** describes Frame Relay?

    a. Because of its variable-length unit of transfer is not suitable for transfer of all types of communication.
    b. Utilizes a dual-bus architecture for increased reliability and a 53-byte cell.
    c. Utilizes time-division multiplexing.
    d. Utilizes virtual path and virtual channel identifies for data routing.

15. Which of the following **best** describes SMDS, the Switched Multi-megababit Data Service?

    a. Because of its variable-length unit of transfer is not suitable for transfer of all types of communication.
    b. Offers data transfer at a rate up to 155 Mb/s via a dual-bus architecture that allows for increased reliability.
    c. Utilizes time-division multiplexing.
    d. Utilizes virtual path and virtual channel identifies for data routing.

16. Which of the following **best** describes STM, the Synchronous Transfer Mode?

    a. Because of its variable-length unit of transfer is not suitable for transfer of all types of communication.
    b. Utilizes a dual-bus architecture for increased reliability and a 53-byte cell.
    c. Utilizes time-division multiplexing.
    d. Utilizes virtual path and virtual channel identifies for data routing.

17. Which one of the following is **not** one of five key steps in the evolution of data transmission as followed by the computer industry?

   a. Circuit Switching.
   b. Frame Relay.
   c. ISDN.
   d. Message Switching.

18. Which of the following is **not** one of the key steps in the evolution of data transmission as followed by the telephone industry?

   a. B-ISDN.
   b. ISDN.
   c. Packet Switching.
   d. SS7.

19. Which of the following is **not** one of the underlying characteristics of ATM, the asynchronous transfer mode?

   a. Ability to globally interconnect networks.
   b. Dynamic bandwidth-on-demand.
   c. Independence from the physical layer.
   d. Simpler network management due to the virtual path concept.

20. Which of the following **best** explains the relationship between virtual channels and virtual paths?

   a. ATM utilizes virtual channels and virtual paths are a Frame Relay concept.
   b. A virtual channel and a virtual path are synonymous
   c. A virtual path bundles virtual channels.
   d. The choice of whether a virtual path or virtual channel is used depends on the type of cabling being used.

21. Which of the following are the three layers of the ATM protocol stack?

   a. The Link Layer, the Network Layer, and the ATM Adaptation Layer.
   b. The Network Layer, The ATM Adaptation Layer, and the Application Layer.
   c. The Physical Layer, ATM Layer, and the ATM Adaptation Layer.
   d. The Physical Layer, the Network Layer, and the Application Layer.

22. Segmentation and reassembly of cells (or the SAR sublayer) are functions of which protocol layer?

a. Application Layer
b. ATM Adaptation Layer
c. ATM Layer
d. Link Layer
e. Network Layer
f. Physical Layer

23. Which of the following is true?

a. ATM LANs are connectionless and traditional LANs are connection-oriented?
b. ATM LANs are connection-oriented and traditional LANs are connectionless?
c. Both ATM LANs and traditional LANs are connectionless.
d. Both ATM LANs and traditional LANs are connection-oriented.

24. ATM LANs, as compared to traditional LANs, offer all of the advantages listed below **except** for which?

a. Ability to span different geographic locations.
b. Less complicated operations and management functions.
c. Potential for global access.
d. Potential to interconnect traditional LANs.

25. Which of the following international organizations is currently concerned with formalizing broadband standards?

a. ANSI.
b. ATM Forum.
c. ISO.
d. ITU.

26. Which of the following is **not** a current issue with ATM development and commercialization?

a. Complexity of network management.
b. Congestion Control.
c. Development of domestic standards.
d. Migration and implementation costs.
e. Multivendor interoperability.

APPENDIX G

ATM For Educators - Posttest

Name: ______________________________

1. The length of the ATM cell is

   a. 5 bytes.
   b. 48 bytes.
   c. 53 bytes.
   d. Variable in length.

2. The two major components of the ATM cell are:

   a. The virtual channel identifier and the body.
   b. The cell and the payload area.
   c. The frame and the cell.
   d. The header and the payload area.

3. Routing in ATM is determined by which of the following, found in the ATM cell?

   a. The virtual channel identifier (VCI).
   b. The virtual path identifier (VPI).
   c. Either the VCI or VPI based on the type of cable used.
   d. The combination of the virtual channel identifier (VCI) and the virtual path identifier (VPI).

4. Key factors that have driven the development of broadband technologies are business demands, residential demands, and (list the **primary** answer):

   a. Advances in enabling technologies.
   b. Demand for a more sophisticated computer-based game environment.
   c. Demand for low cost data transfer.
   d. Educational demands.

5. Which is **not** a benefit achieved through the use of ATM?

   a. All types of data can be transferred via the same physical medium.
   b. Flexibility provided by the variable-length cell.
   c. The use of virtual channels.
   d. Wide-scale acceptance.

6. The goal of the ATM Forum is:

    a. Accelerated availability of ATM products and services.
    b. Development of ATM standards.
    c. Joint advertising and marketing efforts for ATM products and services.
    d. Joint development of ATM-based applications.

7. The first, and perhaps the **key**, phase in the migration to ATM is:

    a. Development of multimedia applications.
    b. Fiber-optic cable to the home.
    c. Growth of the ATM Forum.
    d. Interconnecting LANs.

8. Which of the following types of data is time-based?

    a. Electronic mail.
    b. Spreadsheet data.
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    d. Video.

9. An example of an interactive application is:

    a. Electronic mail between two correspondents.
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    a. Electronic mail between two correspondents.
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11. The goal of SONET, the synchronous optical network, is:

    a. Global interconnection of wide-area networks.
    b. Lowest cost network cabling.
    c. Replacement of coaxial cable in the LAN/WAN environment.
    d. Standard signalling rates and formats as well as simplicity for the fiber network environment.

12. The primary role of SONET is to:

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    d. Utilizes virtual path and virtual channel identifies for data routing.

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    c. Utilizes time-division multiplexing.
    d. Utilizes virtual path and virtual channel identifies for data routing.

17. Which one of the following is **not** one of five key steps in the evolution of data transmission as followed by the computer industry?

  a. Circuit Switching.
  b. Frame Relay.
  c. ISDN.
  d. Message Switching.

18. Which of the following is **not** one of the key steps in the evolution of data transmission as followed by the telephone industry?

  a. B-ISDN.
  b. ISDN.
  c. Packet Switching.
  d. SS7.

19. Which of the following is **not** one of the underlying characteristics of ATM, the asynchronous transfer mode?

  a. Ability to globally interconnect networks.
  b. Dynamic bandwidth-on-demand.
  c. Independence from the physical layer.
  d. Simpler network management due to the virtual path concept.

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  d. The choice of whether a virtual path or virtual channel is used depends on the type of cabling being used.

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  b. The Network Layer, The ATM Adaptation Layer, and the Application Layer.
  c. The Physical Layer, ATM Layer, and the ATM Adaptation Layer.
  d. The Physical Layer, the Network Layer, and the Application Layer.

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c. ATM Layer
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e. Network Layer
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d. Both ATM LANs and traditional LANs are connection-oriented.

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c. Potential for global access.
d. Potential to interconnect traditional LANs.

25. Which of the following international organizations is currently concerned with formalizing broadband standards?

a. ANSI.
b. ATM Forum.
c. ISO.
d. ITU.

26. Which of the following is **not** a current issue with ATM development and commercialization?

a. Complexity of network management.
b. Congestion Control.
c. Development of domestic standards.
d. Migration and implementation costs.
e. Multivendor interoperability.

APPENDIX H

Letter to ATM Experts

Date: Fri Jan 12 08:00:25 1996
Subject: Seeking an Expert
To: ihgp!jrm1
Content-Type: Text
Content-Length: 2232

Judith,

I am Corporate ITS manager currently completing my Ph.D. in Computer Technology in Education, with an emphasis in Computer Systems in Education - only my dissertation remaining. My topic is in the area of ATM. The dissertation effort partially involves working with a local school district to improve staff knowledge of broadband technologies, particularly ATM, as they begin their migration planning in this direction.

To accomplish this effort - improvement of educators' knowledge of ATM - I am authoring a hypertext-based training package. This training addresses ATM at an overview level. Besides an introduction and background, the training addresses:

- benefits and advantages of ATM
- the cell
- the protocol
- related transfer modes (frame relay, SMDS, and STM)
- ATM LANs
- projected applications and services
- the role of SONET
- migration to ATM
- standards and current issues

To evaluate its effectiveness, of course, I will pre and post-test participating educators and school district staff.

Before I embark on this, I need to demonstrate the validity of my pre/post test. One technique in evaluating content validity is to have the test evaluated by a "panel of experts". The reason for this message is to ask for your assistance as an expert in ATM.

Specifically, the assistance I am seeking involves the following:

- Reviewing a copy the pre/post-test. It is currently a 26-question multiple-choice test. I will also send a copy of the learning objectives for each ATM subtopic.

- I would like your comments as to the following:

  - Are the appropriate subtopics covered in the pre/post test?

  - Do the questions address subtopics in an appropriate proportion? (That is, it certainly would not be a valid test if only questions about the ATM protocol would be asked.)

I would like to finish this within the next couple of weeks. Would you be willing to assist? If so, I can send the test and learning objectives to you via e-mail.

Thanks for reading this and for the consideration.

Dan Niswander
Manager, Training and Education
Corporate ITS

(407) 662-3350 or attmail!dniswander

APPENDIX I

Expert Glossbrenner Response

Date: Tue Feb 6 10:30:00 -0500 1996
From: honet6!kcg ("Glossbrenner, Ken")
Subject: RE: ATM Test Evaluation
To: honet6!Danny.A.Niswander@att.com ("dniswander")
Content-Type: text
Content-Length: 5505

Dan,

Thank you for the opportunity to read and review your ATM test. Overall, I think it is a fine test, but as I read it, I wondered whether my answers to the discussion questions would match yours. I wonder how my industry perspective would differ from that of the outside world. I suspect my focus is a lot different, narrower and more jaded. There are a couple of the multiple choice questions for which I couldn't find an answer I would mark. (See below)

I believe the test is balanced. I don't know how long your course is, but you might want to include a bit on the ATM transfer capabilities (ATC = DBR (CBR), SBR (VBR), ABT/DT, ABT/IT, ABR, and UBR)) which are very new, but tend to customize the ATM service for different applications (circuit emulation, data, voice, video). You should also consider discussing the ability to "negotiate" quality of service on a per connection basis using the "quality of service classes" of the ITU-T or on a parameter-by-parameter basis as suggested by the ATM Forum. This quality of service work is not completed and is not resolved between the ITU and the Forum, but it is quite relevant to how networks will be architected and used. (QoS is my focus at the ITU!)

I would like to circulate your test among my colleagues, with your permission, just for fun to see how "up" on things they are.

It has been quite interesting, thanks,

Ken Glossbrenner

AT&T
Rapporteur Question 16 (ATM Performance), ITU-T SG 13 ----------

>1. TOPIC: Introduction and Background.
>
>Learning Objectives:
>

> b. List the three steps in the evolution of data transmission as
> followed by the telephone industry. (Question - 18)

I use the word "data" in a much more restrictive sense. Although voice and video have long been digitized, the telecommunications industry might still refer to them as, "signals", "user signals", "information", or "user information."

>
>12. TOPIC: Standards
>
>Learning Objective:
>
> a. Identify the key organization involved with developing the
> emerging ATM standards. (Question - 25)
>

You might get an argument here. Surely ITU-T (princ. SG 13, but also SG 1, 2, 4, 7, 11, 15 have expanding roles) is developing "standards", but in many areas the ATM Forum is getting out ahead of standards and creating many "defacto" standards, to the dismay of ITU-T.

>**
>4. Key factors that have driven the development of broadband technologies are
>business demands, residential demands, and (list the primary answer):
>
>* a. Advances in enabling technologies.
> b. Demand for a more sophisticated computer-based game environment.
> c. Demand for low cost data transfer.
> d. Educational demands.

E. The total increase in bandwidth demand and the need to satisfy that increased demand with homogeneous in-house networks and a homogeneous network infrastructures.

>7. The first, and perhaps the key, phase in the migration to ATM is:
>
> a. Development of multimedia applications.
> b. Fiber-optic cable to the home.
> c. Growth of the ATM Forum.
>* d. Interconnecting LANs.

In the early going, interconnection of LANs is leading to the adoption of ATM, but in order for ATM to succeed as an integrating technology, it will have to be proven economical (and adequate) for the transport of existing WAN applications (voice, private line), which still today create the vast, vast majority of bits transported.

>11. The goal of SONET, the synchronous optical network, is:
>
> a. Global interconnection of wide-area networks.
> b. Lowest cost network cabling.
> c. Replacement of coaxial cable in the LAN/WAN environment.
>* d. Simplicity for the fiber network environment.

I assume you mean the ability to drop/add without demuxing.
SONET overhead is certainly more complex than STM.

>12. The primary role of SONET is to:
>
>* a. Provide equipment and signaling for network synchronization.
> b. Provide international access for wide-area networks.
> c. Provide an method of integrating local-area and wide-area
> networks.
> d. Provide a vehicle for efficient transfer of electronic mail.

How about providing reliable (unswitched) optical transport of user information?

>18. Which of the following is not one of the key steps in the evolution of
>data transmission as followed by the telephone industry?
>
> a. B-ISDN.
> b. ISDN.
>* c. Packet Switching.
> d. SS7.

Again, the word "data" may be too restrictive here. Certainly AT&T has offered and still offers packet switching as a data communications tool for computers. Replacing "data transmission" by "digital transmission" or even "communications" might be what you are looking for.

>26. Which of the following is not a current issue with ATM development and
>commercialization?
>
> a. Complexity of network management.
> b. Congestion Control.
>* c. Development of domestic standards.
> d. Migration and implementation costs.
> e. Multivendor interoperability.
>
> f. Varying quality of service commitments on a connection-by-
> connection basis (is a current issue with ATM development.)

APPENDIX J

Expert Mcgoogan Response

Date: Mon Jan 15 17:03:15 -0600 1996
From: ihgp!ihgp.ih.att.com!jrm1 (Judith R Mcgoogan)
Subject: Re: ATM Test Evaluation
To: ihgp!mail.att.net!dniswander (Dan A Niswander)
Content-Type: text
Content-Length: 13805

Dan,

I looked over your material and I was quite impressed. I do think the test adequately addresses most topics. You did a good job of covering all of the topics appropriately on the test.

I didn't see any errors in the material, but I would suggest you re-look at questions 11, 13, and 15.

Try to make the "correct" answer stronger, and easier for the student to quickly identify.

In 11, emphasize the need for standard signal rates and formats across a global telecommunications network.

In 13, some would argue that standardizing technology and eliminating vendor proprietary interfaces has resulted in reduced costs, so re-think that one.

I felt 15 was a "trick" question, since ATM also uses a 53-byte cell. Look for something else as an SMDS differentiator.

Definitions from Robert K. Heldlman's book, "Global Telecommunications" that might be helpful for you are:

"SONET (synchronous optical network) A standard that evolved out of the carrier industry to provide for the interconnection of high-speed networks via single-mode optical fiber. SONET transmission speed starts with a building block of 51.840 Mbps. This rate is called STS1 (synchronous transport signal-level 1). The corresonding optical itnerface is called an OC1. The STS and OC prefixes are often used interchangeable, as are T1 and DS1. An ANSI interface standard defining a hierarchy for synchronous transmission beginning at a base rate of 51.84 Mbps."

"SMDS (switched multimegabit digital service) A 1.544 - 155 Mbps public data service with IEEE 802.6 standard user interface. It can support Ethernet, Token Ring, and FDDI (OC-3c) LAN-to-LAN connections.

I hope this was helpful. I found it to be a fun exercise for me.

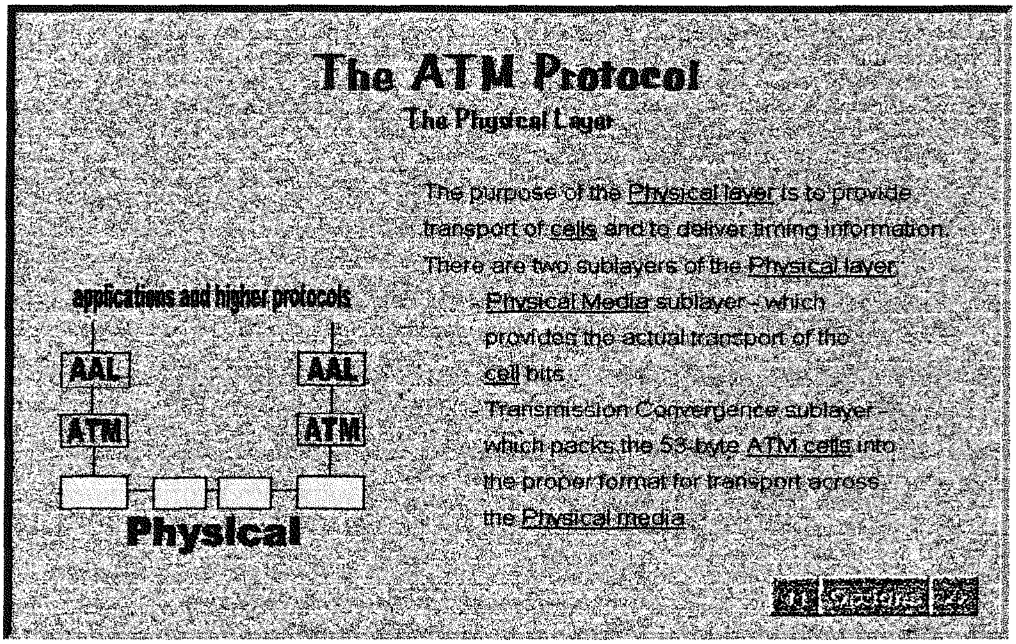
Judy McGoogan AT&T Room 5A-427 P.O. Box 3033 Naperville, IL 60566-7033 USA
+1 708 713-7355 fax: +1 708 979-9364 judith.mcgoogan@att.com

APPENDIX K

Sample ATM Tutorial Storyboard

STORYBOARD

Course Filename:	ATM.CBT	Date:	06/15/96	Frame ID:	AtmProtocolPhysical



Frame Information

Frame Type:	Lesson	Automatic Timeout (sec):	0
Main Template:	Lesn1Grph1Txt	Timeout Advance Frame:	
Navigation Template:	_StuccoMln	Multimedia Advance Frame:	

Filename Reference

Backgrnd:	STCBKBLU.BMP	Graphics:	PROTPHYS.WMF	Text:	PHYSICAL.FTT: untitled
Sound:					
Movie:					

Go To Frame Reference

Forward	AtmProtocol	ATM LANs	AtmLansObj		
Exit Course	ExitCourse	Role of Sonet	AtmSonetOb		
Previous Menu	mainmenu	Related Xfer M	AtmRelated		
Glossary	glossary	ATM Migration	AtmMigratio		
Course Map	coursemap	ATM Projected	AtmApplicati		
Help	HelpScreen	The Final Chap	AtmFinalCh		
Introduction	AtmIntroObj	Back	AtmProtocol		
Features and B	AtmFeature				
ATM Cell	AtmCellObje				
ATM Protocol	AtmProtocol				

Developer's Name:	Dan Niswander	Course #:		Ver #:	1.0	Release Date:	12/02/95

APPENDIX L

Letter to Seminole County Technical Coordinator

February 1, 1996

Dear Seminole County Technology Coordinator,

I am a Ph.D. at candidate at Nova Southeastern University nearing completion of my dissertation. My degree will be in Computer Technology in Education with a specialty in Computer Systems in Education. I am sending you this letter requesting your assistance in completing my dissertations efforts.

Broadband communication networks are currently being installed in school districts across the United States. These networks bring the promise of LAN interconnection between schools, distribution of TV and multimedia via fiber optic cable, and transport of all communication types via a single cable including voice, data, and video applications. The asynchronous transfer mode (ATM) has been chosen by international standards committees, as well as hundreds of communications providers, as the transport mode of choice to implement broadband networks.

It has been well documented that the successful implementation of these networks is dependent upon a well-educated school staff. This is the basis of my dissertation.

To solve the problem of how best to educate a school's professional staff, I have authored a computer-based, hypertext course on ATM. This is where I need the assistance of professional educational staff.

I am seeking participants to assist in evaluating the effectiveness of this computer-based course. This would include:

1. Taking a 26-question, multiple-choice pretest and responding to a pre-course, preference survey.

2. Going through the actual course. The time and location of this phase is based on preferences of the participants as a copy of the course will be provided to each individual. They may keep the software for future reference.

3. Taking a posttest and responding to a post-test preference survey.

I own all rights to the software so there are no copyright issues for you to be concerned about.

The participants need only access to a computer equipped (minimally) as follows:

- 386 PC or higher
- 16 color VGA graphics board
- 4 MB RAM (8 MB recommended)
- MS-DOS 5.0 or higher
- Windows 3.1 or higher
- hard disk free capacity of 6 MB

Potential participants can contact me at

106 Poplar Place
Longwood, FL 32750

or can call me at

work:	(407) 662-3350
weekday evenings:	(407) 332-7835
weekends:	(904) 423-8375

Thanks very much for your assistance in my educational pursuits.

Dan Niswander

APPENDIX M

SPSS/PC+ - Reliability Computation Commands

```
translate from 'rlblty.wk3' /range=b1..c33 /fieldnames.

variable labels oddpre "Number of Odd Pretest Questions Correct"

frequencies oddpre /statistics all.

frequencies evenpre /statistics all.

correlation oddpre evenpre /options 3  5.

list.
```

APPENDIX N

SPSS/PC+ Commands - Precourse/Postcourse ATM Mastery Tests

```
translate from 'results.wk3' /range=b1..g33 /fieldnames.

variable labels Pretest "Pretest Score"

frequencies Pretest /statistics all.

frequencies Posttest /statistics all.

t-test pairs Pretest Posttest.
```

APPENDIX O

SPSS/PC+ Commands -
Precourse/Postcourse Preference Survey (Individual)

```
translate from 'results.wk3' /range=b1..aq33 /fieldnames.

variable  labels

t-test pairs Pre1 Post1.

t-test pairs Pre2 Post2.

t-test pairs Pre3 Post3.

t-test pairs Pre4 Post4.

t-test pairs Pre5 Post5.

t-test pairs Pre6 Post6.

t-test pairs Pre7 Post7.

t-test pairs Pre8 Post8.

t-test pairs Pre9 Post9.

t-test pairs Pre10A Post10A.

t-test pairs Pre10B Post10B

t-test pairs Pre10C Post10C.

t-test pairs Pre10D Post10D.

t -test pairs Pre10E Post10E.

t-test pairs Pre11 Post11.
```

t-test pairs Pre12 Post12.

t-test pairs Pre13 Post13.

t-test pairs Pre14 Post14B.

t-test pairs Pre15 Post15.

APPENDIX P

SPSS/PC+ Commands - Precourse/Postcourse Preference Survey (Total)

translate from 'results2.wk3' /range=x1..as33 /fieldnames.

variable labels totpre "Pre Course Preference Survey"

frequencies totpre /statistics all.

frequencies totpst /statistics all.

t-test pairs totpre totpst.

APPENDIX Q

Number of Correct Pretest and Posttest Responses

Question	Pretest	Posttest
1	8	32
2	10	32
3	10	31
4	12	29
5	11	29
6	7	24
7	7	28
8	18	31
9	29	30
10	11	17
11	19	25
12	11	27
13	14	29
14	7	32
15	19	32
16	14	30
17	5	24
18	11	25
19	3	10
20	17	31
21	8	32
22	8	26
23	4	24
24	16	27
25	6	23
26	7	20

APPENDIX R

Precourse and Postcourse Preference Survey Statistics

Question	Precourse Survey Mean	Postcourse Survey Mean
1	1.5938	4.1250
2	1.5000	3.5000
3	3.8438	4.0313
4	4.0000	4.2188
5	3.5938	4.2500
6	3.9688	3.9688
7	3.3438	3.7813
8	3.5625	3.1563
9	1.7500	3.5625
10A	3.6774	3.6452
10B	4.0313	4.2188
10C	3.7097	4.0323
10D	3.7419	3.3871
10E	3.7419	3.2903
11	4.4063	4.0938
12	2.7500	2.6563
13	3.3750	3.7813
14	3.4000	4.5938
15	2.5938	1.8125

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