THE IDEAL MULTIMEDIA-ENABLED CLASSROOM: PERSPECTIVES FROM PSYCHOLOGY, EDUCATION AND INFORMATION SCIENCE

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ABSTRACT

With the recent technological developments, an opportunity has emerged to introduce more efficient instruction into the classroom. The traditional blackboard approach is gradually giving way to more interaction between the instructor and students. Multimedia can be defined to be multiple forms of media (text, graphics, images, animation, audio and video) that work together. It is unparalleled in its ability to disseminate information quickly and accurately. Before the digital era, multimedia was delivered using one-way communication technologies such as books, magazines, radio and television. The invention of the personal computer and the Internet, however, has introduced interactivity and created an engaging learning environment. Literature on learning and technology contains evidence that multimedia has the potential to transform every aspect of academic endeavor from instruction and learning to research and dissemination of knowledge. In this paper, we will discuss why multimedia should be employed as the centerpiece for an emerging pattern of instruction. It can promote independent and cooperative learning, improve performance of low achievers and special student populations, while heightening interest in learning, writing and research.

1. INTRODUCTION

As this paper evaluates the effectiveness of multimedia in the learning process, we will start with an overview of what *learning* is. The nature of the human mind is one of the most challenging questions that have puzzled the philosophers and scientists through the centuries. Learning is the "*process of acquiring modifications in existing knowledge, skills, habits, or tendencies through experience, practice, or exercise*."(Britannica Concise Encyclopedia, retrieved March 2003).

Until recently, the quest to understand the thinking and learning processes has been hampered by the lack of systematic research tools. The revolutionary progress in the study of the mind since the 60's provides an abundance of scientific information with significant implications for education. *Behaviorism*, an influential school of psychology that dominated the psychological theory between the two world wars, takes the objective evidence of behavior (as measured responses to stimuli) as the only concern of its research and the only basis of its theory without reference to conscious experience (Watson, 1913). It was developed in reaction to *introspectionism*, a doctrine that states psychology must be based essentially on data derived from introspection. A serious limitation of early behaviorism was its focus on observable behaviors in response to stimulus conditions. This narrow approach restricted the study of several critical phenomena (e.g., reasoning, thinking and understanding) that are closely related to education. While preserving behavior as data, *radical behaviorism* allowed hypotheses about internal mental states when they were needed to explain certain phenomena (Spence, 1942; Hull, 1943).

In the late 50's, a better understanding of the complexity of human behavior lead to the development of a new field: cognitive science. From the start, cognitive science attempted to explain learning using a multidisciplinary perspective that included complimentary disciplines such as linguistics, philosophy, anthropology, computer science, neuroscience and several branches of psychology (Norman, 1980; Norman, 1993; Newell & Simon, 1972). New tools, techniques and methodologies enabled a serious study of mental functioning. Scientists were able to test their theories without speculation about thinking and learning (Newell & Simon, 1972; Anderson, 1982; Anderson, 1987; DeGroot, 1965; DeGroot, 1969; Ericsson & Charness, 1994), develop insights into the importance of the social and cultural contexts of learning (Cole, 1996; Lave, 1988; Lave & Wenger, 1991; Rogoff, 1990; Rogoff, Mistry, Goncu & Mosier, 1993), and gain perspectives on learning that complement and enrich the experimental research traditions (Erickson, 1986; Hammersly & Atkinson, 1983; Heath, 1982; Lincoln & Guba, 1985; Marshall & Rossman, 1955; Miles & Huberman, 1984; Spradley, 1979).

Attempts to utilize computers to enhance learning began with the pioneering efforts in late 60s (Atkinson, 1968; Suppes & Morningstar, 1968). The past decade, in particular, has witnessed unprecedented advances in computing and communications technologies that resulted in faster computers and higher bandwidths. Information technology (IT) enables the acquisition, recording, organization, retrieval, display, and dissemination of information in all forms. The digital era not only extends the possibilities of the old one-way communication technologies such as books, magazines, radio and TV but also offers new opportunities. Multimedia is multiple forms of media including text, graphics, images, animation, audio and video. The complexity (i.e., the processing, storage and transmission requirements) of these forms increase in the given order. Multimedia data is increasingly used in a variety of applications ranging from entertainment to education. There are several key reports in the literature that analyze the contribution of IT to education (National Science Foundation, 1996; President's Committee on Advisors on Science and Technology, 1997; Project Kaleidoscope & Sigma Xi, 2001; Bransford, Brown & Cocking, 1999).

In April 1996, the Division of Undergraduate Education of the National Science Foundation (NSF) convened a workshop titled "*Information Technology: A workshop on Its Impact on Teaching and Learning in Undergraduate Science, Mathematics, Engineering and Technology Education*" to discuss the issues regarding the use of IT in higher education (National Science Foundation, 1996). The meeting brought together about 35 participants who represented a cross-section of the broader undergraduate educational community. The group included faculty, students, academic administrators, publishers and representatives of the IT industry. The primary purposes of the workshop were:

1. to identify examples of the "effective" uses of IT,
2. to consider their impact on various parts of the undergraduate enterprise,

3. to investigate dissemination and assessment/evaluation issues implied by the use of IT,
4. to speculate on and help NSF anticipate the impact of future developments.

The President's Committee of Advisors on Science and Technology (PCAST) Panel on Education recently released a report entitled "*Use of Technology to Strengthen K-12 Education in the United States*" (President's Committee on Advisors on Science and Technology, 1997). The Panel on Educational Technology was organized in April 1995 under the auspices of the President's Committee of Advisors on Science and Technology (PCAST) to provide independent advice to the President on matters related to the application of various technologies (and in particular, interactive computer- and network-based technologies) to K-12 education in the United States. Its findings and recommendations are based on a review of the research literature and on written submissions and private White House briefings from a number of academic and industrial researchers, practicing educators, software developers, governmental agencies, and professional and industry organizations involved in various ways with the application of technology to education. A substantial number of relatively specific recommendations related to various aspects of the use of technology within America's elementary and secondary schools are offered at various points within the body of this report. The most important recommendations of the Panel were:

- focus on learning with technology, not about technology,
- emphasize content and pedagogy, and not just hardware,
- give special attention to professional development,
- engage in realistic budgeting,
- ensure equitable, universal access,
- initiate a major program of experimental research.

Project Kaleidoscope (PKAL) is an informal national alliance working to build strong learning environments for undergraduate students in mathematics, engineering and the various fields of science. PKAL was a co-sponsor of the 2001 Change Agent Roundtable "*How Can Technology be Best Used to Enhance Undergraduate SME&T?*" (Project Kaleidoscope & Sigma Xi, 2001). In presentations and small group sessions, participants explored the issues, challenges and opportunities for the informed use of IT in enhancing undergraduate STEM learning. The roundtable discussions focused on the fundamental question "How can information technologies serve contemporary goals for student learning?"

An extensive study titled *"How people learn: Brain, mind, experience and school"* presents a contemporary account of the principles of learning (Bransford, Brown & Cocking, 1999). In response to a request from the Office of Educational Research and Improvement of the US Department of Education for an appraisal of the scientific knowledge base on human learning and its application to education, the National Research Council established a committee to conduct a study whose the primary goal was to report on the useful findings in the relevant disciplines. The committee evaluated the best and most current scientific data on learning, teaching and learning environments. As the scientific literatures on cognition, learning, development, culture, and brain are voluminous, three organizing decisions were made fairly early in the work to provide the framework for the study:

- a focus primarily on research on human learning (though the study of animal learning provides important collateral information), including new developments from neuroscience.
- a focus especially on learning research that has implications for the design of formal instructional environments, primarily preschools, kindergarten through high schools (K-12), and colleges.
- a focus on research that helps explore the possibility of helping all individuals achieve their fullest potential.

2. INFORMATION TECHNOLOGY IN EDUCATION

The above four reports try to address many of the issues regarding the use of IT in education. We will look at their findings in what IT is capable of doing to enhance student leaning.

One outcome of the discussion at a break-out session of the 1996 NSF workshop (National Science Foundation, 1996) was the understanding of IT's ability to

- provide access to world-wide resources,
- facilitate the accumulation, generation and presentation of data,
- provide tools for analysis and modeling of more or deeper and more realistic examples in a short time,
- enable enquiry and extend the human capability to visualize, organize and analyze data,
- provide immediate feedback to the student, either from the technology itself or the facilitator/instructor.

It was further mentioned that the effective use for IT was characterized by applications that

- stimulate students and engage them with the material, such as role playing simulations,
- illustrate the workings of complex systems by exploring cause-and-effect relationships, or demonstrate microscopic, molecular or hypocritical scenarios,
- encourage collaboration with other individuals, teams or institutions to coordinate a group effort while exposing students to different ideas and perspectives,
- foster development of critical skills, visualization, conceptualization, integration of disparate data and resolution of patterns within data,
- utilize the WWW for research, advertising and posting material.

C. Dede, a contributor to the 2001 Change Agent Roundtable Occasional Paper (a collection of presentations and stories from roundtable participants), lists the unique capabilities of sophisticated computers and telecommunications as (Project Kaleidoscope & Sigma Xi, 2001):

- centering the curriculum on authentic problems parallel to those adults face in real world settings,
- involving students in virtual communities-of-practice, using advanced tools similar to those in today's high-tech workplaces,

- facilitating guided, reflective inquiry through extended projects that inculcate sophisticated concepts and skills and generate complex products,
- utilizing modeling and visualization as powerful means of bridging between experience and abstraction,
- enhancing students' collaborative construction of meaning via different perspectives on shared experiences,
- including pupils as partners in developing learning experiences and generating knowledge,
- fostering success for all students through special measures to aid the disabled and the disenfranchised.

Dede also states that a realization of these capabilities requires a complex implementation process that includes sustained, large-scale, simultaneous innovations in curriculum, pedagogy, assessment, professional development, administration, organizational structures, strategies for equity, and partnerships for learning among schools, businesses, homes and communities.

In the National Research Council's study on how people learn, the chapter titled "Technology to Support Learning" reports on several groups who have reviewed the literature on technology and learning and concluded that it has great potential to enhance student achievement and teacher learning (Bransford, Brown & Cocking, 1999). The chapter explores how new technologies can be used in five ways:

- bringing exciting curricula based on real-world problems into the classroom,
- providing scaffolds and tools to enhance learning,
- giving students and teachers more opportunities for feedback, reflection, and revision,
- building local and global communities that include teachers, administrators, students, parents, practicing scientists, and other interested people,
- expanding opportunities for teacher learning.

3. ELEMENTS OF THE IDEAL MULTIMEDIA-ENABLED CLASSROOM

Multimedia has two key uses:

- *Natural presentation* of information through text, graphics, images, audio and video.
- *Non-linear navigation* through applications to access the needed information.

Multimedia-enabled computers and peripherals therefore provide a multi-sensory experience in exploring our world. This experience enhances lectures, research and personalized instruction by allowing the individuals to control and manage multimedia navigation.

Several statistics from different sources show the effectiveness of multimedia in education:

- Multimedia applications can enhance student learning. Active learning indicates what percentage we remember: 10% of what we read, 20% of what we hear, 30% of what we see, 50% of what we hear and see, 70% of what we say, and 90% of what we both say and do (Todd, 1997).

- According to the United States Department of Defense data, we have short-term retention of approximately 20% of what we hear, 40% of what we see and hear, and 75% of what we see, hear, and do. Trainees complete courses with multimedia in one-third of the time as those receiving traditional instruction, and reach competency levels up to 50% higher. In most cases the overall cost of instruction is lower (Oblinger, 1991).
- In broad terms, computer-based instruction works. It offers a 10 to 20% improvement in performance over conventional training methods and a one-third reduction in time on task. They [trainers] can reduce the amount of time that a trainee spends learning by one-third (Fletcher, 1991).
- Students retain 20% of what they see, 30% of what they hear, 50% of what they see and hear, and 80% of what they see, hear, and interact with (Shelly, Waggoner, Cashman & Waggoner, 1998).

The key elements in an ideal multimedia-enabled classroom are: Networked computers, storage devices, printers, scanners, LCD projectors, electronic white boards, digital cameras and camcorders. Brief descriptions of these elements are given in Table 1. Several different types of devices may be needed in the classroom depending on the course material in question.

Table 1. Key elements in an ideal multimedia-enabled classroom

Key element	Description
Networked computer	The essential element needed for all types of computational and communication needs. Speed, memory and storage capacity are the 3 important factors in classifying computers. For a multimedia classroom, only personal computers are normally needed. In this class, there is a range of computers from hand-held computers to work stations. A *server* is a special type of a computer that has been optimized to provide services to other computers over a network. Typical resolutions for computer monitors run at 800x600 pixels (SVGA). However, newer models come with 1024x768 (XGA) or 1280x1024 (SXGA) resolutions which are better suited for a multimedia classroom. A networked computer should be equipped with the following software tools: • Tools for communicating, storing and managing multimedia data • Tools for searching, accessing and compressing multimedia data • Tools for editing, importing and exporting multimedia data • Tools for analyzing multimedia data Some of the most popular tools for multimedia development are Director, Dreamweaver, Flash, FrontPage, Illustrator, PhotoShop and Powerpoint.
Storage device	In a classroom setting, the storage requirements for multimedia data may be huge. In addition to the storage capabilities of the computers, special storage devices called *file servers* are needed. To understand the needed capacity, let us consider two multimedia elements: • Digital image: Digital images are made up of tiny squares called *picture elements* (or *pixels* in short). The size of a digital image is specified by its dimensions in pixels. A 640x480 image contains 307,200 pixels. A 24-bit color image has 307,200 x 24 bits - which is almost 1 MB of storage! • Digital video: A video clip is a sequence of images called *frames*. The size of a 640x480, 24-bit frame is 640 x 480 x 24 = 7,372,800 bits. With a frame rate of 30 frames/sec, the file size of one second of full video is 27 MB! Fortunately, efficient image and video compression techniques reduce these sizes by removing the *spatial* and *temporal* redundancy in the data.
Printer	Printers types generally fall into 2 categories: *Impact* and *non-impact*. With impact printers, a character is formed when paper and ribbon are struck together. This category includes dot *matrix*, *daisy wheel* and *chain/band* printers. Non-impact printers form a character by not striking the paper but by using an ink spray or toner powder. *Inkjet*, *thermal* and *page* printers are in this category. Printer resolution is one of the most important qualities of a printer. It refers to the clarity of a printed image. The resolution indicates the number of dots per inch of the printed image, for example a 600-dpi (dots per inch) printer is one that is capable of printing 600 distinct dots in a line one inch long.
Scanner	A scanner is a device that captures and converts images to a computer format. With a CCD *(charged couple device)* scanner, the light reflected from the original document passes through a system of mirrors and lenses which redirect the light to the CCD array of photosensitive cells. In a CIS *(Contact Image Sensor)* scanner, the array of image sensors lies just under the document to be scanned so the sensors catch the reflected light directly. CIS scanners are cheaper to manufacture, smaller and more durable, however, their image quality is not as good as CCD. In choosing a scanner, several technical factors may be considered: bit depth, resolution, optical density and speed. It is not uncommon today that printers, scanners, and even copiers function as one device at a reasonable price tag.
LCD projector	LCD projectors are grouped into three broad categories: Ultralight projectors, conference room projectors and fixed installation projectors. • *Ultralight projectors*. • *Conference Room* projectors • *Fixed Installation* projectors According to the light technology used, there are two major types of projectors: *LCD (Liquid Crystal Display)* and *DLP (Digital Light Processing)*. In general, DLP projectors tend to offer brighter and more continuous images than their LCD projector counterparts. The key factors used in choosing an LCD projector for the multimedia classroom include resolution (VGA (640x480), SVGA (800x600), XGA (1024x768), and SXGA (1280x1024)), brightness (typical range: 400-10,000 ANSI lumens), weight (few pounds to 100 pounds) and lamp type (two most common types: metal halide lamps and UHP (Ultra High Performance) lamps).
Electronic white board	Electronic whiteboards extend the capability of the traditional whiteboard by capturing text and other data and transferring them to a computer where they can be saved, edited, shared, and printed. There are three generic types of products: • *Copyboards*: scan and print information written on the board. There is no connection to a computer. • *Peripheral boards*: transfer whiteboard information to an attached computer as digital files for storage and dissemination. • *Interactive whiteboards*: are essentially large touchscreen monitors that can control an attached computer. Different technologies are used in detecting the pen as the data is recorded on the electronic whiteboard: *Sonic, resistive membrane and magnetic pick-up.* *Laser scanners*: Laser scanner boards also have a hard writing surface, but they are built into a frame around the board (like those at a grocery store's checkout line). The scanners can track the pen's location because the pens have tiny bar codes on them that the scanners can see.
Digital camera	Digital cameras use a lens (just like a conventional film camera) to direct photons of light onto photosensitive cells of a semiconductor chip, called an *image sensor*. The type of image sensor employed by most digital cameras is a CCD. The captured image is fed to an ADC (Analog-to-Digital Converter) chip which converts the electrical charges to digital data. The number of pixels that are concentrated on the image sensor is measured either as an x/y axis formula, such as 480x640, or as a total number, such as 1,000,000 pixels. After analysis, the digital data is reassembled into an image file for consumption or processing.
Digital camcorder	Camcorders and digital still cameras both take pictures using CCDs. However, since camcorders produce moving images, their CCDs have some additional pieces not found in digital camera CCDs. To create a video signal, a camcorder CCD must take many pictures every second, which the camera then combines to give the impression of movement. There are three consumer digital formats in use: *MiniDV, Digital 8* and *DVD.*

4. FACULTY DEVELOPMENT

The utilization of multimedia equipment will imply new roles for the instructor and the students. The instructor will need to learn and experience how these tools can be used effectively in the classroom. He or she will probably spend considerably more time to prepare the lecture notes. A recent practice, for example, is to publish the notes in the form of a Powerpoint presentation on a web site and allow free access to that site. The minimum requirement for the instructor is a good familiarity of the popular PC applications and web site development tools. The students, on the other hand, will benefit from educational multimedia tools by having active participation in the classroom.

The ideal multimedia-enabled classroom is filled with highly technical modern equipment and sophisticated software applications. If the instructor is expected to widely adopt information technology in teaching, what should be the outcome of his training and how should this outcome be achieved? Is the primary goal to make the instructor technically competent or to focus on new pedagogic approaches made possible by IT?

In Break-out Session 3 of the NSF workshop (National Science Foundation, 1996), it was argued that

- IT must be made more accessible to faculty, and facilitated not only by proximity and ease of use, but also by professionally recognizing its use, and supporting or rewarding these efforts accordingly,
- there is a need for IT that assists faculty, such as authoring or communication applications,
- support for faculty development beyond individuals – to departments, colleges and whole institutions – is also required.

The observations and recommendations derived from the NSF workshop included those for faculty development. One observation was that IT increases the variety of needs for training including the use IT itself, applications and teaching techniques. In the opinion of the participants, faculty development must be long-lived via communities of support, and innovators must aspire to, and be rewarded for, increased efforts for dissemination of effective technology to commercial publishers and via professional societies.

Regarding the need for professional development, the report “Use of Technology to Strengthen K-12 Education in the United States” (President’s Committee on Advisors on Science and Technology, 1997) states that the substantial investment in hardware, software and infrastucture recommended by the Panel would be wasted if K-12 teachers are not provided with the preparation and support they need to effectively integrate information technologies into their teaching. The Panel also believes that the teachers should be provided not only with ongoing mentoring and consultative support but also with the time required to familiarize themselves with available software and content, to incorporate technology into their lesson plans, and to discuss technology use with other teachers.

According to Terri Boneright, another contributor to the 2001 Change Agent Roundtable Occasional Paper (Project Kaleidoscope & Sigma Xi, 2001), the instructor can be a facilitator rather than an information provider with the correct use of technologies. He lists several requirements for faculty to make the best use of information technologies:

- focus on learning, not on coverage of material, on developing habits of mind and higher thinking skills rather on strict acquisition of information,
- set priorities for what students should learn,
- make accommodation for different learning styles,
- have the support of senior administrators,
- have easy access to the right technologies in classroom and lab, and 24/7,
- have easy access to best practices in their disciple and to effective tools for accessing the impact of technologies on student learning.

In a section on the issues about teacher learning, the study "How people learn: Brain, mind, experience and school" (Bransford, Brown & Cocking, 1999) shows evidence that the introduction of new technologies to classrooms has offered new insights about the roles of teachers in promoting learning. These new roles would allow the teachers to experiment and tinker, providing a stimulation to think about the processes of learning. The Teacher Professional Development Institute (TAPPED IN), for example, uses a Web-based multi-user virtual environment designed to support large numbers of education professionals in a single virtual place. Teachers can log on into TAPPED IN to discuss issues, create and share resources, hold workshops, engage in mentoring, and conduct collaborative inquiries with the help of virtual books, whiteboards, file cabinets, notepads and bulletin boards. TAPPED IN helps professional development projects, education agencies, philanthropic organizations, and for-profit organizations use the Internet to connect with and support teachers via the Web.

5. CASE STUDIES

A small number of published experiments exist to assess the benefits of multimedia in the classroom. The reported results are not conclusive but highly promising.

A study (Pilman, 1990) reports on a Tulane University project to *encourage the infiltration of multimedia technology into the classroom* by bringing incentives, tools and knowledge necessary to interested faculty members. Under the leadership of the Director of Academic Computing, a subcommittee of the University Senate Committee on Computing established the guidelines for the project and extended invitations to all tenure and tenure-track to submit proposals to participate in an intensive, 4-day workshop on interactive multimedia. From these proposals, the committee selected ten participants for the workshop. In exchange for participating, each faculty member was rewarded with a Macintosh computer. Apple Computer Inc donated 10 Macintosh computers (7 Macintosh SE/30s and 3 Macintosh II CXs) to be used in this project.

The workshop was held during Tulane's Spring Break so that there would be no conflict with the teaching schedules of the faculty members. Upon completion of the workshop, the committee identified three of the participants with the best proposals and the greatest potential to complete a multimedia courseware project.

At the beginning of the project, there were three expectations:

- At least three completed multimedia courseware projects.
- A group of faculty evangelists who would go to their departments and promote this type of publication, and the inclusion of these materials into the classroom.
- An ongoing program at Tulane to get more faculty members involved in joining the wave of the future.

At the time of reporting, faculty participants were working towards the completion of their multimedia projects. To create a resource for faculty members, a small scale multimedia lab was established with sound and video equipment, and the hardware and software necessary to interface with Macintosh hardware and with software products such as HyperCard.*

Another study (Huang, 1991) describes a prototype that was jointly developed by IBM Singapore and the Institute of Systems Science at National University of Singapore. Specially designed for the Singapore 2000 exhibition (June 6-23, 1990), it *integrates existing advanced technologies to demonstrate the concept of the multimedia classroom for various types of skill training*.

The system was developed using off-the shelf hardware and the Advanced Technology Classroom (ATC - a computer-based education and executive presentation system). It is comprised of 5 major components:

1. A smart lectern: Main control unit with a PC/AT. It houses a flat plasma panel display and a laser sensor unit serving as a touch panel.
2. A student response unit: Interactive response keypad to obtain student responses to questions posed by the instructor.
3. A presentation unit: Visual material is projected on a large, high-gain screen through a video projector or a large projection TV screen.
4. An audio/video equipment unit: Houses the assembly of audio/video equipments.
5. Authoring and command software tools: A software environment to assist the instructor with course development.

Ten lessons were produced including History of the Singapore River, Basic Mandarin, The Making of Micromouse, Computer Numerical Control Lathe and vehicle testing. They were used at the exhibition by instructors from various organizations in Singapore with the participation of students from audiences.

The video materials for the courses were pressed onto laser discs after a careful design that included ten steps: (1) define the audience, (2) research the content, (3) clarify instructional objectives, (4) explore teaching strategies, (5) outline the module, (6) detail the plan, (7) conduct paper walk-through, (8) produce audio/video content, (9) press video discs, and (10) pilot test.

The major effort for this project was to select a set of lesson modules that relate to Singapore's manpower development. The ATC technology, it was hoped, would play an important role in fulfilling Singapore's vision and aspiration to become a developed nation by the year 2000.

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* Developed by Apple Computer Inc, Hypercard is a comprehensive package of tools for authoring media-rich interactive solutions.

A third study (Mathis & Clarke, 1993). focuses on *three generations of multimedia classrooms* at Carnegie Mellon University, each generation being a step forward in improving the ability to serve the university's educational needs.

After briefly mentioning the first two generations, the paper presents the details of a new facility that was designed and constructed as a result of partnership between Instructional Technology and the Art Department. The room was designed with multiple purposes. It had to accommodate concerts, performances, film/theater presentations and 2 or 3 dimensional art. It also had to be suitable for seminars, lectures, meetings and traditional classes offered by any department in the university. An additional requirement was that the equipment had to be easy to use without special, time-consuming training and support personnel.

Use of multimedia elements was enabled by the development of an innovative control system called the *Technology Access Governor (TAG2)*. Consisted of an input screen (similar to an ATM) and a set of Macintosh-based command scripts, TAG2 controls all the equipment in the room including lights, video, audio, slide projectors, and computer displays. A custom-built lectern carries the input screen that displays command buttons for each piece of equipment. The touch-activated buttons are used to send commands to a computer in control of the equipment. TAG2 has two additional features: It is programmable and it gathers statistics on usage patterns.

The study concludes with the architectural specifications of the third generation room regarding the dimensions, lighting/air conditioning/heating systems, projection/exhibition/marking surfaces, floor coating, ceiling covering, electrical outlets, computer network connections, multimedia equipment and security. The cost of the facility was itemized as follows:

- General construction: $57,000
- Electrical, air conditioning, heating: $89,000
- Electronic equipment: $63,000
- Total cost: $209,000

A final study called the *Classroom 2000 Project* (Abowd et al., 1996) at Georgia Institute of Technology was initiated to test the hypothesis that an application of computing technology in the classroom setting to support the classroom's group multimedia authoring and review experience leads to an enhanced teaching and learning experience. Because a long-term project goal was to be able to provide augmented classroom support for all courses at a university such as Georgia Institute of Technology, different styles of teaching and learning were initially examined.

Teaching styles:

- *Presentation*: A set of slides displayed during the lecture. Copies made available to the students.
- *Public notes*: Set of organized notes used as a guide. Copies made available to the students.
- *Private notes*: Set of notes prepared as a means to prompt the lecture. No copies made available to the students.

- *Discussion*: All participants contribute more or less equally. There may be a publicly available agenda.

Learning styles:

- *Verbatim*: The student writes as much of what is experienced in the class as possible.
- *Highlighting*: The student writes only the key points of what is discussed in the class.
- *None*: The student writes nothing and relies on memory or what is made available to the students.

Three prototypes were built to suit different teaching styles and to allow experimentation with different technology in the hands of the teacher and students. Table 2 summarizes the main characteristics of prototypes (i.e., the activities and technology used in the various phases of production).

Table 2. Summary of technologies used in the Classroom 2000 Project

	HCI **Human-Computer Interaction**	**AI** **Artificial Intelligence**	**FCE** **Future Computing Environments**
teaching style	presentation	public notes	discussion
enrollment	25 grad students	60 undergrad CS majors	15 grad students
live recording (teacher)	ClassPad on LiveBoard† captured navigation and annotation	LCD projector to display Web notes; no capture	LCD projector to display outline and Web pages; no capture
live recording (students)	ClassPad on pen-based PC captured navigation and annotation	paper notes; no capture	outline annotator on Newton Message Pad‡ to capture outline entry notes
live recording (classroom)	single digital audio stream recording	single analog audio-video stream recording	single analog audio-video stream recording
post-production	log file, annotated slides and keyword text used by PERL script to create audio-enhanced, searchable Web notes	audio and video links added to HTML§ notes manually; video digitized to QuickTime packets	PERL** script transforms Newton data into audio-enhanced outline with notes

Some objective and qualitative results were obtained in operating the Classroom 2000 prototype in a graduate HCI course. Preliminary evaluation shows favorable student impression, with the most encouraging response being toward the use of the electronic white board and Web notes.

† A large interactive electronic whiteboard supporting group meetings, presentations and remote collaboration.
‡ A personal digital assistant (PDA) manufactured by Apple Computer, Inc.
§ HyperText Markup Language for publishing hypertext on the World Wide Web.
** Perl (an acronym for "Practical Extraction and Report Language") is a programming language for processing text.

6. PERSONAL EXPERIENCE IN TEACHING WITH MULTIMEDIA TOOLS

One co-author recently taught a course titled *Multimedia Production for the World Wide Web*. We will share his experience regarding the benefits and problems associated with multimedia tools in this course.

The Multimedia Production for the World Wide Web course is designed for students who want to learn how to develop web sites with multimedia-rich content. The major software tools chosen by the instructor include Javascript (cross-platform scripting language), Adobe Photoshop (image editing software), Macromedia Dreamweaver (web design tool) and Macromedia Director (multimedia authoring tool).

The classroom is part of a central computing lab that provides services to all students. Technical support is available for routine hardware/software problems. The layout of the 12.65m x 5.5m room is shown in Figure 1. There are 32 networked PCs, a high speed printer, the instructor's PC, an LCD projector (mounted on the ceiling), a projection screen and a white board.

The instructor spent more than 100 hours in the semester to prepare the lecture notes. Approximately 4 hours were needed for each chapter. Using the Powerpoint presentation format, 140 slides were written with many digital pictures, and multi-color diagrams, tables and charts. This presentation is undoubtedly more attractive and organized than anything scribbled on a white board in class.

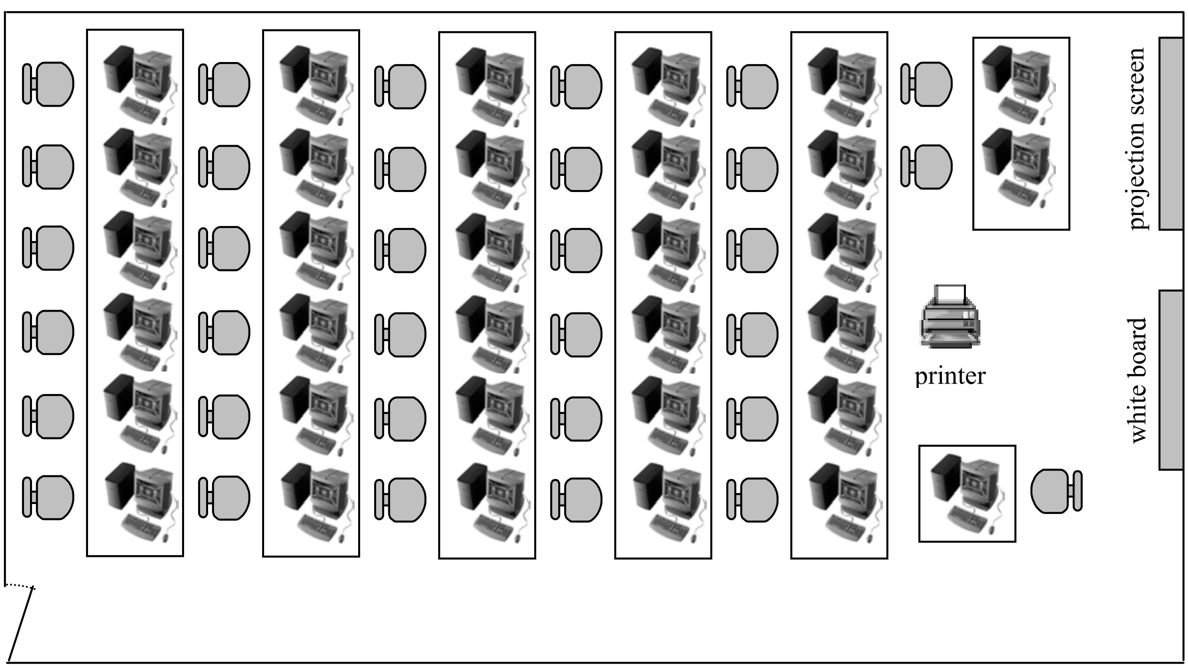

Figure 1. Layout of the multimedia classroom

The instructor has observed the following benefits of the multimedia classroom:

- *On-line availability of lecture notes*: Instead of taking notes, the whole class was able to participate in a lively discussion during each lecture. With the traditional blackboard approach, it is a well-known fact that most of the lecturing time is spent by writing notes on the board. Because of the contents of the web design course, it would be technically very difficult to present pictures and other visual material on anything but the computer.
- *Encouragement of creativity*: A term project was assigned as part of class work. Each student was expected to develop a personal web site with multimedia-rich content including text, graphics, images, audio and video. The class was informed that the grades would be based on how the design parameters (graphic design, interface design, information design and scripting) learned in class were used to ensure an aesthetic, usable and functional web site. This assignment encouraged the students to be creative in designing their web site. They visited many sites to get interesting ideas, and researched the web design principles.
- *Access to additional course material on the Internet*: When needed, the instructor had immediate access to numerous on-line resources that contained relevant information. The students, in turn, realized the immense potential of the Internet as an electronic library.
- *Hands-on experience*: Many hours of Internet usage allowed the students to become fully aware of the Internet architecture, and the related topics such as the World Wide Web, the Internet Protocol, bandwidth and storage requirements, and the server-client relationship.
- *Shared resources*: Although the printer was the only shared device in the classroom, the students understood the importance of efficient resource sharing in a networked environment.

In spite of the aforementioned positive contributions to learning, the use of IT technologies may disrupt the learning process seriously unless the infrastructure is reliable and appropriate. The following problems were encountered throughout the semester:

- Some students were inclined to access web sites that were not related to the course material (games and other attractions). The instructor felt that it was difficult to have the full attention of all students during the lectures.
- Because of sporadic network problems, Internet connection was not available on the PCs from time to time. This simply meant that there was no access to the lecture notes.
- Sometimes, a few of the PCs had hardware or software problems and the affected students had to move to other machines. Fortunately, the number of students in the class was less than the number of PCs.
- The printer was another problem source. It failed to work for several weeks during which technical support was not available.
- The dimensions of the white board were not sufficiently big. Occasionally, the instructor needed to write additional lecture notes on the board, and had to use the eraser a lot. Had the classroom been equipped with an electronic white board, the notes could have been saved and electronically distributed to the students.

- The noise of the LCD projector was quite annoying. The students had to speak with a louder voice to be heard. At one time, the projector was not turned on and the class could not figure out how to use it. A technician had to be called to start it.
- The students sitting in the last few rows had a partial view of the screen. An amphitheater-like design would be a much better alternative for this class.

These problems clearly showed the need for full technical support and a better infrastructure for the multimedia-enabled classroom. Budget allocation needs to be prioritized based on the needs and plans of the institution.

7. CONCLUSIONS

Multimedia may be the greatest educational revolution since the invention of the printing press.[††] The integration of computing and communication technologies has shown a proven potential for effectiveness in many sectors of society including finance, manufacturing and medicine. It also offers a great promise to enhance education in all stages from kindergarten to college.

Collectively, IT tools

- enable experimentation with complex, real-life problems through modeling and simulation
- create interactive environments to receive immediate feedback
- facilitate collection and presentation of data
- provide access to world-wide information sources
- allow self-paced learning
- support the development of interpersonal communication skills
- encourage collaboration among students and instructors

The primary mission of faculty development activities should be improved student learning. The focus needs to be on learning with technology and not about technology. This can be realized by complementing faculty's computer-related skills with new and effective teaching tools enabled by the use of information technology. Their primary role in the classroom must not be reduced to that of an assistant, providing help with minor application-related problems. They must seek to be partners in innovation, be willing to adopt pioneering pedagogic approaches, and help disseminate the best practices in multimedia-enhanced teaching and learning.

Many multimedia technologies are relatively new in developing educational tools. The basic premises about the utilization of multimedia in learning need to be investigated with respect to the new findings in learning principles. The limited number of case studies such as the Classroom 2000 Project and our own experience provide some evidence that supports the potential value of information technologies, but extensive research is required to be able to reach general conclusions.

[††] Johannes Gutenberg, a goldsmith and businessman from the mining town of Mainz in southern Germany, invented the printing press in 1445. This invention is widely thought of as the origin of mass communication, marking Western culture's first viable method of disseminating ideas and information from a single source to a large and far-ranging audience.

Although computer and communication technologies have unique capabilities for enhancing learning, the infrastructure of a multimedia-enabled classroom is complex and implies many radical changes in all areas including curriculum development, pedagogical approach, faculty training and organizational matters. The funding of such an infrastructure is a challenging financial issue at the institutional, state and federal government levels.

ACKNOWLEDGMENT

We would like to thank Dr. Louise Hainline for a very fruitful discussion and useful references that introduced us to the intriguing subject of learning.

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