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ABSTRACT

The four projects described here, a selection of those funded by the Annenberg/CPB Project, focus on the use of telecommunication and information technologies as tools for teaching in higher education. All are written by people directly involved in the projects described. The introductory section, "Overview: Issues in Educational Telecommunications," written by the editors of this report, summarizes some of the issues that the telecommunication and information technologies pose for higher education. The projects described are: (1) a technology demonstration project conducted by Brown University's Institute for Research in Information and Scholarship that introduces networked workstations into two Brown courses; (2) six introductory-level college science lessons, developed by the University of Nebraska-Lincoln, that use a range of videographic combinations to provide technology-based alternatives to traditional laboratory activities; (3) a television-based, freshman physics course, developed by the California Institute of Technology, that combines a historical perspective with a grounding in calculus and animation to help students visualize abstract concepts; and (4) a study conducted by Research Communications, Ltd., that determined how college students actually used and assessed television-based courses and documented the rigorous intellectual demands they place on students. The final section, "Technology for Learning," provides an overview of applications of the technologies in higher education, connecting the work of the Annenberg/CPB Project to broad developments in the field. (EDS)

Overview

Spinning Scholarly Webs

Interactive Science Videodiscs

Physics Teaching Today



Countering Misconceptions

Technology for Learning

**Overview:**

# Issues in Educational Telecommunications

Higher education is on the threshold of a new age of telecommunications. Like all dramatic breakthroughs, this one is often poorly understood by those who have practiced their profession in time-bound ways. Fear of change is an entirely understandable human reaction. Suspicion of innovation is often a rational antidote to trendiness and highly touted fame. Academics would be open to charges of irresponsibility if they failed to look at new concepts with informed skepticism.

Yet, the coming of technology to education is no faddish trend. Still in its beginnings, the field includes not only the already fairly well-known television courses but extends into the use of electronic texts, videodiscs, computer use for teaching through simulation and animation as well as interactive learning.

Application of the new technologies to higher education is a response to new demands made on academia, and it is a natural consequence of the changes the electronic revolution has already brought about in our society-at-large—in communications, production and commerce. If the colleges and universities were to stand aside, electronic teaching and learning would almost certainly circumvent them. It would then most likely fall into less qualified and less responsible hands without the quality controls built into higher education.

The demographics of the American college student have undergone dramatic change. We are well on the way to seeing the majority of students made up of men and women considerably past the traditional college age. While many colleges, with vacancy signs flashing outside the campus gates, put out the welcome mat for older students, they still find it difficult to adjust to the needs of the part-timers, of people who are highly motivated to do the work, but cannot fit their jobs or family schedules into traditional academic time-tables.

The answer for these increasing numbers is flexibility through distance learning. And what gives distance learning new possibilities is the fact that telecommunications now have progressed to a point where distance is readily bridged by the interactive capacity of electronic learning. This means that serious limitations to educational quality can be eliminated or at least reduced.

Many leaders in academia welcome these changes and appreciate new opportunities to capture the wonder and the spirit of great teachers on the video screen, on discs, on computer software. Yet, even though distance learning with its many aspects of electronic education has supporters within the academy, no established system has the capacity to take the lead in entering a future of dramatic change. Outside forces, willing to invest in experiments and evaluation, are crucial. This is the key role played by The Annenberg/CPB Project.

Several vital points are made by those who have taken part in this pioneering venture:

- There is no fundamental conflict between learning on campus and distance learning. The two complement each other; they usually deal jointly with both categories of students. Distance learning depends for its quality on the best minds of the academic departments.
- The electronic teaching media do not replace the human instructor. They lead to a division of labor which gives greater, not diminished time, power, and responsibility to the human factor. For the student, they provide a great variety of ways to move forward, sometimes as individuals and at other times as members of a class.
- Computer simulations, videodiscs and videotape, either individually or linked, make it possible for students to carry out experiments that would be considered too costly or too dangerous in the laboratory, or to combine the study of foreign language and culture, as in the upcoming French language series.
- Computers can be linked to enable students and/or the instructor to communicate, using text and visual materials whenever it is most covenient to all participants.

# Spinning Scholarly Webs

■Through the combined expertise of professors and television producers, lectures by outstanding teachers can be given added vitality and be opened up to countless students, broadening the offerings of their regular faculties.

Much remains to be learned. At the heart of The Annenberg/CPB Project is the premise that technology is a valuable tool to enhance learning on a variety of levels. Moreover, what has been accomplished and analyzed to date is only the preliminary effort which draws a map to an expanding future.

It also illustrates how the available resources—separately and in interaction—stand ready to give colleges and universities a new dimension of service to their faculties and students. The Project extends an invitation to academic leaders to benefit by joining those who are in the forefront of a new age.

Grace Hechinger
*author and columnist for* Glamour Magazine

Fred Hechinger
*President of The New York Times Foundation and education columnist for The New York Times*

In the past few years at Brown University, we have been examining the way professors, especially in the humanities, teach with currently available tools and technology. We observed that professors do not "tutor" students nearly as much as they try to guide them through bodies of material, help them to analyze and synthesize that material, and encourage them to make connections and discover meaningful relationships.

We have kept these methods in mind, therefore, when considering the type of software tools to develop for the "scholar's workstations," the term we use to describe a goal and not a particular machine. To reach this goal—the development of powerful personal computers with hardware and software tailored to the needs of those engaged in learning, teaching and research—we must focus on building tools for synthesizing, arranging, indexing, connecting, sharing, customizing, visualizing, integrating and retrieving information.

With funding from The Annenberg/CPB Project, Brown's Institute for Research in Information and Scholarship (IRIS) is conducting a technology demonstration project which involves the introduction of powerful networked workstations into two Brown courses. The subject matter and educational goals of each course—A Survey of English Literature and Plant Cell Biology—are quite different: nevertheless, we intend to integrate the same fundamental software tools into both courses.

### Historical Context

In the mid 1960's, researchers at Brown and elsewhere recognized that computers could be used to do the sorts of things Bush envisioned for his memex machine, especially helping scholars to make connections and aiding scholars in managing their *webs* of information. Because the electronic medium allows flexible organization of material, it provides authors and students with a greater degree of freedom than printed books. Explicit connections—"links"—allowing readers to travel from document to document (as one does with an encyclopedia) can be made easily by authors, thus fostering the

The idea of creating general-purpose scholarly tools is by no means new. As early as 1945, President Roosevelt's science advisor Vannevar Bush envisioned a "memex" device in which individuals would store all their books, records, and communications, form associative trails through them, and rapidly retrieve specific information contained within those materials. Theodor Nelson, an innovative thinker, coined the term *hypertext* to describe this idea of connecting related materials. A hypertext system allows authors or groups of authors to *link* information together, create *paths* through a corpus of related material, *annotate* existing texts, and create notes that point readers to either bibliographic data or the body of the referenced text.

## Errata

*The following paragraphs were reversed inadvertently on page 2 and should be read as follows:*

### Historical Context

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creation of rich hypertext webs. With a computer-based hypertext system, students and researchers are not obliged to search through library stacks to look up referenced books and articles; they can quickly follow trails of footnotes without losing their original context.

Linking people together–intercommunicability–is another type of scholarly connection that researchers in the 1960's believed could be enhanced with computer technology. Networked computers allow researchers, professors and students to communicate and collaborate with one another.

By 1968, Douglas Engelbart, a research scientist at the Stanford Research Institute, had developed one of the first computer-based hypertext systems. His system, designed for military and industry users, allowed text and line drawings to be organized in a hierarchical outline structure upon which one could superimpose a network of links that point to discrete blocks of information. More importantly, his system had as its central theme the idea of *augmenting* the human intellect with powerful computer-based tools.

At approximately the same time, Theodor Nelson inspired Andries van Dam's research group at Brown to develop an early hypertext editing system. The successor to this system, called FRESS, was used in two educational experiments at Brown in 1974-5. The software was used in an interdisciplinary course on Man, Energy and the Environment and in a poetry course. The results of these experiments showed that given powerful text editing capabilities and communication tools, the students using FRESS wrote substantially more than the students in the control sections; however, the students did not create many of their own links or take advantage of other system features due both to the difficulty in using these potentially powerful tools and to the fact that they could only use the single shared workstation a few hours per week. With the inadequate technology available in the mid seventies, we were not able to adequately test several key hypotheses:

1) Given tools that are easy enough to use, students and professors will be able to create, manage and explore large bodies of connected materials;

2) Given tools that can handle large bodies of unstructured information and promote communication, students' educational experience will be richer than if they used books alone.

The demonstration project sponsored by The Annenberg/CPB Project represents the first experiment at Brown on a large enough scale to test these hypotheses.

Our demonstration project focuses on three general educational aims. First, we believe it is important to facilitate the observation and creation of connections and relationships among ideas, concepts, events and people. Our first general aim, therefore, is to provide software tools that will allow professors to create webs of information and that will allow students to follow trails of linked information, annotate text and illustrations, and communicate with other students and the professors. Secondly, we aim to enhance "audiovisualization." By this we mean everything from enhancing students' ability to visualize complex and/or dynamic phenomena such as cell division or mathematical surfaces, to helping them visualize the structure of ideas and information (e.g., the connections that exist in a web of information), to allowing them to hear sounds which are represented graphically. Lastly, we aim to encourage exploration of an information-rich environment so that students may discover ideas, themes and facts on their own.

### Literature

The material created for *A Survey of English Literature* provides students with a great deal of factual information about the historical and political context of the literary works read in the class as well as biographical information about the authors. In past years, some of this information was provided by lectures, but much of it was not covered at all. The software tools provide easy, fast access to the factual information created by the professor and research assistants. Even though all the information could be found in books, it would be too time consuming to require freshmen and sophomores to conduct full library searches for an introductory survey course. The aim is to provide students with more background information than they had in the past, but not to increase their workload substantially or subtract from the time they have for assigned reading. For example, the first time a student is searching for background information on Alexander Pope, he or she may be interested in Pope's life and the political events that prompted his satiric criticism. To pursue this line of thought, the student might retrieve a biography of Pope and a timeline summarizing the political events taking place in England during Pope's life. Later in the semester the student may want to compare Pope's use of satire with other later authors' satiric techniques. This time the student may look at the same information about Pope, but juxtapose it with information about other satirists instead of a historical timeline.

Moving material that was previously presented in lecture to the computer frees class time for discussion. A primary aim of using computer-based material in A Survey of English Literature is to provide a mechanism for students to *discover* for themselves the main theme of the course—that no literary work can ever be explained by a single fact or event; all works have been influenced by multiple events, people and circumstances.

### Plant Cell Biology

In the Plant Cell Biology course, the primary aim of the computer is to help students visualize cells and their activities in three dimensions. According to Professor Peter Heywood, the course instructor, only a few particularly visual students can look at two-dimensional pictures of cells (electronmicrographs) and piece together the three-dimensional whole. The laboratory equipment necessary to examine actual cells is difficult to use and prohibitively expensive; therefore, our aim is to build computer-based tools that allow students to manipulate and explore cells and their structures in three dimensions without requiring the costly laboratory equipment. Since most cells are still represented by two-dimensional electronmicrographs in the literature, students must also learn to understand these pictures. Another aim, then, is to enhance students' understanding of the electronmicrographs by directly relating the two-dimensional pictures to three-dimensional representations of the same cells and illustrating how the two-dimensional cross-section fits into the three-dimensional reality. These tools will be used both in class as lecture aids and out of class as the basis for homework assignments and term papers.

### Educational Aims

To meet the general and specific educational aims detailed above, we are developing a software framework based on the concept of *hypermedia*, an extension of hypertext that includes multi-media materials. This framework, called Intermedia, is designed to contain application programs or "editors." For example, the courses will make use of a text editor, a two-dimensional graphics editor, a three-dimensional graphics editor and a timeline editor. The editors are used to create factual material (e.g., essays, timelines, illustrations, three-dimensional models) and to display the information.

Material created with any of the editors can be "linked" or connected together, which enables instructors to create a rich, multi-media, exploratory environment. When creating the information web, the instructor can attach *keywords* to blocks of information and to links. These keywords can then be used by students as the basis for searching the web. They could, for example, search for all information that contained the keywords "Satire" and "Political."

In addition to a variety of editors, the Intermedia framework provides *maps* which are used to graphically

## Interactive Science Videodiscs

illustrate the connections between linked blocks of information. These maps help people exploring a web to know where they are, remember what they have already seen and find new material to explore.

By marrying database technology with powerful, interactive editors, the Intermedia systems allow instructors to create exploratory environments that make browsing and discovery fast and easy. The editors allow material to be created with efficient tools and presented in a graphically pleasing manner, while the database functions allow material created with these editors to be searched quickly and efficiently. Software developers at IRIS have designed the Intermedia framework in a way that will allow new editors and applications to be added as the need arises. Future plans include the development of a music editor, an animation editor, a graph editor, a math editor, and applications to access interactive videodiscs and compact "ROM" discs which can store thousands of pages of text and pictures.

### Measuring Success

To measure the success of the demonstration project and to determine whether our hypotheses are valid, a team of social scientists is conducting an extensive assessment of the project. The assessment team will observe each of the two courses before and after the introduction of the Intermedia software. From the assessment, we hope to learn whether or not students and faculty were able to handle large bodies of material in electronic form, whether the students' educational experiences were enriched, whether students took full advantage of the communication and other tools, and whether there were any negative effects of the technology on students or faculty. We also hope to collect much more data about current teaching methods within the university in order to understand the ways in which technology might improve scholarship, teaching and learning.

Andries van Dam, *Professor, Department of Computer Science*

Nicole Yankelovich, *Project Coordinator, IRIS, Brown University*

College is expensive; the higher the quality the more expensive the education. When specific feedback is to be tailored to a student's responses, costs soar. Research points to greater learning gains for those who receive well-designed, individualized feedback for their responses. Suggestions abound on how to use technological media to provide instruction. With the exception of teacher-intensive activities, such as individual tutorials or small group discussions, most instruction does not provide individualized feedback. The most notable exceptions are programmed learning texts with branching, or computer-assisted, learning programs.

Much has been written about computer-assisted instruction (CAI). Results have been largely positive but both expensive and slow in coming. A tremendous amount of computer programming energy in CAI goes into the development of appropriate graphics for a lesson. CAI has provided no opportunity for both picture and sound.

The videodisc is the most powerful graphics enhancement available for CAI lesson designers today. About 5 billion bits of information may be stored on the surface—which translates into 54,000 individual color pictures, 30 minutes of television, or a combination of the two.

A series of technical advantages associated with replicating large numbers of discs, with replaying discs, and with longevity of discs favor that medium over videotape. Videodiscs are reproduced by a "stamping" procedure; in videotape, the entire tape must be passed over a recording head. Capturing individual images from a videotape for replay is a troublesome task. Modern videodisc players can scan through 54,000 frames to select a given individual frame in five seconds or less. Finally, videodiscs do not wear out during play.

The principal disadvantage of the videodisc is its current inability to re-record or to edit program matter. Once the disc has been mastered, video/audio information cannot be changed. However, the computer control program, as well as supportive print materials, are readily changeable.

### Overlaying Images

The most exciting potential of using videographics for instructional purposes is that of overlaying images (usually characters) generated by a computer atop the video images. This allows the disc to serve as a database for measurements in addition to other more traditional uses. Technically speaking, mixing these two signal sources to achieve an overlay is no trivial task. "Overlay boards" add significantly to the cost of a complete videodisc replay system (about $1,000 to $1,800). From the perspective of instructional design, however, this powerful tool allows an extraordinary range of videographic combinations through which a machine may respond to a given student input.

There is a balance between advantage and disadvantage to the videodisc. Were all factors equal, including availability of replay equipment, there is no doubt that videodisc would be the medium of choice for television replay.

Conceptually, the choice of videodisc as a graphics medium is a clear one. To test this notion using real instruction required considerable courage, however, as do most ventures into new instructional media. During the 1981 to 1984 period, The Annenberg/CPB Project provided funding to the University of Nebraska and its broadcast station KUON-TV to produce six introductory college-level science lessons.

### Biology

The lessons developed at Nebraska were designed to explore the videodisc medium and provide technology-based alternatives to traditional laboratory activities. In biology, Dr. William H. Leonard developed one lesson on respiration and another on biomes. The respiration lesson mimicked a traditional biology laboratory experiment used widely in hands-on laboratory teaching programs. The biome lesson broke new ground; similar materials were not normally a part of traditional programs because the worldwide database is not otherwise accessible to students.

### Physics

In physics, Dr. Robert G. Fuller produced lessons on motion and on energy transformation. The motion lesson related laws of motion to dancers, gymnasts, and divers. The energy transformation lesson related to using bicycles. In these lessons, the disc was used as a database. Placement of a flashing pointer on the screen (the computer cursor) over the videodisc-generated image led to a measurement, one that would not be possible in the laboratory.

### Chemistry

Two chemistry lessons produced by Dr. David W. Brooks sought to use videodisc graphics as graphics alternatives. One involved mixing water solutions of chemicals, two at a time, from a group of six possible choices, and using the resulting visible reactions, if any, to deduce the nature of the solutions. The second involved a computer emulation of a routine classical laboratory process called titration.

### Evaluation

Systematic evaluations of these six introductory-level college laboratory lessons—each a national first—conducted by Dr. Barbara Gross Davis of

Berkeley in a wide variety of college settings found all lessons effective. A detailed evaluation report is available from The Annenberg/CPB Project.

The disc lesson based on reactions of water solutions has since been revised for use in the permanent chemistry exhibit in the Museum of Science and Industry in Chicago, and for a special U.S. Agency for International Development trial project in technology applications to teaching in Indonesia. Currently, adaptations of four of the six original lessons are being developed for use by secondary science teachers.

The six pilot lessons have provided a wealth of information about lesson design and use. There are substantial reasons to believe that this foray into the world of technology will provide an important alternative for teaching, especially where the hands-on aspects of developing techniques are not as vital as the enhancement of decision-making skills.

Critics of media lessons point out that a student cannot try a special experiment, such as heating a solution, shown on the screen in a fashion that was not intended or anticipated by the lesson planners. In reply, it should be pointed out that well-trained teaching assistants usually deal harshly with students who heat solutions they are not specifically asked to heat.

The lessons we developed were firsts in biology, chemistry, and physics. No discipline-specific factors emerged–the strategies used in a lesson in one discipline might well be used appropriately in simulations of other classical lessons in the other disciplines. The nature of the lesson rather than the discipline dictates the lesson design.

Conventional college laboratory programs, it should be noted, stress the development of pencil and paper skills, and rarely ask that a student be involved in practical situations. Practical exams in labs are atypical activities. So long as book skills rather than hands-on skills remain a major portion of the laboratory evaluation, excellent performances of students trained using CAI-videodisc, as compared to performances of students receiving hands-on training, should be expected.

Furthermore, the total cost of the technology-based training will be substantially lower, especially when account is taken in student scheduling for the shorter time spent at the computer to achieve an equivalent learning gain. For example, at our University, three-hour-long laboratory classes are limited to 24 students each and we can only schedule eight classes per week even when nighttime hours are used. Since a student can complete a lab simulation of a traditional lab activity in less than half of the time required for a hands-on lab (and achieve the same or greater skill level as determined by a conventional laboratory exam), one videodisc/computer replay can serve one full 24-student section in a week. If the replay unit costs $7,000 (to pick a high figure), and each lesson package costs $500, a 30-week course for one section would have a set-up cost of $22,000. Hardware maintenance has proven inexpensive; software maintenance is minimal–both amounting to no more than $3,000 in five years.

At a typical private school this course would generate $12,000 in annual tuition (two credit hours at $300 each.) Two years of tuition income would pay for the hardware and software. There would be personnel costs, say $3,500 per year for a teaching assistant to supervise students as they worked at the terminals. By the third year, expenses would decline. When the costs of constructing and maintaining laboratories (very expensive relative to traditional classroom spaces on a square foot basis), chemicals, etc., are considered, the technology-based instruction wins on all counts.

There are other potential uses for the materials. Prelaboratory instruction is commonplace, and the use of computers is emerging as an important tool in this area. The interactive videodisc is an excellent, inexpensive tool.

The unique single use of these materials is for distance learning. Heretofore, science courses have been offered infrequently to distance learners because there has been no way to provide a hands-on experience. Now, an attractive alternative to laboratory training is available.

What next? The six pilot lessons are being marketed through the

Great Plains National Instructional Television Library in Lincoln, Nebraska. However, until a complete course is assembled and tested, with students learning via videodisc compared with a traditional laboratory by independent evaluators, the future of the videodisc remains uncertain. Since development costs are high, the risk is significant. Videodisc development requires the availability of a complete course making use of the technological advantages of the medium; but lack of a widespread, established audience precludes development of a course.

College faculty have long been reluctant to embrace any instructional methodology other than lecturing to small groups. On the other hand, college presidents faced with demands for new buildings, soaring laboratory budgets and the like might well demand an alternative that substitutes simulation for half of the hands-on experience.

Jack G. McBride, *General Manager, KUON-TV*

David W. Brooks, *Professor, Teachers College, University of Nebraska-Lincoln*

No academic subject seems to inspire more dread in the heart of the average college student than the study of physics. Yet the importance of that subject is beyond dispute. As a purely practical matter, the ability of the United States to compete in world markets, and the ability of American graduates to compete in domestic job markets, is widely perceived to depend on mastery of subjects that only begin with the study of physics.

This fear of physics does not arise out of a lack of zeal on the part of physics professors who, as a group, share a deep love of their subject and no small measure of enthusiasm to communicate it. Nevertheless, it is a sad but indisputable fact that for a majority of Americans, including students and those with college credentials, physics remains an impenetrable mystery. THE MECHANICAL UNIVERSE AND BEYOND is Caltech's attempt to grapple with this problem.

THE MECHANICAL UNIVERSE AND BEYOND is, by any standard, an extraordinary experiment in higher education. It is a rigorous, mathematically sophisticated college course in physics, done with all the technique and dazzle of network quality television, together with textbooks (published by Cambridge University Press), teachers' manuals, a separate and complementary version for use in high school classrooms, and much more.

Caltech's dedication to the teaching of physics began fifty years ago with a popular introductory textbook written by Robert Millikan, Earnest Watson and Duane Roller. Millikan was Caltech's founder, president, first Nobel prizewinner, and all-around patron saint. Earnest Watson was dean of the faculty, and both he and Duane Roller were distinguished teachers.

### Transition

The teaching of physics at Caltech, like the teaching of science courses everywhere, is constantly undergoing transition. Caltech's latest effort to infuse new life in freshman physics was assigned to me around 1980, and eventually led to the creation of THE MECHANICAL UNIVERSE AND BEYOND. Word reached the cloistered Pasadena campus that a fundamental tool of scientific research, the cathode-ray tube, had been adapted to new purposes, and in fact could be found in many private homes. Could it be that a large public might be introduced to the joys of physics by the flickering tube that sells us spray deodorants and light beer?

About the time when the idea of using television to teach physics started to take on serious proportions in Pasadena, the Annenberg gift was announced.

The ultimate outcome of this happy concurrence of events is a series of 52 half-hour television programs, plus the other materials mentioned above, at a cost of nearly $6 million (the high school version, separately financed by the National Science Foundation, cost an additional $2.5 million).

The genesis of THE MECHANICAL UNIVERSE AND BEYOND (BEYOND refers to the second semester of the course, beyond mechanics) explains why it is not a course prepared by a committee. Although a very large number of people have made indispensable contributions to the project, and although it takes every possible advantage of the opportunities offered by the television medium, it is nevertheless firmly rooted in the Caltech course I taught, in style, emphasis, choice of subject matter and many other ways.

The series covers the standard subjects of introductory physics: mechanics, electricity and magnetism, relativity, thermodynamics and modern physics. Students are assumed to have studied algebra and trigonometry previously, and to be prepared to use them in the study of physics. We do not assume that they are familiar with differential and integral calculus, but we do believe that physics cannot seriously be studied without these techniques. We therefore teach them as part of the science of mechanics, which is indeed how they were discovered originally.

## Calculus Included

From a purely educational point of view, the introduction of calculus as a part of physics in a course at this level is surely the most important innovation in THE MECHANICAL UNIVERSE. Under the guidance of Caltech mathematics professor Tom Apostol (well known for his highly regarded calculus textbooks), the calculus is handled in an intuitive way, designed to make its use seem a simple, easily learned procedure, but without losing sight of its remarkable power. Early returns indicate that the calculus has not turned out to be an important difficulty for students. However, many students are held back because they never sufficiently mastered the trigonometric functions in high school. We have now published a special primer to help in overcoming this difficulty.

If the choice of mathematical level is the most important curricular innovation in THE MECHANICAL UNIVERSE, use of computer animation is the jewel in the crown of teaching techniques offered by the series. Dr. James Blinn, who teaches at Caltech and toils in the Computer Graphics Laboratory of Caltech's Jet Propulsion Laboratory (JPL) is the superstar of the computer graphics field, and THE MECHANICAL UNIVERSE is his magnum opus. Just to take one example, the theory of relativity, the basic physics dilemma, and its resolution in a merging of the concepts of time and space are made comprehensible in ways that cannot be imagined in any book or ordinary classroom.

The approach to physics in the series is firmly rooted in the history of physics. This provides a number of advantages. A subject such as classical mechanics can be made fresh and invigorating by seeing it through the eyes of those who had to discover it in order to discover our place in the universe. Another reason is that not all students are in love with physics, but all people are interested in people. The story of physics as a human enterprise is a common denominator reaching all viewers at the same level.

Each program opens and closes with me lecturing to a simulated Caltech class. When the decision to use that format was made, *Paper Chase* was a popular television series, and college classrooms were *In*. Between the lecture hall bookends (which supposedly suggest that the entire production is a kind of expanded or enhanced college lecture), each program goes into its main sequence, featuring animation, location footage, historical re-creations, live physics demonstrations, pages of rare and original manuscripts, and so on. The historical re-creations are not of specific events, but generic scenes, such as young Newton strolling in an apple orchard. We are not so pretentious as to believe we could recreate the moment of any discovery, nor do we wish to trivialize great scientific works into mere flashes of insight conveniently visible to the camera.

The textbooks for THE MECHANICAL UNIVERSE were written by Dr. Richard Olenick of the University of Dallas, together with Tom Apostol and me. Caltech's Professor Steven Frautschi and other authors have also written an advanced edition designed for use by students of engineering and physical sciences, and used at Caltech. The primary telecourse version has one chapter for each television program, while the advanced edition is organized somewhat differently and contains additional subjects, such as rigid body rotations.

### Evaluation

How well does all this work? To find out whether it is effective education, we sponsored extensive formal evaluation of various components as they were being prepared, and attempts have also been made to investigate experiences in those institutions that used the first semester of the course in the fall of 1985. Briefly, it appears to do exceedingly well when there are serious, well-motivated students and teachers, and it also appeals to general, non-student audiences. However, it does much less well with traditional telecourse students.

To be sure, there is a legitimate—perhaps even a very important—role for telecourses to play in American higher education. The population contains a vast reservoir of people who, for one reason or another, are or were unable to attend college in the conventional way, and who are genuinely eager for the chance to learn. This rich pool of potential talent should not be ignored by a nation whose greatest strength has always been the ingenuity of its people. It also should not be ignored by colleges and physics departments faced with the problems of anemic enrollments. The intent and hope of THE MECHANICAL UNIVERSE is to serve that need, not merely with adequate education, but with the very best that can be created.

However, experiences with the use of THE MECHANICAL UNIVERSE as a self-standing telecourse are decidedly mixed. One campus angrily reports that it is dropping all future plans to use it because they found that students actually needed help—as much as an hour and a half each week—in order to master the material. Others have not yet given up, but they are clearly jolted by the difficulty of THE MECHANICAL UNIVERSE compared to previous telecourses. On the other hand, telecourse administrators on a number of campuses report that for the first time they are basking in the warm glow of congratulations from their academic colleagues on the quality of a course they are offering, and that enrollments are beyond expectation and growing.

Two principal factors seem to govern whether THE MECHANICAL UNIVERSE succeeds as a telecourse at any given institution. One is how it is advertised—whether students are clearly told what they are getting into. Truth in labeling does tend to lose some students, but it also picks up others who would not otherwise be interested. The other factor is the infrastructure that is set up to aid the student. When possible, on-campus, in-person recitation (and laboratory) classes are probably the most helpful, but often defeat the very purpose of a telecourse. Depending on local circumstances, limited on-campus meetings, mail, telephone, and even radio and cable television are being used. The bottom line is that THE MECHANICAL UNIVERSE can succeed as a telecourse, but only where a resourceful telecourse administrator works in full cooperation with a committed physics professor.

Those who have tried using THE MECHANICAL UNIVERSE on campus have been unanimous and enthusiastic in their support. For example, one professor, using the videotapes in class for a course taken by pre-med and pre-professional students, says they are delighted to find that the most dreaded course of their college careers has turned out to be unexpectedly pleasant. The mode of use varies widely with the taste of the instructor. Some use segments, usually of computer animation, in class; others place tapes on reserve at the library; still others report success with showing entire programs in class, using the remainder of the period to discuss, expand, illuminate or refute what has been seen.

Remarkably, wherever the series has been broadcast, there has been much acclaim from viewers. A recent editorial about the series in *The Los Angeles Times* said ". . .if differential calculus is not television's Supreme Test, it would certainly make the semifinals in any competition." Nevertheless, there is no mistaking the genuine pleasure and enthusiasm in the responses of viewers of all ages and backgrounds. I take the meaning of this reaction to be that our programs do succeed, at the very least, in being physics lessons that do not produce hostility toward the subject in students. The *Times* editorial took a more sanguine view. Called "More Than a Promise," its thesis was that THE MECHANICAL UNIVERSE has finally fulfilled the educational promise that has always been inherent in television.

I hope they were right.

David L. Goodstein
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Telecourses have met with considerable success in targeted areas of the country; but for many institutions, such distance learning courses remain an uncertain enterprise. Because little is known about telecourses beyond these pioneering areas, an important part of The Annenberg/CPB Project is to study their impact and share the findings with the educational community. Since this is a new educational enterprise, skepticism and misconceptions abound.

The 1984 premiere offerings of The Annenberg/CPB Project telecourses provided an opportunity to determine how students actually used and assessed the courses. Course use was examined in th. . ways: focus group sessions, study logs ma. ı-tained by students, and a telephone survey of those who dropped the courses. A total of 200 students in 26 institutions participated in focus group sessions at the midpoint and/or end of the semester. An additional 100 dropout students were surveyed.

The courses evaluated in the study were: BRAIN, MIND AND BEHAVIOR; THE CONSTITUTION: THAT DELICATE BALANCE; THE WRITE COURSE; THE NEW LITERACY; and CONGRESS: WE THE PEOPLE. It is hoped that the findings of the study will prove useful to institutions in structuring telecourse offerings, to course developers in generating materials that meet student expectations, and to The Annenberg/CPB Project.

Many educators who consider telecourse learning assume these learners are isolated from all campus experience, unfamiliar with on-campus courses, or in need of materials that would require less rigorous study than on-campus courses.

Our research showed these perceptions to be wrong. Annenberg/CPB telecourse students often are enrolled concurrently in on-campus courses, and most have had prior on-campus experience. While many students live within a half-hour of the campus, most take telecourses to minimize commuting. This, however, was found to be due more to scheduling conflicts than to inaccessibility to the campus.

The aspirations of teleco urse students suggest a high level of motivation. Almost half of the students hoped to achieve a master's or doctoral degree, while more than a third hoped to complete a bachelor's degree. Only 11% aimed only for the associate degree, and only 6% had no college degree planned.

Although some educators encourage the development of introductory level telecourses, students were pleased that their Annenberg/CPB telecourse provided credits at the intermediate and not just the introductory level. One-third were enrolled in an Annenberg/CPB course in their academic major.

### Comparisons

While educators are particularly concerned that telecourse learning will prove less rigorous and represent lower standards than the traditional courses, when specific comparisons were made between on-campus courses and these telecourses, the Annenberg/CPB telecourses were perceived to be as difficult, interesting, and challenging as on-campus courses. Grades for these courses were comparable to those obtained for on-campus courses students had taken. This finding held true for students in both two- and four-year institutions.

Contrary to perceptions, telecourse students were surprised to find that they had to study as hard for a telecourse as for an on-campus equivalent. Across all five Annenberg/CPB telecourses, the materials were seen to be slightly more difficult than those used in other telecourses. Students also rated the textbook linked to the Annenberg/CPB course as slightly more difficult than those used in on-campus courses. Commitment and motivation to stick with a more challenging educational experience may prove to be a key factor which differentiates dropout students from those who complete courses.

### Institutional Role

Educators understandably worry about loss of control over the learning process when students become "distant" learners. Students, they fear, will have no contact with instructors. In reality, although telecourse students must work with much of the material without benefit of formal classes, they actually maintained contact with the institution throughout the course experience.

While some were satisfied with limited on-campus experiences, a number of Annenberg/CPB telecourse students wanted more optional on-campus class meetings. In fact, a key ingredient for a successful telecourse was an instructor accessible to students either by telephone or during office hours. This finding counteracts the misconception that a telecourse eliminates the need for an instructor.

Although telecourse students face many of the same challenges as in on-campus classes, there are important differences. For example, materials must be designed to guide the students who cannot rely on weekly classes and explanations by instructors. Some difficulties naturally arose in scheduling time to view the courses and to study since many students carry heavy job and family responsibilities. Institutions therefore need to cooperate by scheduling repeat broadcasts of the telecourse and by making backup tapes available for missed programs.

For those educators who were concerned that these courses involve less work than on-campus courses, students reported spending a comparable amount of time studying for telecourses as for on-campus courses. On the average, students studied three and a half hours a week in addition to television viewing.

### Course Design

Telecourses have followed an educational mandate to develop programming in the half-hour format in order to parallel the on-campus class experience of multiple lectures held within one week. Our data suggest that students prefer to watch programs in pairs, or one-hour sessions, as opposed to the more traditional telecourses with two separate 30-minute programs in a single week. Since many students tape programs for viewing at their own convenience and PBS program schedules dictate airing half-hour programs back-to-back, the half-hour format could well give way to one-hour programming.

Although reading the print materials prior to viewing the programs was often recommended, students used the materials in a variety of ways. Some students found they learned more by reading after viewing. The variety in study habits underscores the importance of developing flexible materials that contribute to learning independent of sequence.

Of central concern to educators is the presence of television as part of the instructional package. Some educators question the ability of television to provide the student with substantive opportunities for learning. The findings suggest that the television experience doesn't replace the reading of the textbook but rather enhances reading. When students were asked which components of the telecourse were of the greatest importance in learning, the textbook was selected most often with television programs a close second. Many students stated that the television programs in these Annenberg/CPB courses were of high production quality.

Students also expressed satisfaction with study guides that state learning objectives and offer chapter summaries, program synopses, glossaries, and accurate self-tests that permit students to judge their capacity to grasp the material.

### Conclusions

When asked about their reaction, students indicated that they were somewhat to very satisfied with the Annenberg/CPB telecourse. Those with prior telecourse experience reported the highest level of satisfaction.

Eight out of ten students said that they would recommend the course to a friend, and nine out of ten would take another telecourse. Interest in telecourses was even higher among students at four-year colleges than those at two-year institutions.

The Students Uses Study represents the first in a series of studies planned by The Annenberg/CPB Project, in the hope that the research will describe actual use and effectiveness and, as necessary, counteract existing misconceptions. Student satisfaction will be of central concern. These highly motivated adult learners must ultimately determine whether they are getting full value with their hard-earned money.

Valerie Crane, *President*
*Research Communications Ltd.*

After years of extravagant predictions of a revolution in higher education, the academic community has been understandably ambivalent about embracing the telecommunications and electronic information technologies for teaching and learning. Gradually, however, Americans have become accustomed to households dominated by electronics. Tape decks, videocassette recorders and computers have personalized access to information at home and on the campuses.

The challenge is to imagine how the new instruments can be used effectively to enhance teaching and learning. Our approach to the subject is understandably influenced by our work with The Annenberg/CPB Project, created in 1981 by a gift of $150 million from The Annenberg School of Communications to the Corporation for Public Broadcasting to develop college-level instructional materials and to demonstrate the power of technologies in the service of higher education. Since 1982 the Project has funded over fifty such efforts, all of which are concerned with enhancing the quality of higher education and/or increasing a learner's access to that education. Thus, for us, *access* and *quality* provide a useful framework for sorting through the various endeavors that have been funded by the Project and by many others concerned with education and the telecommunication technologies.

Traditional higher education has tended to follow three teaching models: (a) lectures, (b) seminars, (c) one-on-one tutorials. "Telelearning" has tended to follow the same models of one-to-many, few-to-few, and one-to-one communication between instructor and students.

**Improving Access**

Many efforts are underway to expand access to higher education opportunities. One relatively simple way to reach students has been through courses with strong television components that could fit into a working person's schedule. Ninety-nine percent of all U.S. homes have a television set, and more than 70% have two or more sets. The videocassette recorder has given the student even greater control. By 1985, 40% of all students enrolled in telecourses reported having a videocassette recorder in their homes. This allows students simply to record video lessons as they are broadcast and to replay them at convenient times–in a one-way instruction comparable to the lecture.

Broadcast instruction is limited by the finite amount of air time and the station's need to attract enough viewers. The National Narrowcast Service (NNS) of PBS has been developed to provide an alternative delivery system for programming likely to have a limited audience. Using a combination of satellite and microwave technology, NNS will offer a regular schedule of college courses and training programs to worksites, college campuses and community centers nationwide. Its pilot phase began in February 1986, with twenty-one cities participating. Employers cooperate in a variety of ways, from tuition assistance for college courses to establishing convenient study centers and permitting released time for study.

An alternative approach is to free the materials from broadcast, providing lessons directly through tapes. Some colleges make cassettes available in libraries or learning resource centers. For example, the Northern Illinois Resource Cooperative (NILRC) offers cassettes on overnight loan. In Pennsylvania, video lessons of the course, THE CONSTITUTION: THAT DELICATE BALANCE, are available through local public libraries, providing electronic resources as flexible for the student as books.

These efforts assume that a local college offers the course for credit, assigns its own faculty, and provides support services for students. The National Technological University, which provides master's degrees in engineering, has gone a step further. Courses taught by faculty from institutions around the country are delivered via satellite to sites at participating work places. Students receive credits, and ultimately the degree, from NTU itself. This new approach, which challenges the traditional notion of the university as an entity fixed in time and space, is being closely monitored by regional accrediting agencies and higher education faculty.

New technologies, and particularly computer-centered networks, can help to overcome the electronically-taught student's isolation. The University of South Florida has added an interactive component to a television-based course to alleviate "the loneliness of the long distance learner." The university provides students with inexpensive computers, telephone modems and an electronic mail system. The faculty member prepares course notes and a quiz for each lesson as a supplement to the video program. Thus the teacher updates the course each semester, tailoring it to his or her own approach and communicating regularly with students. This model combines the lecture with interaction comparable to the one-on-one tutorial.

Not all distance learning involves video courses. A very different model, emphasizing voice and computer communication between faculty and students, was recently tested by the Institute for Public Administration in conjunction with the faculty of the Harvard University Extension School.

It uses a new modem which permits simultaneous transmission of both voice and data over one telephone line. The instructor is connected with from one to fifty-nine students and can speak to them, display graphics, "write" on their computer screens, and "point" to items on the students' screens. Students can also talk with each other and transmit information to each others' screens, much like in a seminar discussion with graphics.

Improving access to higher education need not be confined to delivering instruction to the home or worksite. It can also create more flexible learning opportunities on campus. For example, videodiscs driven by computer can simulate laboratory experiments which students can actually manipulate, allowing them to do laboratory work at times when the labs are closed. The University of Nebraska recently developed prototype discs–two in biology, two in chemistry and two in physics. Tests at seven colleges and universities showed that students learned as much in less time as from traditional laboratory experiments.

## Improving Quality

Access is only part of the technology's promise; equally exciting is the prospect of improved quality. Collaboration is a key factor. Virtually all technology-based projects require faculty from a variety of disciplines and experts in design and program production to work together to create new materials. Sharing of knowledge and skills encourages fresh thinking about both the subject matter and how it can best be taught.

In addition, the technologies can give students access to richer resources. Undergraduates may be able to tackle problems and concepts previously reserved for graduate students. The technologies may also help students to see ideas differently. Some students, for example, find it difficult to visualize abstract mathematical or scientific concepts on the printed page. Computer simulations or video representations can let the student "see" the concept from different perspectives, making ideas more comprehensible. Stanford University has developed, for instance, computer-based laboratory simulations for introductory physics that would enable a student to manipulate various data under different conditions and see the implications. In one exercise students are given tools to explore the effect of gravity on a projectile, allowing them to manipulate variables such as the force or the angle of projection.

The computer's capacity for serving with intelligence is magnified when coupled with videodisc. It is particularly helpful in subjects where one-on-one interaction and mastery learning are critical. MIT is developing a new generation of language laboratory materials that use these technologies in the development of exercises emphasizing discourse as a key to language skills. They combine text-based instruction with video and audiodisc exercises to improve both comprehension and pronunciation.

Multi-purpose tools, that can be used in a variety of courses and tailored to the specific needs of faculty and students, are also being created. For example, Dartmouth College has developed a database manager called "Atlas," conceived originally as a new kind of historical atlas. The prototype contains mapped geographic and historical information about an area, such as rivers, cities, paths of armies, and trade routes. The user can assemble and print maps composed from any mix of data, "zoom in" on more detailed views, or ask for a quiz about the map.

What makes "Atlas" so intriguing is that it is also being applied to a biology course, where students create their own "maps" of the sequences of reactions in a metabolic process. Creating a map of independent ideas is at the heart of scholarship and learning. "Atlas" allows the creation of a picture of the pattern of ideas.

The Intermedia family of tools being developed at Brown University goes still further, allowing the user to link the texts themselves, as well as graphics, videodisc images, and elements of computer programs. Intermedia will be a family of productivity tools for professional learners, including a word processor, a graphics package, a videodisc manager, and a timeline editor which allows events to be ordered and graphically displayed. These tools will run on advanced computer workstations with large screens, each networked to large databases and other computers. Intermedia will allow the user to connect any bit of information with any other in the system or to connect directly with other learners (including the faculty member). With a simple move of the mouse control device, the student can view other relevant text or images, add new information, annotate the linkages and get a graphic overview of the information terrain. Alternatively, a student could request help from another student, a teaching assistant, or the course instructor.

As faculty experiment with discrete modules, multi-purpose tools and new ways of reaching both scholarly resources and students, some are testing the possibilities the technologies hold for thinking differently about an entire field or discipline. The University of Maryland, for example, where the physics department is redesigning the introductory physics courses, does not simply want to help students learn more, but rather to help them to learn differently by rethinking what could or should be learned more effectively.

### The Challenges

Telecommunication and information technologies have the potential to open up a wealth of intellectual resources–provided a number of obstacles can be overcome.

As new materials and new ways of presenting them are being developed, they are still too often in isolation from each other. Their diffusion occurs slowly or not at all. Faculty and administrators could benefit greatly from updated overviews of what is happening in their fields in particular and in higher education in general. Efficient ways must be found to pass along to others both the latest learning materials and the teaching ideas that give them power.

These changes obviously make new demands on learners. Students must be taught to function independently. It is too easy to say, "Here, work on your own and integrate the materials at hand." The task is to prepare students for the new challenges and opportunities.

Finally, faculty must be helped to approach these resources with flexibility and with the optimism of open minds. Learning to master new resources and techniques will take their time and commitment. Their support will depend on the innovators' ability to show that the new tools can serve teachers and learners alike by opening up new avenues to both quality and access.*

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