

EVALUATING A REMOTE TEACHING ENVIRONMENT
FOR COMPUTER SCIENCE STUDENTS

by

KRISTIN JO BRUNO

B. A., CALIFORNIA STATE UNIVERSITY, LONG BEACH, 1970

M. S., KANSAS STATE UNIVERSITY, 1977

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MASTER OF SCIENCE

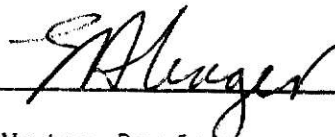
Department of Computer Science

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1980

Approved by:

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Evaluating a Remote Teaching Environment for Computer Science Students

Telecommunications and Remote Education

In recent years there has been an increase in the number of atypical students attending college classes. Many of these people have full time jobs and are interested in obtaining an undergraduate or advanced degree to further their careers. In response to this interest, many universities (such as Kansas State University) have tried to provide continuing education classes for these people at or near their work sites. In the past this type of distance education has required instructors to travel to the remote site to deliver the traditional face-to-face educational program.

However, with the recent advances in telecommunications technology and the increased expense of travel, universities are beginning to explore alternate methods of delivering educational programs to students at remote sites. In the past many one-way communication correspondence courses have been offered. These usually consisted of sending a student a packet of written materials or recorded information (on cassettes, videotape, radio, television, etc.) and allowing the student to pursue an individualized course of study. That is, students worked through the material (often at their own rates) with little or no face-to-face contact with the instructor (Holmberg, 1977). However, there has been

much criticism of these methods since the interpersonal relationship between teacher and student is lost in such a setting.

With the advent of two-way communications technology, some of this criticism has been mediated. At present the most common telecommunications systems are audio only, video only, audio and video, or, more recently, computer telecommunications (Johansen, Vallee, & Spangler, 1979). Some of these methods require participants at the two ends to be present at the same time as with the traditional face-to-face lecture (e.g., audio: using the telephone to conference). Others, most notably computer teleconferencing, do not require participants to be present at the same time. The computer handles the sending and receiving of messages at the convenience of the participant. This frees both the instructor and remote students to participate in the class at their own convenience and is a major advantage of this type of telecommunications system (see Hiltz & Turoff, 1978; Johansen, et al., 1979; and Johansen, McNulty, & McNeal, Note 1, for reviews of various systems).

Social/Psychological Implications of Telecommunications

It is widely acknowledged that technological changes advance faster than societal changes do. Unfortunately, technological advances are often implemented with little or no assessment of the social/psychological impact of these advances on the people who are affected by them.

Technological systems are often designed and implemented based on current hardware technology which has been carefully researched and tested. However, the impact of the system on human users is frequently based on the intuitions of the designer rather than on experimental testing (Brooks, 1977). Ideally, a system should be designed with current technology and literature on the human impact in mind. Human behavioral objectives for system performance should be constructed. Then, after implementation, the system should be experimentally tested against those behavioral objectives. Thus, a truly useful and usable system would not only encompass current computer technology, but would also draw on the behavioral sciences to ensure a smooth human-machine interface. Not only must current hardware technology be taken into account, but human learning strategies must also be considered (Baker, 1977). Thus, it would be highly profitable for all concerned if experts in all areas pooled their knowledge to develop advanced systems with favorable human impact.

Remote education delivery systems are one example of a technology that has developed faster than the experimental assessment of the social and psychological impact on instructors and students. This impact can be divided into at least two domains: affective and cognitive.

The affective domain includes such areas as the social/psychological impact on people of not being face-to-face in the learning situation. That is, what is the impact of not having mutual visual or auditory contact or both on the interpersonal relationship of

student-instructor and student-student? What is the effect of not communicating face-to-face on the group processes of question/answer and decision making, among others? Some attempts have been made to address such issues (notably Hiltz & Turoff, 1978; Johansen, et al., 1979; and Williams, 1977). In general, the consensus seems to be that, while different, various combinations of telecommunications media can compete favorably with traditional face-to-face instruction. Unfortunately, experimental manipulation of these social/psychological variables is difficult in a real-world setting. Thus, controlled experiments assessing the impact of these media in the affective domain are scarce, although some do exist. An excellent review of about 30 experimental studies comparing face-to-face and "mediated" communication can be found in Williams (1977). In addition, both Hiltz and Turoff (1978) and Johansen, et al. (1979) cite a few experimental and several descriptive studies of this problem.

On the other hand, although questions in the cognitive domain lend themselves very well to experimental control, studies on the cognitive effects of remote education through new telecommunications systems are also scarce. One exception to this is in the area of computer-assisted instruction (see, for example, McKeachie, 1974; and Wittrock & Lumsdaine, 1977, for reviews). The cognitive domain deals with the learning rather than the social aspects of the educational system. This can include issues such as how do people process and remember information best? Can a remote delivery system optimize human information processing

capabilities?

Although few studies have been conducted to assess these issues with recent telecommunications technology, a large body of experimental studies in laboratory settings have been conducted in cognitive psychology. The results of these studies can be applied to the new technology in remote education to both predict the optimal combination of variables as well as to experimentally assess the outcome of the implementation of such a system. Thus, the experimental study of the cognitive domain seems to be the most promising at present.

The purpose of this report is to provide an experimental background for a grant to propose the development of a new remote education delivery system at Kansas State University (Wallentine & Hankley, Note 2). The grant will include a literature review of both the current technology and the cognitive impact of such a system on students. Specific behavioral (educational) objectives are included to provide an objective assessment of the success of the system once it is operational. The next section will provide a review of the relevant literature in cognitive psychology followed by a section detailing the behavioral objectives to be used to assess the implemented system and a section on the methodology to carry out such an assessment. Finally, an annotated bibliography of the most relevant work in psychology will be presented followed by an unannotated bibliography of related work.

Relevant Literature from Cognitive Psychology

Most psychologists interested in human learning and memory agree that a strong paradigm shift has occurred in the area in the past 20 years. Previously, most work in psychology in America was dominated by the behaviorist school led by Watson and Skinner. This school viewed the organism (human or animal) as a passive entity, manipulated by the environment. Particular stimuli elicited responses and these responses were governed by their environmental consequences. Thus, the passive organism was controlled by environmental contingencies.

In recent years this stimulus-response view of psychology has been replaced by what is termed "cognitive" psychology. Instead of viewing the organism as a passive black box controlled by the environment, it is viewed as an active information processor acting on the environment. This has led to a large shift in the research undertaken in human learning and memory. Instead of only investigating observable stimuli and responses, researchers now manipulate stimuli, observe responses, and infer the cognitive processes used by people to make those responses. Thus, much information has been compiled about the structure and processes of human memory and problem solving and the learning strategies used by people to actively facilitate their comprehension and retention of incoming information. The study of these variables has been termed human information processing.

The premises of cognitive psychology or human

information processing has been adopted by educational psychologists as well. The view of the learner as an active information processor has substantially altered research in curriculum development and educational delivery systems. It is not enough to study the instructor and his/her presentation of information. Instead, the strategies and cognitive processes used by the learner must also be taken into account.

As will be evident in the subsequent review of the relevant literature in cognitive psychology, some general conclusions about the optimal presentation of information may be drawn. However, it will be equally evident that individuals vary widely in the specific ways that they process information. Thus, the thesis of this grant proposal is that from a psychological point of view, the best delivery system will provide a variety of presentation modes to the student. People process information visually, auditorily, and semantically. Thus, the greater the variety of modes of presentation, and the greater the redundancy of information across modes, the greater are the chances of maximizing all students' comprehension and retention of the material. This thesis will be substantiated by each area reviewed.

Coding in human memory. Most researchers studying human memory agree that several different memory stores exist. For educational purposes, long-term memory is probably the store of most interest. It is generally thought that long-term memory has infinite capacity and

information can be held an infinite amount of time. It is also generally acknowledged that information in long-term memory is primarily semantic in nature. That is, when information is stored in long-term memory it is coded and organized by meaning. Many studies of errors in recalling words show that the errors tend to be semantically similar to the original word (e.g., Anisfeld & Knapp, 1968; Baddeley, 1966; Grossman & Eagle, 1970; and Kintsch & Bushke, 1969).

However, recent experiments (e.g., Brown & McNeill, 1966; and Nelson & Rothbart, 1972) have shown that acoustic information is also stored in long-term memory. For example, Brown and McNeill (1966), studying the tip-of-the-tongue phenomenon, found that people who cannot remember a word can identify some of its characteristics. In addition to such things as the number of syllables and some semantic information, they often know the initial sound and other acoustic information.

Finally, it has been shown by a number of studies (especially by Paivio; see the section on imagery) that people store visual information in long-term memory (e.g., Shepard, 1967). Although it is not clear whether the actual code is verbal or pictorial in nature, there is no doubt that both verbal and nonverbal information is stored in long-term memory.

Based on the evidence that multiple codes exist in long-term memory, it is clear that the more varied the modes of presentation are in the classroom, the greater the probability will be that the learner will encode and store

the information in long-term memory. Language and speech have been shown to be highly redundant to enable the reader/hearer to comprehend the input despite noise, production errors, and periods of inattention. It follows, then, that redundancy in presentation mode (i.e. presenting the same material in written, auditory, and visual forms) will also aid in comprehension and retention. This multiple presentation mode hypothesis is the major thesis of the present grant proposal. That is, since remote students do not have the interpersonal interaction with the teacher and other students as in a traditional classroom, maximizing the variety of presentation modes available seems desirable.

Imagery in human memory. Memory research has clearly shown that people have visual representations of information in long-term memory. For example, Shepard (1967) found that subjects who were shown 612 colored pictures could later recognize them with 97% accuracy. Standing, Conezio, and Haber (1970) showed subjects slides of scenes for ten seconds each. On a later recognition test of some of the 2,560 slides, the subjects' mean accuracy rate was 90%. Since verbal recognition rates are considerably lower (e.g., Shepard, 1967, found mean verbal recognition rates of about 88%), it is clear that subjects must have visual information available to them. A number of other studies provide supporting results (e.g., Frost, 1972; and Shepard & Chipman, 1970). In addition, when people are asked questions such as "How many windows are in your kitchen?", they construct an image of the room and count the windows

(Shepard, 1966).

These results have led some researchers to believe that people not only have both verbal and imaginal representations in memory, but that these representations are actually two separate memory systems. This idea is called the dual-coding hypothesis (Paivio, 1969; 1971). Although the two systems contain either verbal or nonverbal information, they are connected and can interact, providing both an image and a verbal label for a concept. Some concepts may be better represented in one system than the other. For example, abstract concepts such as "justice" can probably be better represented by the verbal system while concrete concepts such as "house" may be better handled by the imaginal system.

Thus, it has been hypothesized that information that can be stored in both systems should be remembered better than information stored in only one. This is because there is twice as much information about a dual-coded concept and it can be accessed by two retrieval processes. By this logic, concrete words should be better remembered than abstract ones. In fact, this prediction has been supported by a number of studies (e.g., Herman, Broussard, & Todd, 1951; Paivio, 1965; Paivio & Csapo, 1969; see the review by Paivio, 1971).

Several researchers have argued against a strict imagery theory in which imaginal concepts are stored as "little pictures" in the brain (e.g., Pylyshyn, 1973). Many researchers now hold a more moderate position. For example, Anderson and Bower (1973) suggested that rather than two

qualitatively different systems (verbal and imaginal) there is one system that codes concepts at quantitatively different levels of detail. Thus, concepts that can be imaged as well as given verbal labels can be stored in more detail, thus providing a richer, more elaborate representation. They should consequently be more accessible and memorable.

Thus, based on this cognitive research, it seems clear that information presented both verbally and graphically will be learned and remembered better than information just presented verbally. Consequently, a graphics system in addition to the verbal communication system should benefit students. This is, of course, an empirical question.

Brain hemisphere specialization. There has been much recent research on the functions of the two hemispheres of the brain. Although a high degree of variability among people has been found, a few general points about the function of the hemispheres can be made. In general, it has been thought that the left hemisphere primarily controls language and other analytic functions, while the right hemisphere primarily controls more visual, non-verbal and analog functions. Converging evidence to support this hypothesis has come from studies of brain damaged individuals (Bogen & Bogen, 1976; Gazzaniga, 1977; Gloning, 1977; Levy, Trevarthan, & Sperry, 1972; Rasmussen & Milner, 1977; and Russell & Espir, 1961) and dichotic listening tasks with normal subjects (e.g., Kimura, 1961; 1964).

In addition, some behavioral differences have been

found with people having different hemispheric organizations. For example, Levy (1976) found differences in completing verbal tasks between people using an inverted versus noninverted handwriting position depending on which hemisphere performed the task. Witelson (1976) found that boys aged 6-13 could identify shapes felt with the left hand (right hemisphere) better than those felt with the right hand (left hemisphere). Girls of the same age showed no difference in performance of the two hemispheres.

Generally, current research has shown more and more individual differences (Glass, Holyoak, & Santa, 1979). Thus, early theories that the left hemisphere completely controlled analytic thinking and the right analog thinking must be modified to include all of the variability found among individuals. Therefore, as with research on memory coding and imagery, this research again points to maximizing the learning of all students by using a variety of modes of presentation.

Problem solving and thinking. There are many differing views of how people solve problems. One of the most influential is the Gestalt school. A major premise of the Gestalt view is that thinking serves to restructure a problem (or relate its elements in a new way) to make it more tractable and, thus, solvable. The "meaning" view of thinking and problem solving is a similar viewpoint (Mayer, 1977). In this view instead of relating parts of the problem in a new way, the parts of the problem are related to the solver's background information in memory. As has

been known since Bartlett (1932), people make sense out of incoming information by relating it to their background knowledge and often by changing it to fit preexisting schemas in memory. This idea of active processing of information is the basis of current cognitive psychology.

In line with this view of the active human information processor is the meaning theory of problem solving. In general it is thought that learning is better and more transferable to new problems if concrete examples and general principles are learned rather than memorizing by rote. For example, Mayer (1975) taught subjects a simple programming language using both verbal instruction and a computer model. The model was a concrete analogy of a computer to everyday concepts. Later, the group that received the verbal instruction first was better at writing programs similar to those in the instruction book, while the group shown the computer model first was better at writing programs using structures not specifically taught. Thus, the concrete model served as a background cognitive structure to relate new ideas and tasks to (Mayer, 1977). This idea of concretizing a problem to provide a meaningful cognitive structure for new problems has been found with various problems and age groups (e.g., Brownell & Moser, 1949; Luchins & Luchins, 1950).

In addition, learning and problem solving have been shown to be facilitated when the learner is actively involved in the solution to a problem rather than just given an answer. When actively involved, the learner must use background knowledge to solve the problem and then

assimilate the new information into memory. This seems to result in broader learning and better transfer to new tasks than rote learning (Gagne & Brown, 1961; Gagne & Smith, 1962; Roughead & Scandura, 1968).

Finally, DeSoto, London, and Handel (1965) suggested that subjects solve linear ordering syllogisms by constructing a visual image of the relationships in the syllogism. Paige and Simon (1966) found that subjects instructed to draw diagrams of algebra story problems were successful at solving them when the diagrams were coherent and integrated. Subjects who were unsuccessful tended to draw an unintegrated series of diagrams. Thus, coherent visual imagery was shown to aid in solving mathematical problems.

Again, the general point made by these studies of thinking and problem solving is that a variety of modalities should be used to maximize learning. In addition, the more the student is encouraged to actively participate in his/her own learning the broader and more transferable that learning will be.

Learning strategies. As has been discussed previously, the cognitive view of the human information processor is an active one. As Weinstein, Underwood, Wicker, and Cubberly (1979) pointed out, most research on instructional innovations has centered on curriculum development and delivery systems. The learner was often viewed as a passive recipient of this instruction. However, with the advent of cognitive psychology, researchers have recognized the active

part learners play in learning. This has led to investigations of learning strategies people employ to facilitate learning. Weinstein, et al. (1979, p. 50) have identified five general categories of learning strategies used by students at various levels:

1. Rote strategies--strategies that emphasized repetition
2. Physical strategies--any strategy that involved using the physical properties of the material to be learned, such as spelling patterns
3. Imaginal elaboration--any strategy involving the formation of a mental picture in order to learn the material
4. Verbal elaboration--actively working with the material by asking and answering questions about it, determining implications of the content, relating it to information already known, etc.
5. Grouping--rearranging the material to be learned into smaller subsets according to some perceived characteristic that is commonly shared

Weinstein, et al. (1979) then conducted a series of investigations to determine the importance of a number of variables. First, they found that extensive training (with practice and feedback) in the use of the latter three cognitive strategies can facilitate their effectiveness in aiding learning of various materials. They also found that in the training period, the practice materials should progress from easy to difficult tasks. Practicing on more difficult materials first can be detrimental to later

performance.

These results along with others have led Kimble (1979) to suggest that people use these strategies to exploit normal cognitive processes to facilitate learning. For example, an elaborative strategy produces a deeper level of processing which has been shown to produce better recall (Craik & Lockhart, 1972; and Craik & Tulving, 1975). Similarly, integrating new information with background knowledge (episodic and semantic memory) can facilitate learning (Tulving, 1972).

Finally, Weinstein, et al. (1979) found individual differences among various populations of subjects differing in educational level and job backgrounds. Thus, further research will probably reveal that people vary considerably in the learning strategies that facilitate learning for them. Consequently, an instructor should use a variety of teaching techniques to aid these individual learning strategies.

As is evident in the preceding review, the learner is an active processor of information. Although most people conform generally to the basic principles drawn from these studies, a large amount of individual variability exists in information processing. Although not much experimental research on the cognitive effects of educational telecommunications delivery systems exists, the relevant literature from cognitive psychology can be used to make predictions about how such systems can optimize learning for students.

The next section will specify the behavioral objectives of the proposed delivery system. In addition, the methodology to assess how well the system meets these objectives will be specified.

Educational Objectives

This section contains a list of educational objectives that define the minimum requirements for success in the Kansas State University computer science program. They are written at a level which is specific enough to define and evaluate the success of the remote delivery system and still encompass both undergraduate and graduate students.

The original formulation of educational objectives by Bloom and presented in Bloom, Engelhart, Furst, Hill, and Krathwohl (1956) is still followed today. Thus, the objectives presented here follow his format. Bloom, et al. (1956, p. 26) defined educational objectives in the following way:

By educational objectives, we mean explicit formulations of the ways in which students are expected to be changed by the educative process. That is, the ways in which they will change in their thinking, their feelings, and their actions.

This definition makes clear some of the purposes of writing educational objectives. First, it clarifies the specific goals that instructors have for their students. Second, writing the objectives forces the instructor to make his/her expectations explicit. The student should clearly benefit if the instructor has clear and specific objectives in mind when conducting a class. Finally, educational objectives can be used as the basis of evaluation of a student's progress. If objectives for success are explicitly defined,

evaluative tools can be written directly from them. Bloom, et al. (1956) demonstrated how educational objectives can be written and used for evaluation by the instructor. Written educational objectives can also allow students to monitor their own progress.

In order for an instructor to write effective and useful educational objectives, several characteristics of good objectives must be included. First, they must be general enough to both define curriculum goals and more specific instructional goals. Second, they must be specific enough to guide the construction and use of evaluative tools designed to measure the degree to which students have met the objectives. Frequently, educational objectives are called behavioral objectives to stress the latter point. That is, although the objective must be general enough to guide curriculum and instructional development, they must also be written to describe specific behaviors a student can do to meet these goals. If the objective is written in terms of a specific behavior, then a specific evaluative item will clearly follow from it, usually in the form of an achievement test item (Bloom, et al., 1956).

The following examples were taken from various sources and analyzed by Bloom, et al. (1956). If an objective, such as (1) and (2), is too general, a student cannot master nor be tested on mastery of it. Basically, these objectives are too vague. Examples (3) and (4) are still too general, but are better versions of objectives (1) and (2), respectively.

(1) to understand the ideas of others and to express one's

own effectively (p. 46)

- (2) to acquire and use the skills and habits involved in critical and constructive thinking (p. 46)
- (3) to communicate through his own language in writing and speaking at the level of expression adequate to the needs of educated people (p. 47)
- (4) to act in the light of an understanding of the natural phenomena in his environment in its implications for human society and human welfare, to use scientific methods in the solution of his problems, and to employ useful nonverbal methods of thought and communication (p. 47)

As was stated previously, an evaluative item can be written directly from a clear educational objective. Examples (5) and (7) are well written objectives with corresponding achievement test items, (6) and (8). Objective (5) is an example of an objective for specific knowledge, while (7) is an objective calling for application of knowledge.

- (5) to define technical terms by giving their attributes, properties, or relations (p. 64)
- (6) Which one of the following phrases about wave motion defines period?
 - a. the maximum distance a particle is displaced from its point of rest
 - b. the length of time required for a particle to make a complete vibration
 - c. the number of complete vibrations per second
 - d. the time rate of change of distance in a given

direction (p. 79)

- (7) the ability to predict the probable effect of a change in a factor on a biological situation previously at equilibrium (p. 124)
- (8) John prepared an aquarium as follows: He carefully cleaned a ten-gallon glass tank with salt solution and put in a few inches of fine washed sand. He rooted several stalks of weed (elodea) taken from a pool and then filled the aquarium with tap water. After waiting a week he stocked the aquarium with ten one-inch goldfish and three snails. The aquarium was then left in a corner of the room. After a month the water had not become foul and the plants and animals were in good condition. Without moving the aquarium he sealed a glass top on it.

What prediction, if any, can be made concerning the condition of the aquarium after a period of several months? If you believe a definite prediction can be made, make it and then give your reasons. If you are unable to make a prediction for any reason, indicate why you are unable to make a prediction (give your reasons). (p.131)

Note that objectives (5) and (7) detail the specific behavior expected of the student, which can easily be tested, while objectives (1)-(4) are vague and a clear test of the ill-defined behaviors would be difficult to construct.

Thus, as the above examples demonstrate, a single good objective can supply a course goal for the instructor, a

specific behavior for the student to achieve, and a method for the student to demonstrate mastery of the objective. Thus, well-written objectives can be valuable and powerful tools.

As was stated above, educational objectives should be general enough to describe curriculum goals. In this section objectives for the computer science program at Kansas State University are defined. The minimum goal for a remote delivery system is that remote students meet the same objectives as on-campus students. These objectives are categorized into two general domains: knowledge and applied skills. Knowledge includes factual learning of principles, concepts, and skills. Applied skills includes the demonstration of practical use of the knowledge in paper and pencil tasks as well as other hands-on activities (e.g., actual programming). However, there is one exception to this goal. Students at the various remote sites will have access to different machines and different software packages. Thus, it may not always be possible to exactly duplicate the on-campus experience at a remote site. For example, a class in database management systems may not have access to an actual system. Although these students would not actually use a system, they could acquire all the knowledge and programming skills necessary up to that point. Consequently, the programming skills section is divided into two parts: knowledge of skills and implementation^{*} of skills. Thus, with this one exception, the following objectives can be used to define and evaluate both on-campus and remote programs.

I. Knowledge Domain (Principles, Concepts, and Skills)

A. Problem solving knowledge

1. knowledge of structured programming methodology
2. knowledge of top-down refinement
3. knowledge of abstraction concepts
4. knowledge of software life cycles

B. Programming knowledge

1. knowledge of the major types of programming languages
2. knowledge of the major parts of high-level programming languages
3. knowledge of debugging and proof principles
4. knowledge of data and control structures

C. Research and writing knowledge

1. knowledge of available journals
2. knowledge of landmark work in the area
3. knowledge of available library facilities
4. ability to critically analyze others' work
5. ability to critically analyze own work
6. knowledge of terminology in the area
7. knowledge of major concepts in the area

II. Applied Skills Domain

A. Problem solving skills

1. to be able to operationalize a problem by using structured programming methodology
2. to be able to structure and subdivide a problem using top-down refinement
3. to be able to apply abstraction concepts to a specific problem

B. Programming skills

1. Knowledge of skills

- a. knowledge of specific hardware available
- b. knowledge of concepts and structures specific to particular programming languages

2. Implementation of skills

- a. to be able to use job control language specific to available hardware
- b. to be able to follow the software cycle with a program
- c. to be able to write code using concepts and structures of a particular programming language

- d. to be able to write a high level algorithm
- e. to be able to operationalize the high level algorithm with a flowchart
- f. to be able to write code from a flowchart
- g. to be able to debug and test a program
- h. to be able to design a system using top-down refinement and modular structuring

C. Research and writing skills

- 1. to be able to read and comprehend books and articles in the area
- 2. to be able to critique verbally and in writing own work
- 3. to be able to critique verbally and in writing others' work
- 4. to demonstrate basic writing skills
- 5. to be able to work independently on a problem
- 6. to be able to give a technical presentation

D. Teamwork skills

- 1. to be able to operationalize a problem into solvable steps
- 2. to be able to present ideas orally to a group
- 3. to be able to work effectively on a team
- 4. to be able to cooperate and do own share of work on a team

Methodology

In this section a methodology for evaluating the remote delivery system is recommended. As is noted, there are several decision points that cannot be resolved until the remote system is operational and the details of courses offered, available instructors, etc. have been determined. Thus, this section should be viewed as a framework to be modified and elaborated on when the remote delivery system is implemented.

As was stated in the introduction, a number of presentation modes for educational and conference communication have been implemented. Of these the most common are audio only, video only, audio and video, or, most recently, computer telecommunications. The proposed remote delivery system is audio-only based. Its main contribution is the addition of a sophisticated graphics package including a graphics language to supplement audio and written contact with remote students with a pictorial component. The probable cognitive advantages of such a system were predicted from the cognitive-psychological literature in the introduction.

However, as with all new packages, the cost of the system must be weighed against its benefits. When fully implemented the cost should be determined. Thus, the purpose of the preceding section on educational objectives and the present methodological section is to provide a clearly defined method for determining the system's

benefits. It is hypothesized that students receiving the audio-only presentation mode will not do as well on the evaluative instruments as the students receiving either the audio-plus-graphics or the face-to-face presentation modes. These latter two groups are not expected to differ.

Test Sample

The sample of students will be drawn from various remote sites as well as from on campus. They will be tested in intact classroom groups.

Evaluative Materials

The tools used to evaluate the remote delivery system will consist of standard materials used to evaluate student performance in the classroom. The basic objective is to demonstrate the equivalence of face-to-face teaching and remote teaching with the proposed system (except as noted above). Consequently, both groups of students will be evaluated using traditional tools. These include objective tests, subjective tests (i.e. essay tests), written papers, oral presentations, teamwork, and programming assignments. Identical tests and assignments will be administered to classes on the same subject. The educational objectives listed in the previous section will be the basis of the particular items on the evaluative instruments (see Bloom, et al., 1956, for examples).

Design

The optimal design of the evaluative study is a four factor completely between-students design to be conducted during one semester. That is, each student will receive only one level of each factor. As noted below, some factors will be crossed with the others (i.e. each level of the factor appears in combination with each level of the others). In addition, some factors will be nested within others (i.e. each level of one factor appears in combination with only one level of the others). The number of levels for some factors is predetermined, while others will not be determined until the courses are offered. Refer to Figure 1 during the following discussion of the design.

The four factors are:

1. Presentation mode

This factor will have the three levels of interest: face-to-face presentation, audio-plus-graphics presentation, and audio-only presentation.

2. Course

This factor refers to the topic covered in a particular class. The number of levels will be determined by which courses are offered at the time of the evaluation. Course will be crossed with presentation mode.

3. Instructor

This factor refers to the particular person acting as the instructor in a course. The levels of this factor will be determined at the time of

**THIS BOOK
CONTAINS
NUMEROUS PAGES
WITH DIAGRAMS
THAT ARE CROOKED
COMPARED TO THE
REST OF THE
INFORMATION ON
THE PAGE.**

**THIS IS AS
RECEIVED FROM
CUSTOMER.**

Figure 1
Between-Students Design

	Presentation Mode					
	Face-to-Face		Audio-plus- Graphics		Audio-Only	
Course (a)	DBMS	OP SYS	DBMS	OP SYS	DBMS	OP SYS
Instructor	A	B	A	B	A	B
Class	1	2	3	4	5	6
Student	1	6	11	16	21	26
	2	7	12	17	22	27
	3	8	13	18	23	28
	4	9	14	19	24	29
	5	10	15	20	25	30

(a) DBMS = Database Management Systems

OP SYS = Operating Systems

evaluation. Probably the same instructor will not teach different courses. The same instructor should teach all sections of one course to reduce variability. This will make this factor nested within course, but crossed with presentation mode. However, instructor can only be meaningfully tested as a separate factor if it is crossed with course. If it is nested within course, the two factors will be completely confounded and any differences may be attributable to either factor or a combination of the two. Practically, however, this confounding is probably unavoidable.

4. Class

This factor refers to the intact class of students to be tested. Since it will be impossible to divide a particular classroom of students into three parts (each third receiving one of the presentation modes), this factor will be nested within the other three.

Two additional factors may be considered. See Figure 2. First, if it is not possible to administer identical evaluative instruments to all classes, test type should be included as a factor nested within course and instructor and crossed with presentation mode. It is assumed a particular instructor will use the same evaluation in all sections of a single course. The same problem of confounding exists for this factor as with instructor (see (3) above). Second, if independent information (such as grade point average) is available for each student, then ability level of student

Figure 2
Between-Students Design
With Additional Factors

Presentation Mode												
	Face-to-Face				Audio-plus- Graphics				Audio-Only			
Course (a)	DBMS		OP SYS		DBMS		OP SYS		DBMS		OP SYS	
Instructor	A		B		A		B		A		B	
Test Type	T1		T2		T1		T2		T1		T2	
Class	1		2		3		4		5		6	
Ability Level	H	L	H	L	H	L	H	L	H	L	H	L
(b)												
Student	1	6	11	16	21	26	31	36	41	46	51	56
	2	7	12	17	22	27	32	37	42	47	52	57
	3	8	13	18	23	28	33	38	43	48	53	58
	4	9	14	19	24	29	34	39	44	49	54	59
	5	10	15	20	25	30	35	40	45	50	55	60

(a) DBMS = Database Management Systems

OP SYS = Operating Systems

(b) H = High

L = Low

may be included as a completely crossed, between-students factor.

Finally, it may be possible to alter the design to make it a more powerful test of the differences among the presentation modes. See Figure 3. The change would be to make presentation mode, course, and instructor within-students factors rather than between-students factors while leaving the rest of the design intact. That is, instead of a particular student receiving only one of the presentation modes, courses, and instructors, a particular student would receive all three. This might be possible to do with the master's students in the Army attending Kansas State University. In this program, currently at Kansas State University, students spend one year at the remote site taking classes. Then they relocate at Kansas State University for a summer and one semester to complete the program. Thus, it would be possible for these students to receive both the audio-only and the audio-plus-graphics presentation modes at the remote site in addition to the face-to-face mode at Kansas State University. Obviously, care would have to be taken to counterbalance the order of receipt of the presentation modes and the experiment would have to be carried out during more than one semester.

Analysis

The specific dependent variable(s) to use will be determined at the time of the evaluation. These could

Figure 3
Within-Students Design

	Presentation Mode								
	Face-to-Face			Audio-plus- Graphics			Audio-Only		
Course (a)	DBMS	OP SYS	SE	DBMS	OP SYS	SE	DBMS	OP SYS	SE
Instructor	A	B	C	A	B	C	A	B	C
Class	1	2	3	4	5	6	7	8	9
Student	1	6	11	6	11	1	11	1	6
	2	7	12	7	12	2	12	2	7
	3	8	13	8	13	3	13	3	8
	4	9	14	9	14	4	14	4	9
	5	10	15	10	15	5	15	5	10

(a) DBMS = Database Management Systems

OP SYS = Operating Systems

SE = Software Engineering

include individual test or project scores and final grades. It may also be possible to construct a survey test to assess the opinions and reactions of students to the various presentation modes. In addition, a single dependent measure or a single composite dependent measure may be used. In this case the data should be analyzed using analysis of variance. However, it would also be possible to use a number of different evaluative scores as separate dependent measures. In this case the data should be analyzed using multivariate analysis of variance (MANOVA). While any standard statistical package could handle the analysis of variance designs (e.g., BMDP2V, Brown, 1977; SAS, Helwig & Council, 1979; or SPSS, Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975), SAS is the recommended package due to its flexibility. SAS can also handle MANOVA.

Finally, one note of caution is in order. Of necessity, the recommended methodology in this report is not firm. The exact design can only be determined when the system is operational. While the designs presented here are experimentally and statistically sound, any changes may make the experiment uninterpretable. Thus, statistical advice should be sought before conducting this evaluation. Further information about experimental design principles and analysis of variance may be found in Winer (1971) and Keppel (1973), and information about MANOVA can be found in Finn (1974).

Conclusions

Technological advances tend to occur faster than the analysis of their impact on human beings. Thus, it is important to assess that impact as soon as a new system is implemented. The proposed system that generated this report is no exception. This system is a remote education delivery system using telecommunications. It is an audio-based system with the addition of a sophisticated graphics package including a graphics language. It is assumed that this addition of a graphics component to the typical audio-only presentation mode will benefit the student. However, this is an empirical question.

The purpose of this report was threefold. First, the cognitive-psychological literature was reviewed and presented in the first section. Based on past cognitive research, the prediction that a graphics component in the remote delivery system would benefit students was substantiated. However, whether or not this particular system would provide those benefits is still an open question.

The second purpose of the report was to present a description of educational objectives and guidelines for writing good ones. This information was presented in the second section of the report. Additionally, it included a list of objectives for the Kansas State University computer science program. The objectives were written on the program level to encompass all uses of the proposed remote delivery system. Besides providing guidance for curriculum and

individual courses, they can be used as evaluative tools. That is, evaluative instruments to be administered to students can be written directly from educational objectives. Thus, the purpose of the second section was to provide a basis for evaluation of the effectiveness of the remote delivery system in aiding remote students in meeting the objectives of the computer science program at Kansas State University.

The third purpose of the report was to present the recommended methodology to carry out the assessment of the remote delivery system in the final section of the paper. The actual assessment is left to a future researcher when the system is fully operational. Based on the evaluative instruments that will be derived from the educational objectives and based on a number of important factors such as presentation mode, courses, etc., some possible experimental designs were presented in this section. In addition, suggestions were made on the types of analyses to be performed on the data and the statistical packages to be used to carry them out.

In conclusion, the findings of this report substantiated the prediction that the proposed remote education delivery system will substantially benefit remote students in meeting the objectives of the computer science program at Kansas State University. This conclusion is based on current research in cognitive psychology. In addition, program-level educational objectives were presented and a methodology for experimentally assessing that prediction was recommended. Thus, an

interdisciplinary, experimental approach to system development was recommended in this report. Hopefully, by incorporating research from the behavioral sciences into the design and implementation of the system, a more rational and multidisciplinary approach to the human-machine interface can be taken.

Reference Notes

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APPENDIX I

Annotated Bibliography

This annotated bibliography contains the references deemed most relevant to the grant proposal by the author. The references were found in a search of Psychological Abstracts, for the years 1975-1980.

- Albertson, L.A. Telecommunications as a travel substitute: Some psychological, organizational, and social aspects. Journal of Communication, 1977, 27, 32-43.

The author of this paper questions whether or not telecommunications can be an effective substitute for face-to-face communication in office settings requiring much interpersonal interaction. This travel substitute, using home office and video teleconferencing, is considered from a social/psychological viewpoint.

- Anandam, K., & Fleckman, B. Telephone dialogue intervention in open learning instruction. Journal of College Student Personnel, 1977, 18, 219-223.

Students who enrolled in a psychology course taught through television and a computerized instructional feedback system were studied. Students were more likely to complete the course if they participated in the first assignment and/or were contacted by the instructor via telephone than those who did not participate or were not contacted.

- Christie, B., & Kingan, S. Electronic alternatives to the business meeting: Managers' choices. Journal of Occupational Psychology, 1977, 50, 265-273.

Civil servants were first given experience with a telecommunications system and were then asked to decide whether they would use such a system or travel to meet face-to-face in nine hypothetical cases. They chose telecommunications more often the longer the trip or the shorter the conversation. Factors having no effect were whether or not the system had a visual channel, how convenient access to it was, and amount of previous experience with telecommunications.

- Dixon, P.N., & Judd, W.A. A comparison of computer-managed instruction and lecture mode for teaching basic statistics. Journal of Computer-Based Instruction, 1977, 4, 22-25.

Two groups of secondary teacher trainees were given

pre- and posttests on their attitudes toward using computer-managed instruction for teaching statistics and on their attitudes toward and performances in statistics. No differences were found between the two groups.

Harper, R.G., Wiens, A.N., & Matarazzo, J.D. Nonverbal communication: The state of the art. New York: John Wiley & Sons, 1978.

This book contains a review of specific studies in five areas of nonverbal communication: facial expression, nonverbal vocal behavior, kinesics, visual behavior, and proxemics.

Hershey, M. Telephone instruction: An alternative educational delivery system for teacher in-service. Gifted Child Quarterly, 1977, 21, 213-217.

Two groups of graduate students received either face-to-face or telephone in-service teacher instruction. On a cognitive-outcomes posttest, the telephone-instructed group performed better than the face-to-face instructed group.

Israel, A.C. Some thoughts on correspondence between saying and doing. Journal of Applied Behavior Analysis, 1978, 11, 271-276.

This paper contains a critique of research on verbal-nonverbal correspondence and a discussion of conceptual, methodological, and applied issues in the area.

Kaplan, K.J., & Greenberg, C.I. Regulation of interaction through architecture, travel, and telecommunication: A distance-equilibrium approach to environmental planning. Environmental Psychology and Nonverbal Behavior, 1976, 1, 17-29.

This study investigated interpersonal distance and crowding in planning for architecture, travel, and telecommunication. Telecommunication was found to compare favorably with face-to-face interaction on several dimensions. The perception of crowding was found to occur in some situations using either face-to-face or telecommunications interactions.

Krauss, R.M., Garlock, C.M., Bricker, P.D., & McMahon, L.E. The role of audible and visible back-channel responses in interpersonal communication. Journal of Personality and Social Psychology, 1977, 35, 523-529.

Pairs of college students worked cooperatively on a communication task in one of two groups: those communicating over a normal audio channel and those communicating over a delayed channel. On the delayed channel one second elapsed after one speaker finished before the second one had access to it. Half the subjects in each group had video access to their partners and half did not. The delay reduced encoding efficiency relative to no-delay, but delay-video facilitated encoding efficiency to the level of the no-delay conditions.

Miller, L.A., & Thomas, J.C. Behavioral issues in the use of interactive systems. IBM Research Labs, Yorktown Heights, New York: IBM Research Div. RC 6326, 1976.

The authors of this paper discuss behavioral issues and possible solutions regarding the use of interactive systems by general users. Two main areas are considered: System characteristics and Interface characteristics.

Ryan, M.G. The influence of teleconferencing medium and status on participants' perception of the aestheticism, evaluation, privacy, potency, and activity of the medium. Human Communication Research, 1976, 2, 255-261.

Canadian civil servants were assessed on reaction to and performance using teleconferencing. Each subject was tested using audio-video, audio-face-to-face, and video-face-to-face conferencing. A number of differences were found among the modes of presentation.

Tollefson, N.A. A comparison of computerized and paper-pencil formative evaluation. College Student Journal, 1978, 12, 103-106.

Students in two sections of a graduate measurement class were given either computerized or paper-pencil formative evaluation strategies. The computerized strategy included self-paced learning and unlimited trials to mastery. The paper-pencil strategy was teacher-paced and only one trial was allowed. On an achievement test at the end of the course the students using the computerized strategy performed better on both knowledge and application items than the paper-pencil-strategy students.

Towle, N.J., & Merrill, P.F. How students use behavioral objectives. Educational Technology, 1975, 15, 41-42.

Students in a graduate course using computer-managed

instruction answered a questionnaire on their use of behavioral objectives for the course. Results showed they used them to focus studying, to determine what is relevant, and to generate questions for self-evaluation.

Wilson, C., & Williams, E. Watergate words: A naturalistic study of media and communication. Communications Research, 1977, 4, 169-178.

This paper contains a report of a naturalistic study comparing telephone and face-to-face conversations using the Watergate tapes. The content analysis showed that there are differences between conversations with and without visual contact. However, conclusions must be tempered by the fact that this is not an experimental study.

APPENDIX II

Unannotated Bibliography

This unannotated bibliography contains references related to the grant proposal, but not as directly relevant as the references in Appendix I. These references were obtained in a search of Psychological Abstracts, for the years 1975-1980.

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attitude change, source credibility and speaker performance. Dissertation Abstracts International, 1978, 39, (5-A), 2602-2603.

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television-presentation methods in teaching a unit to college students in conventional size groups and independent study-learning situations. Dissertation Abstracts International, 1977, 37, (9-A), 5543-5544.

EVALUATING A REMOTE TEACHING ENVIRONMENT
FOR COMPUTER SCIENCE STUDENTS

by

KRISTIN JO BRUNO

B. A., CALIFORNIA STATE UNIVERSITY, LONG BEACH, 1970

M. S., KANSAS STATE UNIVERSITY, 1977

AN ABSTRACT OF A MASTER'S REPORT

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requirements for the degree

MASTER OF SCIENCE

Department of Computer Science

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1980

With the advent of telecommunications technology, various types of teleconferencing have been implemented in business and education. The most common conferencing modes are audio-only, video-only audio-plus-video, or computer teleconferencing. One recent application of telecommunications is as a travel substitute for remote, university classes enabling direct instructor-student contact. Currently, an audio-based remote education delivery system is being designed and implemented at Kansas State University. In hopes of enriching such a system, a graphics package and language is included. However, whether or not such a system can provide an acceptable substitute for face-to-face contact in the classroom is an empirical question.

This report provides a framework for assessing the Kansas State University remote delivery system when it is implemented. Based on the survey of the cognitive-psychological literature presented in the report, it was predicted that a graphical component should facilitate learning in the remote environment. Further, a set of program level educational (behavioral) objectives was constructed as an evaluative tool for assessing the performance of students using the system. Finally, a methodology, including experimental designs and analyses, was recommended to assess the system once it is implemented. Taking a human-behavioral and technical interdisciplinary approach to system evaluation should produce a superior system both in its human impact and its technical quality.