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ABSTRACT

Five PLATO exercises on linear decision models were developed to investigate the feasibility of teaching material from operations research on the PLATO computer-based education system. The exercises were administered to business administration students enrolled in an introductory course in operations research. Each PLATO session was monitored to observe student reactions and performance, and questionnaires and an attitude survey were administered. Results indicated that it is technically and operationally feasible to teach subject material in operations research on the PLATO system, but this teaching medium is costly. Students favored this teaching medium and learned the material as well or better on the PLATO system. A shorter time was involved using the computer than using traditional teaching materials. Attributes of computer-based systems were also derived from the study. (CH)

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THE USE OF THE PLATO SYSTEM IN AN OPERATIONS RESEARCH COURSE

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An Investigation of the Feasibility of Teaching Material from an Introductory Course in Operations Research on the PLATO Computer-Based Educational System

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Note: The following material is based upon the writer's doctoral dissertation which was prepared under the direction of Professor Richard V. Evans of the Department of Business Administration. The work was supported in part by the College of Commerce and Business Administration of the University of Illinois.

Table of Contents

Introduction

Scope of the Research

During the academic year 1971-1972, a dissertation project was conducted to investigate the feasibility of teaching material from an introductory course in operations research on the PLATO III computer-based educational system of the University of Illinois. Three aspects of the question of feasibility were considered:

1. the technical aspect in terms of the hardware and software which support the PLATO system
2. the operational aspect in terms of the capability to develop instructional material on the PLATO system which could be used to teach subject material from an introductory course in operations research
3. the economic aspect in terms of the costs and benefits of utilizing the PLATO system.

The emphasis in the research was to develop information relevant to the operational feasibility of the PLATO system to teach this type of subject material, but the other aspects of feasibility were considered where appropriate.

Throughout the research, various attributes of the PLATO system were examined. The major characteristics of this type of educational system explored in the instructional material developed were:

1. the ability to provide better individual attention to a student through faster and concurrent responses to student input
2. the ability to provide a student with immediate feedback on the evaluation of his answer.

3. the ability to provide the student with the computational power of the computer during a lesson
4. the ability to allow a student to work through a lesson at his own pace
5. the ability to insure that the student "learns" the current material in a lesson before moving on to subsequent material
6. the ability to accommodate students with various levels of competence
7. the ability to present instructional material in a more consistent manner
8. the ability to judge student responses in a broader and more accurate manner
9. the ability to provide the student with a variety of visual material
10. the ability to collect data throughout a lesson regarding the nature and timing of student responses
11. the ease with which a lesson can be modified.

In addition to investigating these educational attributes of the PLATO system, it was attempted to collect information relevant to related questions of interest, such as:

1. Would a student's use of the PLATO system to learn operations research material instill in him a greater appreciation for the use of the computer and the techniques of operations research in problem solving?
2. In which aspects of an introductory course in operations research can computer-assisted instruction be advantageously utilized?

3. Can an analysis of a student's participation in a PLATO lesson provide insight into his problem-solving and decision-making processes?
4. What are the effects of enabling the student to participate more actively in the teaching-learning process?
5. How well can a computer-based educational system handle the routine types of teaching responsibilities to free teachers to perform more meaningful work?

Methodology

In order to investigate this question of feasibility, PLATO exercises were developed to treat one of the primary topics in an introductory course in operations research, linear decision models. Initially, a PLATO type of exercise was developed and administered to graduate students in an operations research seminar, BA 474, in the fall of 1971. This exercise was a simulation of a PLATO exercise and was designed to observe how students would react in this type of a learning environment.

Subsequently, five exercises were developed on the PLATO system and administered to M.B.A. students who were enrolled in the introductory course in operations research, BA 573, in the spring of 1972. The exercises were developed to present the subject of linear decision models in a manner which should be readily comprehended by first year M.B.A. students. All the students in BA 573 were scheduled to attend the first PLATO exercise to acquaint them with the PLATO system and an interactive computer environment as well as to teach them the subject matter presented in this exercise.

The next three PLATO exercises were administered to controlled groups of students as a homework assignment and the remaining students were requested to complete a comparable PLATO type of homework set. Tests were given to examine a student's understanding of the material presented in the PLATO exercises and homework sets to determine if differences in learning occurred between the PLATO and non-PLATO groups.

The fifth PLATO exercise was offered to all the students in BA 573. This exercise was designed to provide the students with a review of a basic approach for solving linear programming problems. The approach had been presented previously in lecture-discussions and textual material for the course, but the students had demonstrated a relatively poor understanding of this approach on the mid-term examination. Therefore, the fifth PLATO exercise was developed to enable students to review this material before the final examination was given.

During the implementation of these five PLATO exercises, an effort was made to collect as much as possible of the objective and subjective data available concerning a student's performance in a PLATO exercise and his reaction to this type of teaching medium. In addition to administering the tests mentioned previously, each PLATO session was monitored to observe the reactions of students and data tapes were prepared which contained all student responses in an exercise. Questionnaires were distributed to students at the conclusion of each of the first four PLATO exercises to obtain the students' opinions of the specific exercise and the PLATO type of teaching medium. An attitude survey was distributed to all the students in BA 573 prior to the completion of the course to collect data relevant to their attitudes about computer-assisted instruction and the capabilities of the computer and the techniques of operations research.

Summary of Results

Introduction

Throughout the dissertation project data was collected relevant to the design and implementation of the PLATO exercises. The significant results realized in this project will be summarized in this section and grouped into the following categories:

1. development of educational material
2. technical feasibility of the PLATO system
3. operational feasibility of the PLATO system
4. economic feasibility of the PLATO system
5. indirect benefits realized.

Development of Educational Material

As a result of this research project, five exercises have been developed on the PLATO system which can be used to complement an introductory course in operations research. Table 1 summarizes the amount of educational material developed and presented in this research effort.

TABLE 1

Summary of Educational Material Developed and Presented

PLATO Exercise	Session	Students in Attendance	Average Lesson Time (minutes)	Student Contact Hours
1		43	49.5	35.5
	1	15	38.9	9.7
	2	10	44.2	7.4
	3	13	60.7	13.2
	4	5	62.4	5.2
2		15	39.3	9.8
3		17	40.3	11.4
4		13	42.9	9.3
5		32	92.6	49.4
	1	11	95.5	17.5
	2	11	85.2	15.6
	3	10	97.5	16.3

Thus, it can be stated that the students in BA 573 collectively worked on the PLATO system approximately 115 hours as a part of this research effort. This figure is composed of the total student contact hours on the PLATO system for each of the five exercises.

The number of lesson hours of instructional material prepared in this research is a little more difficult to determine. Table 2 which follows presents the data relevant to the number of these hours.

TABLE 2

Number of Lesson Hours of Instructional Material in the PLATO Exercises

PLATO Exercise	Average Completion Time (minutes)	Range of Completion Times (minutes) Low	High
1	59.4	45	90
2	39.3	30	55
3	40.3	22	59
4	42.9	28	54
5	92.6	60	134
totals (minutes)	274.5	180.5	392.
totals (hours)	4.6	3.0	6.5

The above data should be interpreted on the high side for several reasons. First, for each exercise, there was at least one student who did not complete it and who would have raised the average completion time if time had been available for him to complete the exercise. Also, the times recorded on a tape print show only the times for student responses. Thus, the times reported for each exercise are based on the time until the student's last response in the exercise. Each exercise concluded with some summary narrative material, so the exercise continued several minutes beyond the student's last response. An additional consideration is that the time allowed for a PLATO exercise should provide for about ten minutes of start-up time to acquaint the student with the PLATO system and to introduce the exercise to him.

The five lessons developed for the PLATO system covered only part of the material normally presented in an introductory course in operations research. In these exercises, many of the basic concepts in the field of operations research were treated in general and the subject of linear decision models was presented in greater detail. The following list of topics summarizes the specific material presented in these exercises:

1. concepts of a policy, behavior and utility in a decision-making situation and their representations verbally, symbolically and with mathematical abstractions
2. basic concepts of modeling and representations of models with algebraic, inner product and vector notation
3. general capabilities of the digital computer
4. basic concepts of vector algebra and vector operations such as addition, subtraction and multiplication
5. basic concepts of matrix algebra with an emphasis on dimensioning of matrices and matrix multiplication
6. general concepts of the technique of linear programming with special emphasis on the aspects of:
   a. the matrix representation of the constraining equation $Ax = b$
   b. verbal description of the policy and behavior spaces and their basis vectors
   c. iterative procedure of searching for better alternative policies through a change of basis in the constraining equation
7. introduction to the information generating capabilities of the techniques of modeling and linear algebra and the computer when used together in a decision making situation.

Technical Feasibility of the PLATO System

In this research effort, the technical feasibility of the PLATO system was assumed to exist. This technical feasibility is measured, in general, by the capability of the hardware and software available in the PLATO system. There is no doubt that the capability exists to develop lesson material on the PLATO system and to have students interact with this material on the PLATO system. However, in view of the author's recent experience on the PLATO system, a few remarks about the technical feasibility of this system are in order.

In general, the hardware capabilities of the PLATO system are considered adequate. The PLATO author and student do not come into direct contact with all the physical components of the system, so only the relative items of hardware will be commented upon in this discussion. The primary piece of hardware to the user of the PLATO system is obviously the terminal. In general, the terminals used on the PLATO system are good devices for viewing information and for keying information into the system. However, these terminals are old and have had many contact hours of use. Consequently, the viewing screens of the terminals sometimes behaved in a manner comparable to the way a picture tube in an old black and white television set does. There are times, for example, when images fade, get distorted, are too dark or are too light. The keys in the keyset may stick at times, also. It is believed that perhaps the terminals are not maintained as well as they should be since the implementation date of the PLATO IV system with its new terminals is imminent.

The other hardware component of the PLATO system which the user is most directly concerned with is the computer. During the author's work in this

research effort, there were several instances of systems failure attributed to the computer when he was working as an author, but none when students were working on exercises on the system. Like the terminals, the computer is old in terms of design and hours of use. It is presumed that the computer and the terminals for the PLATO IV system will alleviate most of these problems because of their newer design and improved capabilities. Despite the few problems encountered with the operation of the hardware for the PLATO III system, it is the author's belief that the hardware for this system was entirely adequate for the preparation of the lesson material and the student participation in the exercises developed in this research effort.

The other major aspect of the PLATO system which relates to its technical feasibility is the software. In general, the writer considers the software for the PLATO system to be very good. The TUTOR language appears to be a versatile and useable compiler level language. Its set of commands provide an author with the ability to display and sequence instructional material in a variety of ways. The author learned to use most of the TUTOR commands and has come to appreciate the capabilities of the TUTOR language. There are undoubtedly other uses of the TUTOR commands which the writer is unfamiliar with which can be used to present instructional material more effectively and efficiently. However, it has been the writer's experience that one does not become highly proficient in the use of a programming language until he has had several years of solid experience with the language.

The TUTOR language was developed specifically for the PLATO computer-based educational system. Its set of commands were designed especially to display instructional material, sequence instructional material and evaluate

responses. Therefore, it is the writer's opinion that in developing lesson material for a computer-based system it would be more efficient and effective to use a specially designed language such as TUTOR than commercially available languages such as FORTRAN. This indeed must have been the thinking of PLATO's technical staff since TUTOR was designed to replace FORTRAN as the primary user language on the PLATO system back in 1967.

However, in the development of the PLATO exercises for this research effort, there were some aspects of the TUTOR language which caused problems. Specifically, the available commands to build uncomplicated response judging routines for verbal answers did not appear to be entirely adequate. The biggest fault appeared to be the judging of correct student answers as incorrect. It is primarily the author's responsibility to designate the acceptable responses for a question, but it becomes quite a sizeable and complex task to designate for every acceptable word that, say, its plural form and all reasonable synonyms are acceptable, also. If commands could be developed which allowed the judging for verbal responses to be more flexible, then TUTOR would be an even better user language.

The other major aspect of the software of the PLATO system which a user frequently comes in contact with, although indirectly, is the operating system. This set of programs allows an author to go from author mode where he develops new lesson material or modifies existing lesson material to student mode where he can interact with the lesson material. In this respect, the operating system for PLATO appears to be excellent. Existing TUTOR programs can be revised in a very expeditious manner. In the author mode, the set of commands for the program is viewed. By the use of very simple procedures, a command can be deleted, revised or replaced or additional

commands can be added to the program. Then, an author can go directly to student mode and test the changed program. This interactive type of program modification makes the use of an author's time much more efficient than if program changes had to be made through some type of batch processing system.

The above remarks were intended to substantiate the assumption that the PLATO system is considered technically feasible as a medium for developing educational material and presenting this material to students. The hardware and the software for PLATO III is quite useable and it is anticipated that these components of PLATO IV will have even improved technical characteristics.

Operational Feasibility of the PLATO System

1. Introduction

The major question to be answered in this research effort was could the PLATO system be used to teach material from an introductory course in operations research. Throughout the research, various ways were used to collect data relevant to this question. Several methods to collect objective data were attempted, such as, tape prints of student responses during a PLATO exercise, graded homework sets for the non-PLATO students and tests administered to all the students over the subject material presented in the PLATO and homework exercises. Various ways were used to collect subjective data, also, such as questionnaires, attitude surveys, observations of students during a PLATO exercise and personal discussions with students. The results of the data collected relevant to the operational feasibility of the PLATO system will be summarized in the succeeding sections of this report in terms of the objective results and the subjective results.

2. Objective Results

The objective results realized in this study regarding the operational feasibility of the PLATO system to teach material from an introductory course in operations research will be summarized in terms of:

1. the test scores realized in PLATO related tests by students participating in the PLATO exercises contrasted to the test scores attained by the students who did not participate in the PLATO exercises
2. length of time necessary to complete a PLATO exercise in contrast to the length of time necessary to complete a comparable homework exercise.

The results in this research indicate that the students who participated in a PLATO exercise scored higher, in general, in the related test than did students who did not participate in the relevant PLATO exercise. TABLE 3 summarizes the results realized in these tests.

TABLE 3

Summary of Results of PLATO Tests

PLATO Test	Question	PLATO Group	non-PLATO Group	Other
1		87.8	80.4	82.2
	1	21.5	20.4	19.7
	2	48.7	39.1	34.2
	3	17.7	20.9	28.3
2		83.9	81.4	91.5
3		87.9	90.2	69.8
4		46.8	43.0	
	1	11.2	11.1	
	2	10.3	7.4	
	3	12.4	10.9	
	4	7.3	9.8	
	5	5.6	3.9	

PLATO Test 1 was designed to test the students on the material covered in PLATO exercise 2 and its related homework set, to test the students on their ability to extend the concepts presented in these exercises and to test the students on their ability to formulate and solve a linear decision problem. Question 2 on this test was the question designed to specifically cover the material presented in the homework exercises, so the results on this question most directly relate to the question of the operational feasibility of the PLATO system. The students in the PLATO group scored on the average about 24 percent higher on this question than did the students who did the comparable homework set and about 42 percent better than the students who participated in neither exercise. Furthermore, a statistical interpretation of these results indicates that a t-test of the difference of the mean score on question 2 by the PLATO group and the mean score on this question by the non-PLATO group signifies that the probability of this difference occurring by chance was between .02 and .04. This t-test was conducted using a standard deviation of 3.52 for the scores of the PLATO group on question 2, a standard deviation of 14.5 for the non-PLATO group and 45 degrees of freedom.

Question 1 on test 1 was designed to test how well the student understood the material presented in the homework exercises and could extend the use of this material based on other material previously presented in classroom lecture-discussions. On this question, the students in the PLATO group scored only slightly better than the other students did. It was observed that on question 3 in this test, the students in the PLATO group scored noticeably lower than the students in the other groups did. This question required the students to formulate and solve a linear decision problem and was considered the most difficult question on the test. Therefore, it could be inferred

that since the students in the PLATO group scored lower on this question than the other students did, their ability to do well with operations research material, in general, was less than that of the other students. The final course grades achieved by the students in BA 573 support the claim that the PLATO group of students in this exercise had a lower ability to perform in this course than the other students did. This initial PLATO group contained about 28 percent of the students who were enrolled in BA 573 at the time, but 75 percent of the students who eventually dropped this course were in this group and only 13 percent of the students who received A's in BA 573 were in this group. In summary, the results on PLATO Test 1 strongly indicate that the PLATO system has the ability to teach material from an introductory course in operations research. It appears that students with a lower aptitude for operations research learned this subject material better in a PLATO exercise than the other students did in the related homework set or by studying other material on their own.

PLATO Test 2 was designed to test the student's knowledge of the material presented in PLATO exercise 3 and its related homework set directly. An attempt was made to develop a test which closely covered the material presented in these exercises and which would indicate a student's understanding of that material. As Table 3 indicates, the students in the PLATO group on the average had about 3 percent higher scores on this test than did the students in the non-PLATO group which completed the homework exercise.* The fact that the students in the "other" group scored higher should be discounted

*The t-test of the difference of the mean score of the PLATO group on this test and the mean score of the non-PLATO group indicates that the probability of this difference occurring by chance is between .8 and 1. This test was based on a standard deviation of 8.3 for the PLATO group and 12.3 for the non-PLATO group and upon 46 degrees of freedom.

since there were only two students in this group, one who stated he completed the homework exercise but lost it and another student whose background was so strong in this type of material he felt he did not need to prepare for the test. Thus, the strongest statement which can be made based on this test is that it tends to indicate that when this specific type of material was presented in a PLATO exercise and a comparable homework exercise, the students in the PLATO group demonstrated on an appropiate test that they learned the subject material as well or better as the students who did not participate in the PLATO exercise did.

PLATO Test 3 was designed in much the same manner that test 2 was. The test was developed to examine the students on the material presented in PLATO exercise 4 and its related homework set in a straightforward fashion. The results in Table 3 indicate that the students in the PLATO group did well on this test, but not as well as the group who completed the homework [redacted]. An analysis of the students in the group which completed the homework set disclosed that this group contained about 64 percent of the students who took the test, 69 percent of the students who received A's in BA 573, 63 percent of the students who received B's and none of the students who received C's. So, the non-PLATO group for this test appeared to have a higher percentage of the better students in it and it appears these students were able to learn this subject material as well or better on a homework exercise than the other students did on a PLATO exercise or by other means. Nevertheless, the results on this test, also, tend to indicate that students can learn this type of material through exercises developed for the PLATO system. Moreover, the results suggest that for the type of material presented in PLATO exercise 4 a well structured homework exercise was also a very good teaching instrument.

The fourth test used in this research was the final examination for BA 573. This test was designed to examine students on their knowledge of definitions and problem formulations and solutions over the entire range of material presented in BA 573 during the semester. Therefore, only questions 3 and 4 on this test related directly to the material presented in PLATO exercise 5. Question 3 basically required the students to identify alternative solutions in a linear programming problem through the change of basis procedure. This question was designed to examine the student very closely on the material presented in PLATO exercise 5. The results on this question as depicted in Table 3 show that students in the PLATO group on the average received about 14 percent higher scores than did the students in the non-PLATO group. Furthermore, when the results achieved by these groups of students on this question are contrasted with the scores achieved by the same groups of students on the prior question concerning the solution of a linear programming problem on PLATO Test 1, the results attained by the PLATO group on this question on the final examination are even more impressive. Table 4 which follows summarizes the performance of these groups of students on the two test questions which related to the formulation and solution of a linear programming problem.

TABLE 4

Summary of Performance on Linear Programming Problems

Group	Students	PLATO Test 1 Question 3	PLATO Test 4 Question 3
PLATO	32	18.8	12.4
non-PLATO	17	27.9	10.9

These results tend to suggest that without the benefit of participating in a PLATO exercise which presented the general concepts of linear programming,

the PLATO group averaged scores only 67 percent as high as those in the non-PLATO group on a test question concerning the formulation and solution of a linear programming problem.* After participating in a PLATO exercise which covered the concepts of linear programming, the PLATO group on the average made 14 percent higher scores than the non-PLATO group did on another test question regarding the formulation and solution of a linear programming problem.**

Question 4 on the final examination in BA 573 required the students to formulate the problem presented symbolically as an optimization problem and to identify a set of basis vectors for each finite dimensional vector space used. This problem was an adaptation of a problem assigned as homework during the semester which the students found very difficult to solve. PLATO exercise 5 would not have directly prepared a student to answer question 4 on the final examination. Rather, if a student fully understood the concepts of linear programming as presented in PLATO exercise 5 and could extend this type of reasoning to a more complex problem, he would have done well on question 4. An analysis of the individual grades on this question showed that one-half (16) of the students in the PLATO group scored five or less points on this question and only two people in the non-PLATO group scored five or less points on the question. These sixteen people in the PLATO group averaged 10.5 points on question 3 while the two

*The t-test of the difference of the mean score of the PLATO group on this test question and the mean score of the non-PLATO group indicates that the probability of this difference occurring by chance is between .04 and .10. This test was based on a standard deviation of 12.5 for the PLATO group and 15.5 for the non-PLATO group and upon 47 degrees of freedom.

**The t-test of the difference of the mean score of the PLATO group on this test question and the mean score of the non-PLATO group indicates that the probability of this difference occurring by chance is between .8 and 1. This test was based on a standard deviation of 6.5 for the PLATO group and 7.1 for the non-PLATO group and upon 47 degrees of freedom.

people in the non-PLATO group who scored five or less points on question 4 averaged only 3.0 points on question 3. This analysis tends to indicate that this PLATO group of students learned the basic material in PLATO exercise 5 well as evidenced by their scores on question 3, but did not have the ability to extend this type of thinking and perform well on question 4. These results are summarized in Table 5 in terms of the average scores received on questions 3 and 4 by the students who received a score of five or less points on question 4 of the final examination.

TABLE 5

Analysis of Students Receiving Low Scores on Question 4 of PLATO Test 4

Group	Students	Question 4	Question 3
PLATO	16	2.6	10.5
non-PLATO	2	2.0	3.0

The results on this test, also, serve to support the conclusion that it is operationally feasible to teach material from an introductory course in operations research on the PLATO system. In general, it can be inferred from the results on this test that the students who participated in PLATO exercise 5 did not know the basic concepts of linear programming as well as the non-PLATO group before the exercise, but that they understood these concepts better than the non-PLATO group after the exercise. It appears that PLATO exercise 5 was effective in presenting some of the basic concepts of the technique of linear programming. Furthermore, the results in Table 5 suggest that even students in the PLATO group who did very poorly on question 4 on this test, indicating that they did not have a sound understanding of the technique of linear programming, were able to score fairly

well on question 3 exhibiting that they understood some of the basic concepts of linear programming after they had completed PLATO exercise 5.

In summary, the tests administered in this research have indicated that students who participate in PLATO exercises learn the material well which is presented in these exercises as demonstrated by their scores on the related tests. In most instances, it was seen that these students scored better on the related tests than the students who completed the homework exercise or used other means to prepare for the tests. Perhaps one reason for this better performance by PLATO students was the level of correct information which a student had when he completed a PLATO or homework exercise. With the PLATO exercises, a student was required to enter a correct answer before proceeding with the next question. Thus, a student satisfactorily completing a PLATO exercise was aware of the correct answer for every question asked in the exercise. In fact, he physically had to enter each correct answer into the system to move through the exercise. In contrast to this, students who completed the homework exercises wrote in their answers, had their answers graded and determined the correct answers for questions marked wrong only if they so desired. There was no way to determine whether students in the homework exercise groups in fact reviewed their graded homework and corrected wrong answers so that they were aware of the correct answers to homework questions before they took the related tests. Table 6 which follows summarizes the student's awareness of the correct information when he had completed either the PLATO exercise or the related homework assignment for the three PLATO exercises where comparable homework sets were developed. The percent correct was computed by dividing the total correct responses entered for an exercise by the total responses required.

TABLE 6

Summary of Homework Performance

PLATO Exercise	PLATO Exercise Group		Homework Exercise Group	
	% Correct	Time (minutes)	% Correct	Time (minutes)
2	99.2	39.3	80.0	53.6
3	98.9	40.3	83.0	28.7
4	97.3	42.9	82.3	71.0

The results depicted in Table 6 suggest that students in the PLATO group could have performed better on the related tests because they had greater knowledge of the correct information when they completed an exercise.

Table 6 also presents the information developed relevant to the average time required to complete a PLATO or homework exercise. It is contended that the length of time required to complete an exercise relates directly to the operational feasibility of the PLATO system. A discussion of the average time required to complete each of the exercises identified in Table 6 follows.

PLATO exercise 2 was a relatively straightforward lesson, but an analysis of the tape print for this exercise indicates it caused the students some difficulty because of the confusion surrounding the fill-in-the-blanks type questions and the routine used to calculate the value of the student's year-end portfolio. This calculating routine was not meant to save a student time in this relatively simple problem, but rather was used to demonstrate the computational capabilities of the PLATO system. In fact, the value of the year-end portfolio could probably have been calculated just as quickly by hand. Nevertheless, the results indicate that on the average the students required only about 73 percent as much time to complete the PLATO exercise as they did to complete the comparable homework exercise. As indicated,

this group of students appeared to be lower in ability than the other students, but they scored higher on the related test. So, the presumption can be made that for this group of students with less ability in operations research, the PLATO exercise prepared them better for the related test in a lesser amount of time than the homework assignment prepared the other group of students who appeared to have more ability in operations research.

PLATO exercise 3 was developed as an introduction to matrix algebra and matrix operations. It contained a routine which could be called by the student to perform the necessary vector multiplications. Table 6 indicates that, on the average, students required 40 percent longer to complete the PLATO exercise than to complete the comparable homework exercise. The tape print for this exercise and a summary of the results of the homework exercise were analyzed to determine why the PLATO exercise required more time than the homework exercise. The following aspects of PLATO exercise 3 were discovered to be the major reasons why the exercise was not completed in less time.

1. Students averaged over five minutes on the lead in question which asked "What type of information is necessary to determine capacity?" because the response judging routine was not flexible enough, but on the homework exercise any reasonable item of information was accepted as a correct answer for this question. For this question, there were 68 incorrect responses in the PLATO exercise and only four incorrect responses in the homework set.

2. A question which asked what the appropriate vectors were to compute the capacity used in a processing operation required their names and some students entered the numeric representation of the vectors instead. The PLATO exercise would not accept the numeric representation, so there were 132 incorrect responses on this exercise for this question and students

required an average of almost six minutes to answer the question correctly. To the contrary, over one-half the students in the homework exercise group answered the question with the numeric representation of the vectors and were given full credit for the answer.

3. The exact definition for matrix multiplication was requested and students found it difficult to enter the precise answer. There were 91 incorrect responses to this question and the average student required over ten and one-half minutes to enter the correct answer. Over one-half the students who completed the homework exercise also missed this question, but were not required to spend the additional time necessary to develop the correct answer which a PLATO exercise requires.

4. The average student required about six minutes to use the vector multiplication routine developed for this exercise and since this was a relatively simple example, the computation could probably have been done faster by hand. In addition, five students did not bother to compute the answer required in the vector multiplication question in the homework exercise, so their times to complete this exercise would be expected to be lower.

Nevertheless, the PLATO group for PLATO exercise 3 did perform better than the non-PLATO group in the related test. Even though the PLATO group required longer to complete the exercise than the non-PLATO group did, there were extenuating circumstances. The PLATO exercise required more precise answers and was used to illustrate the computational power of the PLATO system, so this exercise understandably took more time for a student to complete than the associated homework exercise.

PLATO exercise 4 was developed to extend the student's knowledge of matrix operations. In this exercise, a routine was developed which performed three vector-matrix multiplications and a subtraction to compute profit. Once the student had set up the matrix representation of the profit equation, he could call this routine to perform the necessary calculations. Thus, the answers requested in this exercise required more complex calculations than were required in the prior exercise, so the computer routine in PLATO exercise 4 was not only illustrative of the computational power of the PLATO system, but it was a much faster way to perform the necessary calculations than by hand. So, on the average, the students in the PLATO group required only 60 percent as much time as the students in the non-PLATO group to complete this exercise. Therefore, the inference can be drawn from the results related to PLATO exercise 4 that the PLATO group of students learned the subject material almost as well as the non-PLATO group did in considerably less time.

It is realized that the objective results attained in this research effort must be put into proper perspective. An attempt has been made to interpret these results in a rational manner based on reasonable assumptions, but there is much information relevant to the PLATO exercises and the homework assignments which is unknown. The questions listed below are the kind which need answering to be certain that the results realized in this research are truly objective indicators of the operational feasibility of the PLATO system.

1. Did the students actually learn the material presented in the PLATO exercises or did the exercises merely motivate them to study other

material better before the test?

2. How much of a disadvantage was it to the PLATO students not to have a graded homework exercise to review before the test?

3. How accurately did the students report their times required to complete the homework exercise?

4. What was the effect on the results that some students received and gave assistance on the homework exercises?

5. What was the effect on the results of the author's inexperience with the PLATO system and the TUTOR language in developing effective PLATO exercises, especially the initial ones?

The objective results presented in this section were based on the assumptions that a PLATO exercise and its related homework exercise presented comparable educational material, that the related tests did provide a good measure of a student's understanding of the material presented in these exercises and that the homework exercises and the tests were graded in a fair and consistent manner. With respect to these assumptions and all that is known about the objective results in this research, it should be stated that the evidence indicates that it is operationally feasible to teach material from an introductory course in operations research on the PLATO system. Furthermore, the results suggest that most students learn certain types of material better and faster on the PLATO system than by the more traditional means of instruction.

3. Subjective Results

As has been indicated, an extensive effort was made in this research effort to collect the objective data relevant to the question of the operational

feasibility of teaching material from an introductory course in operations research on the PLATO system. Furthermore, the students who participated in this research effort were asked their opinion of the feasibility of teaching this type of material on the PLATO system in order to collect subjective information relevant to this question, also. Questionnaires were distributed to the students who participated in each of the first four PLATO exercises and an attitude survey was distributed to all the students in BA 573 at the end of the course. In addition, each PLATO session provided the author with an opportunity to observe the students' reactions to the PLATO system and to discuss with students various aspects of this teaching medium. Therefore, written comments, observations and discussions form the basis for the presentation of the subjective results of this research.

The comments to the questionnaires which were completed by the students after the PLATO exercises have been summarized and included as Appendices A, B, C and D. It can be observed that the majority of the students who returned questionnaires were positive in their remarks concerning the PLATO system as a teaching medium. Some of the more significant comments made by the students are included below:

1. It causes me to learn faster because of the feedback.
2. My impressions are entirely positive. I like to learn at my own speed and have immediate feedback.
3. It's easier to learn concepts this way.
4. This method is much better than classroom presentations since the material is easier to follow.
5. This exercise was more interesting than the conventional type of homework.

6. This method provides greater personal involvement and greater demands placed on my learning.

7. This exercise was very helpful and practical. I am impressed with this type of teaching procedure.

These types of comments emphasize the students' appreciation for some of the unique characteristics of this type of teaching medium.

Furthermore, the comments made on the attitude survey which have been summarized in Appendix E support the belief that it is operationally feasible to teach material from an introductory course in operations research on the PLATO system. In response to the question on this survey, "What teaching techniques used in this course have been the most effective in your opinion?" seventeen of the forty-two students who responded to this question answered "PLATO". Eleven types of teaching techniques were named by the students in answer to this question and the techniques named the most often besides PLATO were "computer work" by seven students and "class problems" by six students. So, more students in BA 573 considered PLATO to be the most effective teaching technique used in this course than any other technique.

In addition, the majority of the responses to the question on this survey, "What is your general impression of the PLATO system as a teaching technique?" also supported the operational feasibility of the PLATO system. Forty-one students marked their impression of the PLATO system on the attitude scale provided for this question which ranged from unfavorable to very favorable. The average ranking was computed to be very near the favorable position on the scale. Also, the majority of the written comments to this

question were complimentary to the PLATO system as a teaching technique. Only three of the forty-one students who responded to this question considered PLATO an unfavorable teaching technique.

The other question on this survey which related directly to the operational feasibility of the PLATO system was "What recommendations would you make for using PLATO type instruction in future BA 573 courses?" Students interpreted the intent of this question differently. They considered it to mean how much PLATO instruction should be used in the course or to what aspects of the course should PLATO be applied or how should the development and implementation of PLATO exercises be improved. Whichever way the student interpreted the question, his response was favorable to the PLATO system in general. The students who interpreted the question to mean how much PLATO instruction should be used in BA 573 made the comments which related most directly to their opinion about the operational feasibility of the PLATO system as a teaching technique. Twenty-six students made comments which reflected they interpreted the question to have this meaning. Of these comments, twenty-three were positive and three negative toward the continued use of PLATO exercises in BA 573. The relevant comments extracted from those listed for this question in Appendix E are:

1. increase its use (11 students)
2. use it right from the beginning of the course (6 students)
3. continue to use it (3 students)
4. use it as much as possible (3 students)
5. none (1 student)
6. drop it (1 student)
7. prefer an instructor (1 student)

Thus, most of the relevant information provided on the attitude survey indicates that the students in BA 573 found the PLATO system to be an effective and desirable teaching medium.

As indicated previously, the students were observed during each PLATO exercise and numerous conversations were held with them throughout the semester to better determine their reactions to the PLATO system. From the initial PLATO exercise, the writer received the impression that the students considered the PLATO exercises worthwhile learning experiences. In the beginning exercises, the students did express some frustration because they did not believe some of the questions and directions were clear enough and because they thought that some of the response judging routines should have been made more flexible. However, as the writer gained experience on the PLATO system and with the TUTOR language, the reactions of the students seemed to indicate that each succeeding exercise was an improvement in terms of the content of the material and the way in which the material was presented. Furthermore, at the conclusion of PLATO exercise 5, many students commented that they liked the exercise and considered it a very good learning experience since it tied together many of the concepts of linear programming for them very well.

Thus, it is believed that the objective results and the subjective results for this research are compatible. These results strongly suggest that it is operationally feasible to teach material from an introductory course in operations research on the PLATO system.

Economic Feasibility of the PLATO System

Although the primary purpose of this research effort was to develop relevant information to determine the operational feasibility of teaching material from an introductory course in operations research on the PLATO

system, some information relevant to the economic feasibility of the PLATO system was collected. The determination of the economic feasibility of a system is based upon a determination of the costs and the benefits of the system. The costs of the system can normally be divided into the developmental or one time costs and the recurring or maintenance costs. The developmental costs associated with the preparation of exercises for the PLATO system are basically a function of an author's experience with the PLATO system and the TUTOR language, his familiarity with the subject material to be presented in the exercises and the type of educational strategies to be used in the exercise. These developmental costs are generally in terms of the time an author requires to develop an exercise and the time the PLATO system is required in the development of an exercise.

In the development of an exercise, an author spends his time laying out the content of the lesson, programming the lesson material at the PLATO terminal, testing the material at the PLATO terminal and making suitable modifications to the program through the PLATO terminal. At the PLATO laboratory, different authors can be observed programming lesson material straight from textbooks, from notes or without reference to any material at all. This author wrote narratives which substantially outlined the material to be included in a PLATO exercise. No detailed records were kept during this research as to how time was allocated, so no objective statements can be made as to how much time it required the author to develop each PLATO exercise. However, by referring to Table 7 an estimate can be made of the time required by the author to develop PLATO exercises for the course material presented in BA 573.

TABLE 7

Implementation Dates of PLATO Exercises
in BA 573 During Spring Semester 1972

PLATO Exercise	Date Implemented	Average Hours of Instruction*
1	March 13, 14	.99
2	April 10	.66
3	May 2	.67
4	May 16	.72
5	June 1, 2	1.53

*Based on the average completion times for each exercise reported in Table 2.

Exercise 1 required an unusual amount of development time. Probably five weeks of elapsed time occurred between the beginning of the development of the exercise and its implementation. Even though the author was experienced in the use of computers and other programming languages, there was a considerable amount of time required learning how to use the PLATO system and the TUTOR language to develop suitable instructional material for BA 573. Referring to Table 7 it can be seen that exercises 3, 4, and 5 were each implemented about two weeks after the prior exercise was implemented. This basically reflects how much faster the author could develop an exercise once he had the experience of developing two PLATO exercises behind him. The best estimate of author development time required to develop PLATO exercises for this type of material can be drawn from the results of exercise 5. It is estimated that the author spent about 50 hours in the development of this exercise. Therefore, at this stage in the author's experience with the PLATO system, since exercise 5 provided 1.53 hours of instruction, about 33 hours of development time were required to produce 1 hour of instructional material for a PLATO exercise covering a relatively

complex topic in a technical course.

This estimate appears realistic when compared to the average development time of 27 hours per hour of instructional material developed which is quoted at the PLATO laboratory by staff personnel. It appears that this figure was developed by asking all authors for a specified time period to report the development time required for their lessons. So, this figure was probably based on times reported by new authors and very experienced authors alike for the development of everything from straightforward drill exercises to the complex inquiry exercises over subject material which varied greatly in its technical content. These time estimates do not include the time necessary to properly document a PLATO exercise so that someone else could understand or modify the exercise.

At this stage in its development, PLATO is considered to be an experimental system so there are no charges incurred directly for the use of the PLATO system. Therefore, the only real costs incurred in this period are those related to the time required for an author to develop exercises for the PLATO system. Likewise, when the recurring costs for the PLATO system are considered, no comment can be made about the charges for the use of the PLATO system since no charges were incurred for the students in BA 573 who participated in the exercises at the PLATO laboratory in this research effort. The other major element of recurring costs, the amount of an author's time required to maintain developed exercises cannot be estimated either based on this research, but the major requirements from him can be identified. An author would be required to monitor each session of a PLATO exercise scheduled for students and make appropriate revisions to these exercises based on significant developments in his field and the PLATO

system. Thus, based specifically on this research effort, not much information can be provided relevant to the direct costs associated with developing and processing exercises on the PLATO system.

However, based on material published by the originators of the PLATO program, a few comments can be made about the estimated operating costs of PLATO III and the projected operating costs of PLATO IV. The cost projections for PLATO IV and the related costs for PLATO III are based upon a unit of viewing time of instructional material, a student contact hour. The individual elements of cost considered in these estimates are categorized into those associated with:

1. central computer facility which provides the communication control and data processing facility for the system
2. computer software system which supports the language in which instructional material is written,
3. student console or terminal which provides the interface between the author or student and the computer
4. central management services which are associated with the computer-based educational system
5. communication channels which carry the information between the computer and the individual student terminal
6. development of lesson material which is to be presented on the computer-based educational system.

The costs of the current PLATO III system are not specified in detail, but it is suggested that the operating costs of the PLATO III system with the optimum number of 50 student terminals in use range from $1.90 to $2.90 per student contact hour. These operating costs include charges for the

central computer facility, student terminal and central management services. It is estimated that the cost for the development of the software for the PLATO III system should be allocated at an additional $.30 per student contact hour. These costs for the PLATO III system are based on the assumption that the 50 student terminals will be used 2000 hours per year to provide about 100,000 student contact hours per year.

These costs which it is estimated are presently being incurred on the PLATO III system can be contrasted to the projected costs for the PLATO IV system. The features of PLATO IV which enable the projected costs per student contact hour to be significantly less are:

1. the use of a large third generation computer which can service up to 4000 student terminals concurrently with several hundred different lessons available for use at the same time
2. the use of a lower cost student terminal with improved design characteristics
3. the capability of serving student terminals at remote locations within a 150 mile radius of the central computer facility at reasonable costs.

Thus, the PLATO IV system is projected to have the capability to provide over 8,000,000 student contact hours of use per year through its 4000 student terminals which each can provide 2000 student contact hours of use per year. This broader base of student contact hours over which costs can be allocated and the lower unit costs of the hardware components of the PLATO IV system cause the projected operational costs per student contact hour for this version of PLATO to be significantly lower than the estimated operational costs of PLATO III per student contact hour. Table 8 has been

developed to compare the estimated costs for the current PLATO III system and the planned PLATO IV system.

TABLE 8

Summary of Estimated Operating Costs
of PLATO III vs. PLATO IV

(per student contact hour)

Type of Cost	PLATO III	PLATO IV
Central computer facility	-	$0.11
Student terminal	-	$0.18 to $0.50
Central management services	-	$0.03
total of above operating costs	$1.90 to $2.90	$0.32 to $0.64
Computer software system	$ .30	$0.01
Communication channels	$0.01	$0.01 to $0.03
total of all operating costs	$2.21 to $3.21	$0.34 to $0.68

The other major element of cost incurred in a computer-based educational system is for the development of lesson material. It is estimated that on the PLATO III system this cost has ranged form $400 to $800 per hour of instructional material prepared. It is suggested that if the number of students who took a given one hour lesson were 500 per year for five years, then this cost could be prorated in terms of a charge of about $.25 per hour of student use of the lesson. This type of charge could be applied to a course which required 50 hours on the PLATO system per semester to suggest that a fee for this course for using the PLATO system could be $12.50, a charge comparable to the cost of a textbook. It has been suggested that this type of thinking can be extended to the PLATO IV system as a method to be considered for recovering the costs associated with the development of lesson material.

All of the above cost information was extracted from an article written by the originators of the PLATO program in order to provide the reader with the flavor of the type of reasoning which has been done relative to determining

the economic feasibility of the PLATO system. The research effort which is the subject of this paper can only comment on this economic feasibility to the extent previously indicated. The reader is referred to the article referenced in this discussion of economic feasibility for the detail data behind the quoted costs.[1]

The benefits associated with the use of the PLATO system are the other major aspect which must be considered to determine the economic feasibility of the PLATO system. During this research, many of the potential benefits of teaching material from an introductory course in operations research on the PLATO system were identified. The major benefits which it is believed would be derived from implementing this type of material on the PLATO system are listed below. They include:

1. Students could learn certain subject material better.
2. Students could learn certain material faster.
3. Students could become more involved in the educational process and motivated to perform better work.
4. Students could become more aware of the capabilities of the computer, especially interactive computing.
5. Students deficient in certain subject areas could be brought to a desired level of competence at their own pace.
6. Instructional material could be presented to students in a more consistent manner.
7. PLATO exercises could be modified more easily than other textual material could be revised.

Most of these benefits would be difficult to quantify, but an estimate

[1]Alpert, D., and D. Bitzer, Science, 167, 1582 (1970).

could be made for the value of a benefit which reduced the amount of time required to teach specific subject matter. In contrast, it would be very difficult to quantify the value of a benefit related to producing a better quality student. No attempt has been made to quantify the benefits which were realized in the educational process for course BA 573 as a result of this research. Therefore, to conclude this section it should be stated that this report cannot comment objectively on the question of the economic feasibility of the PLATO system, but has only presented information considered relevant to this question that was uncovered during this research effort.

Indirect Benefits Realized

An important secondary objective of this research was to determine whether a student's use of the PLATO system to learn operations research material instills in him a greater appreciation for the use of the computer and the techniques of operations research in the problem-solving process. The capabilities of the computer were demonstrated to the student both directly and indirectly in the PLATO exercises developed for BA 573. Routines were developed in the individual exercises which demonstrated the computational power of the computer as well as the value of subroutines which could perform iterations of calculations, vector multiplication and all the vector-matrix calculations associated with a profit model. In the PLATO exercises, the student was indirectly exposed to the capabilities of the computer when various types of instructional material were presented and various types of response judging routines were used which demonstrated the versatility of the computer. In addition, each PLATO exercise was built around a problem situation which the student participated in solving using

the techniques of operations research.

Therefore, in the attitude survey which the students were requested to complete on the last day of class in BA 573, an attempt was made to gain information about how valuable the students believed the techniques of operations research and the computer would be in solving problems in the business world. In addition, the attitude survey was designed to attempt to determine what educational experiences in BA 573 caused the students to have these opinions. Appendix E presents a summary of the students' comments and rankings on these surveys. The following remarks will attempt to interpret their responses regarding the value of the techniques of operations research and the computer.

Question 1 on the survey asked "What is your opinion about the role the computer will play in your career as a manager?" The composite student ranking on the attitude scale provided for this question was approximately midway between a composite opinion of useful and very useful. Furthermore, sixteen of the nineteen students who provided written comments to this question indicated a high regard for the capabilities of the computer. The students' responses to question 2, "How do you foresee using the material taught in this course in your responsibilities as a manager?" showed that 27 of the 40 students commenting anticipated applying the material taught in BA 573 constructively. Question 3 was meant to draw out the student's opinion about the combined use of the tools of the techniques of operations research and the computer in problem solving. In this question, the student was asked "What is your opinion about how valuable the techniques of operations research and the computer will be as problem solving tools in the

business world?" The composite ranking on the attitude scale provided for this question was very close to a combined opinion midway between valuable and very valuable. Therefore, it is assumed that the students in BA 573, in general, had a fairly high opinion for the computer and the techniques of operations research as problem solving tools at the conclusion of this course.

In question 4 on the attitude survey, the student was asked whether his attitude toward these problem solving tools had changed during his coursework in BA 573. In response to the question, "How have the learning experiences in this course caused your regard for the computer and the techniques of operations research to change from what it was before this course?" 24 of the 37 responses indicated that students now had a more enlightened attitude toward these tools after having completed their coursework in BA 573. In reference to these comments which reflected an attitude change, 21 students indicated a more positive opinion about using the computer and the techniques of operations research for problem solving. Since most of the students indicated a high regard for these problem solving tools in prior questions, it can be assumed that the thirteen students who commented that their learning experiences in BA 573 changed their attitude toward these tools slightly, if at all, probably had a fairly good attitude regarding the use of the computer and the techniques of operations research before they entered BA 573. Therefore, it can be assumed that the learning experiences in BA 573 did cause some students to appreciate more the use of the capabilities of the computer and the techniques of operations research in the problem-solving process.

Question 5 was designed to determine what effect the student's experience on the PLATO system had on his formation of a more favorable attitude toward these tools. Question 5 asked the student, "To what extent has your work on the PLATO system affected your attitude towards the use of the computer and the techniques of operations research as problem solving tools?" The composite measure on the attitude scale provided for this question indicated that the use of the PLATO system affected the student's attitude toward these tools favorably, in general. Appendix E shows that eleven of the fourteen students who made written comments to this question were very complimentary to the PLATO type of teaching and found the PLATO exercises to be helpful in making them aware of the capabilities of the computer and the techniques of operations research. Thus, it appears that the subjective evidence tends to indicate that a student's participation in PLATO exercises developed for an introductory course in operations research does cause him to appreciate more the capabilities of the computer and the techniques of operations research in the problem-solving process.

Conclusion

The results of this research effort indicate that it is technically and operationally feasible to teach subject material from an introductory course in operations research on the PLATO system, but that this type of teaching medium is not currently economically feasible. The hardware and the software which support the PLATO system were completely adequate for the development and presentation of instructional material. For the PLATO exercises developed in this project, the subject students appeared to learn the material as well or better on the PLATO system and in a lesser amount of time, in

general, than through the more traditional means of reading textual material and completing homework assignments. Furthermore, the majority of the students who participated in PLATO exercises expressed the opinion that they believed a computer-based educational system was an effective teaching medium and that this type of instruction should be continued and increased in the introductory course in operations research.

Although the economic feasibility of this type of instructional medium was not proven, there are several considerations which should be evaluated when the future potential of computer-based educational systems is being investigated.

1. The hardware and software supporting these systems is being improved continually to provide instructional systems with improved operating characteristics and lower unit operating costs.
2. Instructional material developed for these systems has the potential for widespread usage which would reduce the unit developmental costs.
3. The student who participates in this type of educational system is receiving a beneficial educational experience by functioning in an interactive computer environment.
4. The unit costs associated with the more traditional educational media have been exhibiting a steady growth trend.[2]

Since it is believed that the potential exists to apply the capabilities of the modern digital computer to upgrade the educational process in an economic manner, it is recommended that research to determine the feasibility of computer-based educational systems be continued. The major objective of

[2]Atkinson, C. R., and H. A. Wilson, Editors, Computer-Assisted Instruction - A Book of Readings, Academic Press, Inc., New York City, New York, 1969.

future research in this area should be to develop the additional information required to answer fully the question of the feasibility of this medium of instruction. However, another important objective of this research should be to explore further the characteristics of computer-based educational systems to more completely understand and evaluate the educational strategies and techniques possible with this type of medium.

In summary, the attributes of computer-based educational systems which were identified in this research project were:

1. capability to accommodate students with a wide variety of individual ability levels and learning styles through highly individualized instructional sequences which are either student controlled or based upon an analysis of the student's past performance
2. provision of an educational environment which enhances the learning process by enabling a student to become more actively involved in the educational process, to have his responses evaluated on a real-time basis, and to work at his own pace in relative privacy
3. ability to provide instructional material from session to session on a more consistent basis in terms of lesson content than an individual instructor could or different instructors could
4. provision of an opportunity for students to become aware of the capabilities of the computer and to develop a positive attitude regarding the use of computers in a modern society
5. provision for students to use the computational power of the computer during a lesson and for authors to use the data handling capabilities of the computer to collect data during a lesson to analyze the performance of students and the effectiveness of the lesson

6. ability to provide a student with the opportunity to explore a problem situation and discover answers for himself in an unstructured inquiry type of environment
7. capability to provide a student with the opportunity to express his feelings about a learning experience at the time when these feelings occur by entering appropriate information into the system
8. capability to record a student's responses during a lesson and the potential to analyze the pattern of his responses to provide significant information about the student's learning process, problem-solving process and decision-making process
9. ability to easily modify a lesson to improve it so that it will affect all students in comparison to the means available to modify other types of instructional material
10. capability to provide a wide variety of visual instructional material and related audio material during a lesson
11. ability to handle a wide variety of teaching tasks and, thus, provide instructors with the opportunity to do more meaningful work.

As indicated, these characteristics of computer-based educational systems should be evaluated to determine which aspects of this medium are more efficient and/or effective than the attributes of the more traditional media of instruction. To facilitate this type of evaluation, future research with computer-based educational systems should be documented better in terms of the principles utilized in preparing the instructional material to be presented, the educational strategies and techniques used to implement lesson material, and the specific results attained through the use of this medium. This

kind of proposed evaluation implies that the attributes of the more traditional educational media should be better understood and more capable of measurement, also. Moreover, a related objective of future research with computer-based educational systems should be to discover how best to integrate this medium into the instructional process with the traditional media to improve the overall educational process.

To conclude this report, it should be stated that computer-based educational systems appear to have the capability to improve the educational process. The major advantages which it is believed could be realized through the use of this type of educational system are:

1. a more efficient educational medium with attendant lower unit developmental and operating costs dependent primarily upon the necessary technical improvements in such systems and the widespread usage of instructional material developed
2. a more effective educational medium whereby student achievement and performance is improved in learning and applying subject material
3. a more versatile educational medium in terms of the type of student who can be accommodated, the type of subject material which can be presented and the setting in which the learning experience can be accomplished
4. a better understanding of the learning process based upon the collection and analysis of the student responses provided by a computer-oriented instructional system.

Thus, computer-based educational systems seem to have the potential to revolutionize the educational process. As the modern digital computer, which provides the capabilities for this type of instructional medium, has

revolutionized the field of data processing, so can this method of presenting subject material impact on the field of education. Computer-based educational systems can provide the opportunity to enhance the educational process by presenting instructional material in a more effective, versatile and efficient manner and by providing the means to gain additional insight into the learning process.

Appendix A

Summary of Comments from Questionnaires
for PLATO Exercise 1

Typical Comments	Students Commenting
Do you have any suggestions to improve this specific exercise?	
allow more time	8
make questions clearer	2
explain keyset better	1
make answer judging more flexible	1
allow more use of ANS key	1

* * * *

What is your impression of this type of teaching procedure where you interact with a computer-based system such as PLATO through a terminal?

excellent teaching procedure	5
great, outstanding, very impressed	6
interesting, fun, enjoyed it	7
good supplementary exercise	5
limits way to answer questions	1
prefer reading a good text	1
prefer to have a good instructor	1
had a feeling of man vs. machine	1

* * * *

How do you believe the PLATO system can best be utilized to teach the material usually presented in an introductory operations research course?

supplement lectures	5
reinforce basic concepts	5
for examples and homework problems	5
teach FORTRAN and linear programming	3
make students be more explicit	1

* * * *

In what way has this exercise served to clarify or reinforce the material currently being taught in BA 573?

clarifies course material and direction	6
presents good examples of use of material in real world	5
good review of linear algebra	3
helped me to understand vectors	1
computer interaction made me understand computers better	1
exercise was a novelty	1

* * * *

Appendix A---Continued

Typical Comments	Students Commenting
Do you have any additional comments or suggestions regarding the development of a computer-based operations research course?	
mechanize calculations	2
furnish written material before the exercise	2
develop more operations research material	2
furnish a copy of lesson material after exercise	1

Appendix B

Summary of Comments from Questionnaires for PLATO Exercise 2

Comments which related to how this lesson or future lessons might be improved:

1. clearly indicate when computations should be performed manually and the result entered into the system
2. introduce the use of the PLATO system better
3. use the computational capabilities of the machine more
4. try using multiple choice questions
5. develop harder problems
6. don't compliment the student when his answer is correct
7. some questions were ambiguous

Comments which related to the student's impression of this type of teaching procedure:

1. very valuable method
2. good possibilities
3. effective teaching procedure (two students)

Appendix B---Continued

4. I like it since it's easier to learn concepts this way

5. impressions are entirely positive since I like to learn at my own speed and to have immediate feedback

6. impressive and more interesting than conventional type of homework

7. good because of feedback to answers (two students)

8. good method and would cause me to learn faster because of immediate feedback on errors

9. I don't like it because it is frustrating to have to guess what answer is acceptable .

Comments relevant to the value of the continued use of the PLATO system in teaching material in an introductory course in operations research:

1. use for homework problems (five students)

2. use to teach modeling, vector algebra and a problem solving approach (three students)

3. use to perform computations

4. use to reinforce concepts taught in class and make them clearer

5. use to solve problems illustrating concepts

6. use to test students

Appendix C

Summary of Comments from Questionnaires for PLATO Exercise 3

Comments which related to how this lesson or future lessons might be improved:

1. provide more instructions on the forms of correct answers which are considered acceptable

2. provide more instruction on how to get into subroutines

3. indicate specifically when word answers are required and when numeric answers are required

Appendix C---Continued

4. provide class lectures on material to be covered by a PLATO lesson and then require related homework to be completed after a PLATO session

5. develop more complex follow-up problems

6. make the lessons more difficult and challenging

7. provide more than one assistant to answer questions during a PLATO exercise

Comments which related to the student's impression of this type of teaching procedure:

1. like it very much

2. much better than classroom discussion

3. interesting and enjoyable learning experience

4. gain satisfaction from completing an exercise

5. like real time grading of your answer

6. like the subroutine to multiply vectors

7. O.K., if it fits into the course

8. process interesting, but can only act as a review of material taught in class

9. am concerned about the consequences of exposing a graduate student to this system

10. very frustrating, typing answers is tedious

11. prefer class

Comments relevant to the value of the continued use of the PLATO system in teaching material in an introductory course in operations research:

1. reinforce basic concepts of linear algebra (five students)

2. solving homework problems (three students)

3. teach new and more difficult concepts

Appendix D

Summary of Comments from Questionnaires
for PLATO Exercise 4

Comments which related to how this lesson or future lessons might be improved:

1. provide additional written material for the lesson to facilitate understanding it
2. provide for more extensive review of prior material in the lesson when the student requests it
3. provide the written material for the lesson to the student for his review prior to the lesson
4. make the questions less vague and the hints as to the correct answers clearer
5. provide the acceptable answer for a question to the student automatically after he responds incorrectly a certain number of times

Comments which related to the student's impression of this type of teaching procedure:

1. impressed, can be very helpful and practical
2. thoroughly enjoyed it
3. much easier to follow than class presentations
4. believe in audio-visual teaching procedures and would like to take more tests of this nature
5. much greater personal involvement and greater demands placed on my learning
6. it is a viable idea
7. tedious, but would be very worthwhile the first couple of weeks of the course
8. not as frustrating since this was my second exercise, with even more familiarity it could become much more efficient and fun
9. fair, like having an average instructor
10. exercise was O.K., but sometimes it got down to man vs. machine

Appendix D---Continued

Comments relevant to the value of the continued use of the PLATO system in teaching material in an introductory course in operations research:

1. supplement and reinforce basic course material (six students)
2. act as a means to integrate course material
3. help to solve problems
4. tackle all areas of the course
5. provide the step-by-step solution of classic operations research problems
6. provide a student intermittent feedback on progress in the course provided now only by tests
7. have PLATO classes in basic areas before classroom instruction, then have similar lessons after classroom instruction as feedback for progress analysis

Appendix E

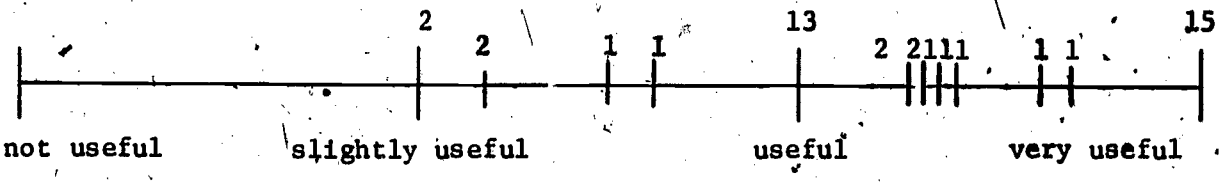
Summary of Comments and Rankings from the Attitude Surveys

1. What is your opinion about the role the computer will play in your career as a manager?

Typical Comments	Number Commenting
immensely useful tool	3
great deal	3
important role	3
key to doing better business	2
big supporting role	1
ever increasing role	1
large, depending on company	1
fairly important role	2
not used much in management in India	1
don't know	1
the less, the better	1
Total commenting	19

Appendix E---Continued

Summary Attitude Scale for the Above Question



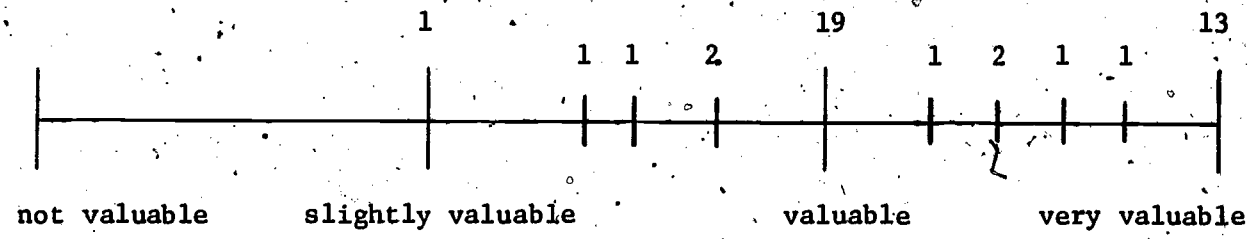
2. How do you foresee using the material taught in this course in your responsibilities as a manager?

Typical Comments	Number Commenting
provide a basic understanding of the area	16
perform reasonable problem solving	5
problem formulation	3
concept construction	1
control and recordkeeping	2
don't know	1
not much	12
Total commenting	40

3. What is your opinion about how valuable the techniques of operations research and the computer will be as problem solving tools in the business world?

Typical Comments	Number Commenting
no other efficient way	1
computer will be excellent	1
may be valuable	1
Total commenting	3

Summary Attitude Scale for the Above Question



Appendix E---Continued

4. How have the learning experiences in this course caused your regard for the computer and the techniques of operations research to change from what it was before this course?

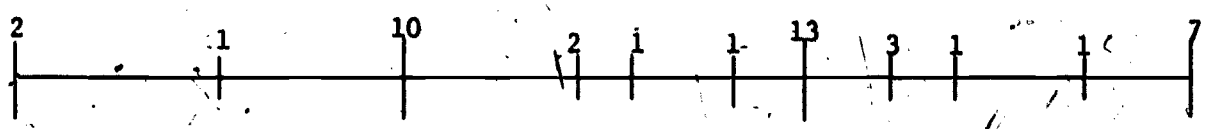
Typical Comments	Number Commenting
realize how valuable they are now	6
understand them better	5
place value on them now	7
more interested now	2
see them more as tools now	1
now realize their imperfections	3
slightly, if at all	13
Total commenting	37

5. To what extent has your work on the PLATO system affected your attitude towards the use of the computer and the techniques of operations research as problem solving tools?

Typical Comments	Number Commenting
PLATO was very helpful	1
PLATO was excellent	1
work on PLATO was very useful	1
PLATO has helped me see their relationships	1
using PLATO was fun and effective	2
didn't use PLATO enough	1
use PLATO as much as possible as a tool to learn operations research	1
the more exercises, the better	1
changed from attitude of frustration and worthlessness to feeling of valne	1
improved attitude toward the computer some	1
not at all	1
indifferent	1
PLATO was too picky on answers	1
Total commenting	14

Appendix E---Continued

Summary Attitude Scale for the Above Question



6. What teaching techniques used in this course have been the most effective in your opinion?

Typical Comments	Number Commenting
PLATO	17
computer work	7
class problems	6
graded homework	2
PLATO homework problems	2
quizzes	2
direct problem solving	2
availability of outside assistance	1
working with the instructor in his office	1
lectures	1
self study	1
Total commenting	42

7. What recommendations would you make for using PLATO type instruction in future BA 573 courses?

Typical Comments	Number Commenting
increase its use	11
use it right from the beginning of the course	6
problem solving	4
continue to use it	3
as much as possible	3
supplement lectures	3
basic concepts	3
quiz preparation and quizzes	2
definitions	2
extend its use to more complex concepts	1
application of theory	1

Appendix E---Continued

Typical Comments	Number Commenting
introduce student to use of computer	1
make it a programmed learning course	1
none	1
drop it	1
prefer an instructor	1
needs more improvement	1
allow more time in an exercise	1
coordinate with class lectures better	2
make keyboard instructions better	2
make programming more flexible	3
Total commenting	53

8. What is your general impression of the PLATO system as a teaching technique?

Typical Comments	Number Commenting
helped me considerably	1
very impressed	1
excellent teaching method	1
very useful	1
like its immediate feedback	1
has much potential, use it to solve harder problems	1
very worthwhile if integrated with classroom instructions	1
learned more from it than classroom instructions	1
interesting exercise	1
provided helpful teaching	1
valuable, but could be improved	1
could be good, can also be very frustrating	1
O.K. for some courses	1
by requiring the exercise, you force the student to do some studying	1
another method of exposure	1
you can guess your way through the exercise	1
prefer a good text to reference	1
Total commenting	17

Summary of Attitude Scale for the Above Question