DOCUMENT RESUME

ED 125 659 IR 003 751

TITLE Instructional (II); Computerized Testing; and CATC Discussion and Demonstration. Papers Presented at the Association for Educational Data Systems Annual Convention (Phoenix, Arizona, May 3-7, 1976).

INSTITUTION Association for Educational Data Systems, Washington, D.C.

PUB DATE May 76

NOTE 91p.; For related documents, see IR 003 748-756; Some parts may be marginally legible due to print quality of original

AVAILABLE FROM Association for Educational Data Systems, 1201 Sixteenth Street, N.W., Washington, D.C. 20036 ($10.00 for entire proceedings)

EDRS PRICE MF-$0.83 HC-$4.67 Plus Postage.

DESCRIPTORS *Computer Assisted Instruction; Computer Oriented Programs; *Computer Programs; *Computers; Data Processing; Educational Innovation; Educational Research; Feedback; Grading; Higher Education; Information Services; Information Systems; Instructional Materials Centers; Instructional Media; *Instructional Technology; Linear Programing; Man Machine Systems; Mathematics; *On Line Systems; Programing; School Libraries; Student Evaluation; Systems Approach; *Test Construction; Tests

IDENTIFIERS AEDS 76; ALLCOMBS; *Association for Educational Data Systems; Calculators; CREAM; SOCRATES

ABSTRACT

Eighteen papers on instructional technology, computerized testing, and computer assisted test construction (CATC) presented at the 1976 Association for Educational Data Systems (AEDS) convention are included here. Two papers discuss computer assisted instruction in calculus and teacher education courses. The use of computers in theoretical mathematics, school media centers, and individualized instruction programs is presented in four papers. Goal programing in education is explained and the uses of the hand-held calculator for education are reviewed. Faculty rating policies for mathematics students are analyzed. Eight articles examine aspects of computerized testing and CATC. They include an overview of computers and testing, the use of computerized quiz grading, interactive computerized testing, descriptions of SOCRATES, ALLCOMBS, CREAM, and the Classroom Teacher Support System. (CH)

INSTRUCTIONAL (II); COMPUTERIZED TESTING; and CATC DISCUSSION AND DEMONSTRATION. Papers presented at the Association for Educational Data Systems Annual Convention.

Martin T. Lang
B. Isselhardt
R. Vandusseldorp
J. Kelly
J. C. Gunderson
R. Vanderwiel
W. R. Johnson
Dale Woods
Don D. Shirley
A. R. Kaled
Eugene A. Collins
Dean C. Larsen
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ASSOCIATION FOR EDUCATIONAL DATA SYSTEMS

The 1976 AEDS International Convention

Proceedings

TODAY'S REVOLUTION: COMPUTERS IN EDUCATION

May 3 - 7, 1976

Phoenix, Arizona

These Proceedings have been made possible by a grant from the IBM Corporation as a service to the educational community.

THE EFFECTIVENESS OF USING COMPUTER EXTENDED INSTRUCTION TO TEACH BASIC CONCEPTS OF INTRODUCTORY CALCULUS

Martin T. Lang
California Polytechnic State University
San Luis Obispo, California 93407

ABSTRACT: The purpose of this experimental study was to develop and evaluate a particular mode of computer extended instruction (CEI) in introductory calculus. Prepared computer programs were used by students in an otherwise conventional calculus class to investigate the concepts of functions, limits and derivatives. The CEI was evaluated on two dimensions: concept attainment and general knowledge. The results indicated that the use of CEI can have a significant effect on the learning of basic concepts of introductory calculus. Male students seemed to benefit particularly from the CEI, while female students were not measurably affected by it. No significant effect on the learning of general knowledge in calculus was observed. However, there was some indication of the presence of a differential effect (interaction) of the CEI on students with varying levels of proficiency in algebra and trigonometry.

There is a growing awareness among educators that the vast capabilities of modern computers have brought us to the verge of a revolution in education that far exceeds anything that man has ever experienced. It is easy to see that the computer technology which now exists could readily provide us with a totally different instructional program in our schools. Some changes have already been implemented while needed experimentation is continuing briskly in all areas of instruction.

Mathematics educators have been interested in this computer revolution right from the start. In fact, most of the pioneering studies in computer aided learning were done with mathematics students at various levels. This interest has expanded exponentially so that now many mathematics educators feel that the computer will soon become a standard tool throughout the mathematics curriculum. It is therefore of great importance that we direct our attention toward devising effective modes of computer utilization in the classroom.

In this paper I would like to describe a research study which concerned itself with the development, implementation and evaluation of a particular type of computer use in an introductory calculus class.

Modes of Computer Use in Mathematics Education

Several modes of computer utilization have been suggested for mathematics programs in the schools and colleges. Three general categories that are often mentioned are Computer Assisted Instruction (CAI), Computer Managed Instruction (CMI) and Computer Extended Instruction (CEI). A brief if somewhat oversimplified explanation will serve to distinguish these categories.

In CAI, the computer more or less assumes the role of the instructor. It may be used for the purpose of presenting a particular learning sequence, providing drills and exercises to the student, and testing diagnostically as well as for mastery (Suppes, 1968). Though the teacher is not replaced, many of his traditional functions are altered and he is freed to concentrate on individual problems in his class.

CMI, on the other hand, provides a managerial tool for the instructor. The function of the computer in CMI is to assist the teacher and the student in planning instructional sequences. Through repeated diagnostic evaluations and detailed record keeping handled by the computer, a student is able to receive individualized prescriptions for learning tasks.

CEI is a label which has been used to describe the role of computers as a supplementary teaching tool in a conventional classroom setting (Bitter, 1971; Dorn, 1970). Though the instruction is not presented on the computer, CEI is intended to provide the teacher with instructional capabilities that would not otherwise be possible. At the same time the student can be provided with a tool to aid him in mathematical explorations far beyond his usual limits. In this mode, the computer becomes a type of laboratory device which can be used as an aid to the teacher in presenting material to the students or as a means of leading students to observe mathematical properties, to discover mathematical relations, and to perceive mathematical concepts.

It was this third category, Computer Extended Instruction, which was the focus of this research study. The specific objectives were to develop and evaluate a particular mode of CEI in a college level introductory calculus course.

Related Studies

The use of CEI in an introductory calculus course has received attention by a number of researchers in recent years. Already nine years ago, Smith (1970) conducted an experiment with honors level calculus students in which the students were given special computer assignments to investigate the limit of functions. In 1968, Fiedler (1969) carried out a study to determine whether students develop a deeper grasp of some of the concepts of calculus through programming problems dealing with these concepts on a computer. Later during the same year, Bitter (1970a) conducted an experimental calculus course in which students used a time-sharing system to work special computer assignments. The objective was again to illustrate and fortify some of the basic concepts of calculus. The experiment by Bitter was repeated with some revisions the following year and a formal educational study was carried out to assess the effectiveness of this approach (Bitter, 1970b). Holoien (1970) conducted another study in the Fall of 1969 using some computer augmentation with students of introductory calculus and a few years later Bell (1972) devised still another experiment where certain computer projects were used to enhance the learning of calculus concepts.

Though not all of these studies produced conclusive results, the studies of Bitter, Holoien, and Bell seemed to give strong indication that the use of CEI in introductory calculus provided an effective means of improving instruction. Statistically significant results were obtained by each of these researchers favoring CEI groups over classes receiving only conventional instruction. It seemed also transparent in these results that the teaching of fundamental concepts of calculus, such as functions, limits, derivatives, etc., rather than techniques was most positively benefitted with the use of CEI.

A Special Mode of CEI

Although the above mentioned studies were all similar in their objectives, the nature of the CEI that was employed was quite different in each case. This resulted both from the difference in computing power available on the various campuses and the difference in the philosophy of how the computer should be used. In all cases cited above, students were required to learn a simple computer programming language and to write some of their own programs.

Because of certain problems encountered when students must write their own programs to illustrate a mathematical concept, it was decided for this study to develop several programs which would be readily available and usable by the students, including those with little or no knowledge of computer programming. Consequently, programs were devised by the experimentor to illustrate functions, graphs, limits of functions and derivatives. The programs were general in nature, requiring the student to supply the function to be investigated and the necessary parameters (e.g., a value where the limit of the function was to be taken). The programs were stored on disk files on a large multi-programmed computer system (CDC 6600/6400) and were accessed through the submission of four or five control cards in the batch processing mode. Turnaround time was minimal on this system -- usually only a few minutes -- providing the students with almost immediate results and the opportunity to freely experiment with varying input parameters.

The type of computer extended calculus described above was labeled the "PCP mode of CEI" (Prepared Computer Programs mode) to distinguish it from other forms of CEI. (At the time the study was made, this form of computer use was judged to be most appropriate for the particular students involved. Similar types of CEI could of course be devised on time-sharing systems using teleprinters as I/O devices.)

All the computer augmentation was accomplished through special supplementary assignments which directed the students to investigate certain phenomena regarding various mathematical functions. The emphasis was on teaching the underlying concepts of calculus and not on teaching problem-solving or techniques.

Experimental Design

To assess the effectiveness of using this special mode of CEI in introductory calculus, an experimental setting was created and several formal hypotheses were formulated and tested. The design for the experiment was the (non-equivalent) pretest-posttest control group design (Campbell and Stanley, 1963). Two pretests were given to the subjects to control for initial differences in preparation in precalculus mathematics, while two posttests served as separate measures of effectiveness in the study.

Procedures

The students involved in this experiment were selected from introductory calculus classes in the Fall semester of 1972 at the University of Texas at Austin.

Two lecture classes taught by senior faculty members were arbitrarily selected to participate in the experiment. Each of these classes was subdivided into four discussion sections, headed by two teaching assistants. Thus a total of two professors and four teaching assistants (besides the experimentor) were indirectly involved in the study. Complete test data were available for subsequent analysis from 84 students in these classes, and from this group certain subsamples were defined.

In order to evaluate the effectiveness of this special mode of CEI in introductory calculus, the sample was partitioned into two groups. Four out of the eight discussion sections involved in the study were selected to comprise the experimental or CEI group, while the remainder was designated as the control or Non-CEI group. This assignment of intact classes to the CEI and Non-CEI groups was random, but subject to certain constraints which assured a crossing of professors, teaching assistants and class time with the experimental variable. Both groups were provided supplementary assignments, but the computer augmentation was confined strictly to the CEI group.

Several specific questions (which are given in the next section together with their responses) were considered during the evaluative phase of this study. (The formal hypotheses relevant to these questions will not be stated here.) Statistical tests were made using two separate criterion measures. One of these was the author-produced Calculus-Concepts Test, a test of the basic concepts of introductory calculus, while the second criterion was the Calculus-General Test, a standardized test of general knowledge in introductory calculus. Two standardized precalculus tests, one in algebra and one in trigonometry, served as covariates in the study. The general technique of analysis used was the multiple linear regression analysis.

Conclusions

The three fundamental questions that were asked in this study and their responses which are based on the statistical analyses follow.

Question 1. Does the PCP mode of CEI, when used in an introductory college calculus class, have a positive effect on achievement and concept attainment?

The statistical tests of the main hypothesis which pertained to this question provided strong indications that an affirmative answer is justified when the focus is on concept attainment, especially for the male students. When considering those students in the sample who showed active participation in the experiment, a nearly significant ($\alpha = .059$) difference in adjusted means was observed on the Calculus-Concepts Test favoring the CEI group over the Non-CEI group. For the subsample consisting of only male students, this difference was clearly significant ($\alpha = .016$), again favoring the CEI group. No significant difference was apparent for the female subsample.

On the other hand, when achievement in calculus was measured by a test of general knowledge (the Calculus-General Test), no statistically significant differences between the CEI and Non-CEI groups were apparent. It should be kept in mind, however, that the CEI was not aimed at teaching general techniques, but was primarily designed to elucidate the basic concepts of calculus.

The analysis pertinent to Question 1 revealed therefore that the use of CEI can be an effective supplementary tool in teaching the basic concepts of calculus. However, with the particular objectives which were used in this study, the CEI seems to be of questionable value in bringing about improvement in the general techniques of calculus, although there are apparently no deleterious effects. This is in pricise agreement with the finding of Bell (1972). Holoien's (1970) results seem also to point in this direction since he found that certain concepts, such as the limit of a function and the evaluation of a function, seemed to benefit more directly by the computer augmentation than other topics. Bitter (1970b) found in his experiment that even on a general test, the CEI group outperformed the Non-CEI group. No separate test of the effects on concept attainment was made by Bitter.

It will be observed that since each of these studies utilized different modes of CEI in calculus, they cannot be considered as replications. Nevertheless, the general support for the use of CEI in calculus, particularly toward teaching the basic concepts of functions, limits, derivatives, and so forth, seems to point toward the fact that the computer can be used effectively to enhance calculus instruction. Therefore serious thought should be given toward implementing CEI in introductory calculus in our colleges and universities.

Question 2. Is there a differential effect from the use of the PCP mode of CEI on students of varying levels of ability in precalculus mathematics?

The results of the analyses dealing with this question showed that when the criterion is concept attainment, there is no reason to suspect any interaction of treatment with prior achievement in precalculus mathematics. However, when a test of general knowledge was the criterion, there was some indication that students with high trigonometry pretest scores benefitted more from the CEI in calculus than those with low trigonometry scores, while the reverse seemed to be true for students with high algebra pretest scores. In the statistical tests, this differential effect of CEI on students with varying levels of precalculus achievement was observed to be close to significant, with an α-level of .084. Thus the answer may well be affirmative when a general knowledge of calculus is of primary concern.

Figure 1 shows the regression planes for the CEI and Non-CEI groups and indicates the region where the expected score of the CEI group exceeds that of the Non-CEI group for different combinations of trigonometry and algebra pretest scores. From the equations of the regression planes, it can be shown that the predicted score for a member of the CEI group is greater than that for a member of the Non-CEI group whenever the linear inequality $35A - 29T < 348$ is satisfied, where A and T are the Algebra and Trigonometry pretest scores.

If this result regarding the effect of CEI on the acquisition of general knowledge in calculus can be substantiated in further research, it may be advisable to use different strategies of instruction — some with CEI, others without — for students of varying levels of prior achievement in trigonometry and algebra. Considerably more research is necessary, however, before any such conclusions are warranted.

Question 3. Is the effect of using the PCP mode of CEI different between the male and female students?

In regard to this question, the statistical tests provided some evidence that there is a difference in the effectiveness of using CEI between the male and female students when the criterion is concept attainment. The test of the main hypothesis using only male subjects revealed that the

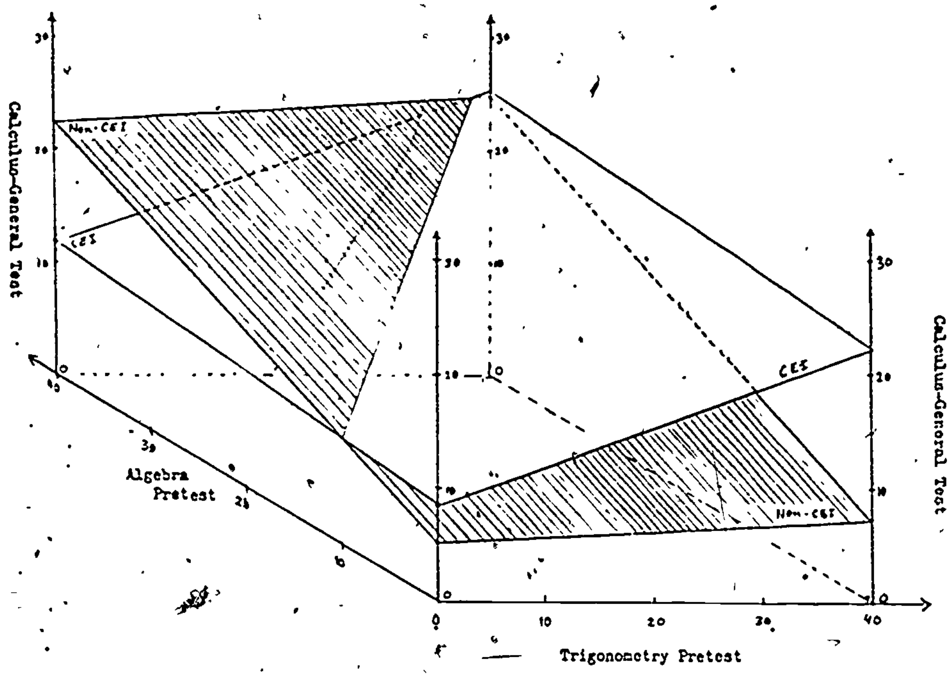

Figure 1.

Regression Planes for CEI and Non-CEI Groups

adjusted means on the Calculus-Concepts Test were significantly (α = .016) higher for the CEI group than for the Non-CEI group. A similar test restricted to the female subsample showed no significant difference. On the other hand, when the Calculus-General Test was used as criterion, there were no significant differences between the CEI and Non-CEI groups for either the male or female subsamples.

The fact that the male subjects apparently responded more favorably to the CEI than the female subjects substantiates a similar observation by Bitter (1970b) who surmized that this difference may be the result of a difference in attitude toward mechanical devices by these two groups. It may also be possible that the female students tend to be more apprehensive and fearful than the male students when confronted with new and unfamiliar situations. The experimentation in computer extended instruction certainly provided some uncertainties for the students throughout the semester, and it may be this factor that destroyed the potential effectiveness of the CEI for the female students.

Possible implications of this result are that different modes of instruction may be appropriate for male and female subjects in order to achieve optimal learning in calculus. Much more research is needed before such action is contemplated, for it may well be that there is a need to provide the female students with more opportunities of dealing with mechanical devices or of exposing them to more unique and unfamiliar situations at an earlier age so as to eliminate any unusual misgivings they may have toward computers.

Limitations

Several factors which may have affected the outcomes of this experiment should be considered when evaluating the results. Any conclusions based on this study must be tempered with these limitations in mind.

1. The subjects who were included in the experiment were all students who had enrolled in the introductory calculus classes taught by two cooperating professors at the University of Texas. Although the assignment of subjects to the experimental and control groups involved a process of randomization, the original selection of the sample from the total population of introductory calculus students at the University of Texas at Austin was not random. Therefore, any generalizations beyond this population at the University of Texas will require even greater care.

2. The homework assignments which served as the vehicle for the CEI were supplementary and were given in addition to conventional assignments relating to the class lectures. Since the supplementary assignments were given to the students through their teaching assistants while the regular assignments originated directly from their professors, there was a tendency for the students to place more weight on the regular assignments. This fact seems to have significantly reduced the number of active participants in the experiment and may in addition have diminished the impact of the computer augmentation.

3. Although the problems which were investigated in the supplementary assignments involved

standard topics from introductory calculus, the timing of the assignments was not precisely coordinated with the lecture presentations of these topics. Thus the effect of the CEI may conceivably be increased with a closer conformity of the assignments with the classroom presentations.

4. Independent investigations apart from the assigned problems using the prepared computer programs were also encouraged, but the rapid pace that is typical in a beginning calculus course and the considerable demands placed on the students due to the dual sets of homework assignments seemed detrimental to the realization of the goal of individual experimentation. Closer coordination of the CEI with both the classroom presentations and the regular assignments may also lead to more spontaneous computer experimentation, and may enhance the effectiveness of the CEI.

5. The mode of CEI which was used in this experiment involved the student use of prepared programs dealing with certain basic concepts of introductory calculus. Student access to the computer was gained at one of several remote job-entry terminals, using a "batch-processing" method where turnaround time was usually between five and ten minutes. At installations where computer turnaround time is substantially longer than this, the positive effects of this type of CEI may be seriously reduced. However, minor modifications are easily possible which would provide access to calculus programs of this nature via on-line teleprinter terminals or CRT terminals when such terminals are readily available.

6. The fact that no positive conclusions could be made regarding the effectiveness of the CEI relative to learning the general techniques of calculus is probably due to the fact that the supplementary assignments and the computer programs were specifically intended to strengthen the understanding of some of the basic concepts of calculus and not the techniques. This objective was apparently accomplished without causing any deleterious effects on the learning of techniques. Therefore it should not be concluded that the CEI cannot be used also as a tool for enhancing the learning of other aspects of introductory calculus. The type of assignments as well as the mode of computer use will surely need to be altered to bring about positive results in this direction.

Recommendations

The following recommendations are suggested in consequence of the experiences gained through the research study in computer extended calculus conducted at the University of Texas at Austin in the fall of 1972.

1. When CEI is used in calculus, it should be carefully integrated into the regular instructional program, with conventional as well as computer oriented assignments originating from the instructor who is primarily responsible for the course.

2. Although the use of "batch processing" in CEI has the advantage of providing the user with printed results including long lists and extensive graphs, the use of on-line teleprinter and CRT terminals should be carefully explored. Whenever the turnaround time of batch-processed programs is excessive, these alternate means of computer communication seem preferable. Further research is needed to explore the possibilities of such use and to assess their effectiveness.

3. Because students who are unfamiliar with computers often have a considerable fear of them or of the peripheral equipment associated with them, it is advisable to provide some close guidance in the use of any equipment which is utilized in conjunction with the CEI programs. Carefully written instructions are important but often inadequate to dispel initial fears, so personal instruction should be provided at the start. A computer consultant who is familiar with the CEI programs should also be available for additional help throughout the duration of the course.

4. The use of the prepared programs should be as simple as possible so as to provide the student with a readily usable means of investigating mathematical concepts without first requiring him to learn a new complex skill.

5. Additional programs illustrating basic mathematical ideas in various courses should be developed and research assessing their effectiveness as part of the instructional program should be conducted.

6. Further investigation into the possible presence of an interaction between the use of CEI in calculus and the prior ability of students in algebra and trigonometry is necessary.

7. Concerns for the differential effectiveness of CEI on male and female students need further research.

Concluding Statement

The general purpose of this study was to develop a particular mode of computer extended instruction in introductory calculus and to assess its effectiveness in bringing about learning. The results of the research showed that the PCP mode of CEI which was developed for use at the University of Texas at Austin can be effective in teaching basic concepts and should be explored more fully as an aid in calculus instruction. This generally confirms the earlier results of similar studies by Holoien (1970), Bitter (1970b) and Bell (1972), who also found CEI to be a useful tool in calculus instruction.

It is true that the computers which are available at different schools vary widely and that computer access by students is possible in many ways. Experimentation at the local level with several modes of CEI in various areas of mathematical content is therefore strongly recommended prior to a wholesale commitment to one form or another.

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APPLICATIONS OF GOAL PROGRAMMING TO EDUCATION

Ralph A. Van Dusseldorp, The University of Iowa
Bernard J. Isselhardt, Jr., The University of Iowa
James O. Gunderson, Multonomah County Intermediate Education District
John R. Kelley, The University of Iowa
Raymond Vander Wiel, Cedar Rapids Community Schools
William R. Johnson, Loras College

ABSTRACT. Goal Programming (a generalized extension of linear programming) is a method of allocating resources while considering multiple objectives or goals. The brief history of goal programming will be explained with reference to its development from linear programming. The basics of problem formulation will be discussed for educational settings. The primary requirement of problem formulation is an ordinal ranking of the goals. These goals may represent incommensurable quantities. Likewise, the goals may be mutually conflicting. Examples of educational applications will be presented and discussed with respect to linear programming solutions to the same or similar problems.

Goal programming is both a modification and extension of linear programming (Lee, 1972). Linear programming is the name given to the operations research technique wherein a mathematical model of a problem situation is formulated to contain a linear objective function and constraints. Through the use of an iterative algorithm known as the simplex technique or a modification thereof, the objective function and its components, homogeneous choice variables, are optimized (maximized or minimized) subject to the constraints (limited resources or restrictions) stated in the model. Constraints represent relationships between the choice variables and are stated as linear inequalities and/or equalities. Because of the availability of computer programs for performing the mathematical calculations necessary to the solution of complex linear programming problems, it is not the computation but rather the model formulation that is the chief concern of the probelm-solver.

The goal programming approach was originally formulated by Charnes and Cooper (1955) and named in Volume I of <u>Management Models and Industrial Applications of Linear Programming</u> (1961). The method presented used a weighted objective function. Ijiri (1965) presented an algorithm for goal programming in which the objective function is prioritized rather than weighted. This causes all resources in a problem to be applied to the first goal until it is satisfied and then the second goal until it is satisfied and so on. By 1968 Charnes and Cooper et. al., had made applications in the fields of media planning and manpower planning. In the last six years the number of articles concerning goal programming has increased greatly, and one book, in particular (Lee, 1972) provides an excellent introduction to the area. Lee presented an algorithm for goal programming that is a modification of the standard linear programming simplex method. The computational basis of the examples discussed here depend on Lee's algorithm and his Fortran program. His program has also been adapted for time-sharing on the H-P (access) system at the University of Iowa.

How Goal Programming and Linear Programming are Alike

1. Both require the formulation of a model for transforming a real-world decision problem into a prescribed format.
2. Both are concerned with goal or objective achievement.
3. Both have the following model characteristics:
   a. The optimization of the objective function subject to a set of constraints or limited resources.
   b. Variables must have the property of non-negativity.
   c. Constraints and objective function are linear, i.e. all variables are to be the first power or "of the first order". No quadratic or higher order relationships may be included in the model formulation.
4. Both represent a systematic attempt toward rationality in decision-making.
5. Both are adaptable to analyzing decisions. When a computer program is available to perform the necessary calculations, the educational manager can easily "try-out" different formulations of the problem model. He can, for example, observe the effects upon the solution of changing the coefficients of constraint variables.

How Goal Programming is Unlike Linear Programming

1. Goals -- The goals of a particular problem are modeled as constraints although they may be statements (written in the same format as

constraints) which are not restrictive or descriptive of limited resources but positive in nature, representing a desirable condition. These constraint/goals will be hereafter referred to simply as goals. Since it is not usually necessary that each goal in the model be achieved exactly, goal programming allows for the likelihood that goals in a real-world problem may be conflicting. The deviational variables preserve the equality of each goal when combinations of goals are conflicting. Although the choice variables within goals must be consistent as to units of measure, goals may represent incommensurable quantities.

2. Deviational variables -- A feature of goal programming models not found in linear programming models is the use of deviational variables. These variables enable all goals to be stated as equalities. Of primary concern are the variables known as slack and surplus deviational variables. After all goals which are to be incorporated in the model are identified, each must be assigned slack and/or surplus variables.
3. Objective function -- In goal programming the objective function usually contains no choice variables, but rather is made up of the deviational variables contained within the goals. When multiple goals are thus represented in the objective function, it is said to be multidimensional. Because the optimal solution would be the one in which the sum of the deviations from goals is minimal, the objective function is always minimized. In order that goals be achieved according to their importance, the deviational variables in the objective function must be prioritized according to the ordinal ranking of goals or the importance of each goal to the manager. The same priority level may be assigned to one or more deviational variables. Deviational variables on the same priority level may be weighted; it is perhaps most desirable to weight such variables when it makes clearer that the "cost" of underachievement of a particular goal is greater or lesser than another of equal importance. The units of measure of the deviational variables within the objective function may be nonhomogeneous, e.g., representing dollars and weeks, rather than one type of unit.

Limitations of Goal Programming

Lee (1972) indicates four limitations of goal programming as: (1) proportionality, (2) additivity, (3) divisibility and (4) deterministic. Proportionality, as a limitation, means that the linear relationships in the problem model must be proportional. Additivity indicates that the activities expressed in the objective function and goals must be additive in order to ensure linearity. Divisibility means that the values for decision variables in the optimum solution of a goal programming problem can be nonintegral. Recently, a study on integer goal programming has appeared (Keown and Lee, 1975), therefore it is not anticipated that the application of goal programming will long be limited to a feasible solution set of positive real numbers. The deterministic nature of the goal programming model means that model coefficients must be constants. In this sense, the goal programming procedures is not better than most other rational procedures which require a "snapshot" of a continually changing world. Again, there is reason to believe that this limitation may be eliminated or at least reduced, in light of recent work showing that constraints may have variable limits (Sweeney and Williams, 1974) or represent a unique probability distribution (Contini, 1968).

Despite its present limitations, goal programming is believed to be applicable to a wide range of educational problems.

Educational Applications of Goal Programming

As an extension of linear programming, it is assumed that goal programming can readily be adapted to the solution of educational problems previously utilizing linear programming techniques, but it appears that a greater value of goal programming lies in its facility for providing a more realistic model of the decision environment than has previously been possible with linear programming.

Linear programming has been utilized in the solution of such educational problems as:

1. minimizing travel distance in busing for integration (Ontjes, 1971).
2. maximizing the district-wide assignment of teachers (Bertie, 1972).
3. optimizing various aspects of a foundation type of state aid program (Matzke, 1971).
4. determining university faculty salaries (Hartley, 1973).
5. designing alternative forms of salary schedules for public school teachers below the university level (Bruno, 1969, 1970).

Goal programming models have been created for the solutions to such educational problems as:

1. allocation of resources in institutions of higher learning (Lee, 1972).
2. determining a job factor compensation plan in a public school setting (Gunderson, 1975).

While applications of goal programming in education have been relatively scarce, there is reason to believe that it will prove to be a valuable decision-making aid to the school administrator once programs are widely available (Gunderson, 1975).

Model Formulation

The basic linear programming problem is formulated as follows:

$$\text{Optimize } Z = \sum_{j=1}^{n} c_j x_m$$

$$\text{such that } \sum_{j=1}^{n} a_{ij} x_j \leq b_i$$

and $x_j \geq 0$

where a_{ij}, b_i, and c_j are arbitrary constants.

The basic goal programming problem is formulated as follows:

$$\text{Min. } Z = \sum_{i=1}^{n} (d_i^- + d_i^+),$$

$$\text{such that } \bar{A}x + \bar{I}d^- - \bar{I}d^+ = B$$

$$\text{and } x, d^-, d^+ \geq 0$$

where $\bar{A}$ is a n x n matrix, $\bar{I}$ is a n x n identity matrix and $\bar{B}$ is a n component column vector.

As in any model formulation the following steps should be taken:

1. define the variables and constraints.
2. formulate the constraint equations.
3. develop the objective function.

Summary

Goal programming is an extension and modification of linear programming which allows the educational manager to more closely simulate real-life situations. Both linear and goal programming are optimization techniques which lend themselves to increasing the rationality of decision-making. The foremost value of goal programming is in its facility for solving problems with hierarchically arranged, conflicting goals. While there are presently certain limitations of goal programming which may slightly narrow the scope of its feasible applications, it is believed that its potential for educational problem solving is vast.

Examples of Educational Problems and Goal Programming Solutions

In the following three sections, examples of goal programming applications to educational problems are given. The reader will find that, while all three examples are simplified, the complexity of the given model formulations increases substantially from one model to the next.

1. Scheduling Instruction

Problem

In a high school, 60 students are enrolled in algebra. Those students can be taught through large group instruction (all 60 in a class), medium sized group instruction (30 to a class), small group instruction (15 to a class) or individual instruction. We need to decide how much time they should spend in each type of instruction, subject to certain conditions:

Condition 1. Regulations require that each student spend at least 250 minutes per week in algebra class or individual instruction. But, we also want to avoid having students spend more than 250 minutes per week in algebra. Letting T_L stand for the number of minutes per week each student will spend in large group instruction and similarly for medium group (T_M), small group (T_S) and individual instruction (T_I), this may be expressed by:

$$T_L + T_M + T_S + T_I + d_1^- - d_1^+ = 250$$

where d_1^- is the number of minutes per week less than 250 that each student spends in algebra and d_1^+ is the number of minutes per week more than 250 each student spends in algebra.

Condition 2. Due to limited space for large classes to meet, we would like to schedule algebra students for not more than 60 minutes per week of large group instruction. This is expressed by:

$$T_L \qquad -d_2^+ = 60$$

where d_2^+ is the number of minutes per week over 60 schedules for large group instruction in algebra.

Condition 3. We would like to schedule each student for at least 40 minutes per week of small group instruction. This is expressed by:

$$T_S \qquad +d_3^- = 40$$

where d_3^- is the number of minutes per week less than 20 that each student is scheduled into small group instruction.

Condition 4. We would like each student to have at least 10 minutes per week of individual instruction. This is expressed by:

$$T_I + d_4^- = 10$$

where d_4^- is the number of minutes per week less than 10 that students spend in individual instruction.

Condition 5. We would like to limit the amount of teacher time used to teach algebra to 1,070 minutes per week. This is expressed by:

$$T_L + 2T_M + 4T_S + 60T_I - d_5^+ = 1070$$

where d_5^+ is the teacher time used in excess of 1,070 minutes per week.

Priorities

Now priorities must be established for the conditions - actually for the deviation variables, the d's. Let us place the highest priority on each student having at least 250 minutes of instruction per week. This is expressed as $P_1d_1^+$. Let us say that our second priority is to use not more than 1,070 minutes of teacher time per week. This is expressed as $P_2d_5^+$. Similarly, priorities are established for the other deviation variables. These made up our object function which is expressed by:

$$\text{Minimize} = P_1d_1^- + P_2d_5^+ + P_3d_2^+ + P_4d_1^+$$
$$P_5d_4^- + P_6d_3^-$$

Model

Thus the goal programming model for this problem is:

$$\text{Minimize } Z = P_1 d_1^- + P_2 d_5^+ + P_3 d_2^+ P_4 d_1^+ + P_5 d_4^- + P_6 d_3^-$$

$$T_L + T_M + T_S + T_I + d_1^- - d_1^+ = 250$$

$$T_L - d_2^+ = 60$$

$$T_S + d_3^- = 40$$

$$T_I + d_4^- = 10$$

$$T_L + 2T_M + 4T_X + 60T_I - d_5^+ = 1070$$

Solution

Solving the above model yields the following results:

Type of Inst.	Min/Week
Large Group (T_L)	60
Medium Group (T_M)	155
Small Group (T_S)	25
Individual (T_I)	10

With that solution, students spend exactly 250 minutes per week in algebra and exactly 1070 minutes per week of teacher time is used. Thus all conditions except the one having to do with the minutes per week for small group instruction are met. Only 25 minutes per week are allocated to small group instruction rather than the 40 we wanted. That, however, was our lowest priority.

2. Busing

This example will deal with the busing of students to achieve specified percentages (or better a range of percentages) of students in schools by groups (such as race, sex, vocational interest, etc.). There has been a great deal of work done on this problem using a linear approach (Stimson and Thompson, 1974). Here a goal programming formulation of a busing problem and the solution for a sample problem will be presented.

The basic problem can be viewed as having two requirements. The first is to achieve a specified percentage range composition by group. The other is to minimize transportation costs via minimization of total busing distance.

The sample problem will be constructed as follows. We will assume a community with three schools and three corresponding tracts that provide students for the three schools respectively. The student population by group, the school capacities, and the busing distances (using an average distance) are summarized in Tables 1 and 2.

Table 1

Tract	STUDENTS Group 1	Group 2	School Capacity
1	450	225	750
2	600	0	1000
3	50	700	650
Totals	1100	925	2400

Total Student Population: 2025

Table 2

Distances to Schools (in miles)

Tract	1	2	3
1	1.2	1.5	3.3
2	2.6	4.0	5.5
3	0.7	1.1	2.8

A linear programming formulation of this problem could only consider one objective - busing distance or percentages of students by groups. The goal programming formulation can consider both objectives. In the problem four priorities will be used. Priority one will be to have all students assigned to a school. Priority 2 will be to have no school assigned more students than its capacity will allow. Priority 3 will be to achieve a student composition such that each group falls within a range of 40% to 60% of the total school population. And finally, priority four will be to minimize the total busing distance.

The problem can be summarized as follows where

X_{ijk} = the number of students from tract i in school j from group k.

School

1 $\Sigma X_{i1k} + d_1^- = 750$

2 $\Sigma X_{i2k} + d_2^- = 1000$

3 $\Sigma X_{i3k} + d_3^- = 650$

These constraints force students to be assigned to all schools with no school filled beyond its student capacity.

Tract

1 $\Sigma X_{1j1} + d_4^- = 450$

and

$\Sigma X_{1j2} + d_5^- = 225$

2 $\Sigma X_{2j1} + d_6^- = 600$

and

$\Sigma X_{2j2} + d_7^- = 0$

3 $\Sigma X_{3j1} + d_8^- = 50$

and

$$X_{3j2} + d_9^- = 700$$

These constraints force all the students to be assigned to a school.

Ratios for school:

1 $$-0.6\Sigma X_{i11} + 0.4\Sigma X_{i12} + d_{10}^- = 0$$

and

$$0.4\Sigma X_{i11} - 0.6\Sigma X_{i12} + d_{11}^- = 0$$

2 $$-0.6\Sigma X_{i21} + 0.4\Sigma X_{i22} + d_{12}^- = 0$$

and

$$0.4\Sigma X_{i21} - 0.6\Sigma X_{i22} + d_{13}^- = 0$$

3 $$-0.6\Sigma X_{i31} + 0.4\Sigma X_{i32} + d_{14}^- = 0$$

and

$$0.4\Sigma X_{i31} - 0.6\Sigma X_{i32} + d_{15}^- = 0$$

These constraints establish the 40% to 60% range for each group of students.

Distance

$$1.2\Sigma X_{11k} + 1.5\Sigma X_{12k} + 2.6\Sigma X_{13k} + 2.6\Sigma X_{21k} + 4.0\Sigma X_{22k} + 5.5\Sigma X_{23k} + 0.7\Sigma X_{31k} + 1.1\Sigma X_{32k} + 2.8\Sigma X_{33k} - d_{16}^+ = 3800$$

This constraint forces the total distance bused beyond 3800 miles to be minimized. The value of 3800 miles was obtained as the solution to a linear programming transportation problem for the given data with the objective being to minimize total distance bused. Therefore for this goal programming problem, 3800 miles represents an ideal minimum distance.

Now according to stated priorities the objective function is

$$\text{Minimize } Z = P_1 \sum_{i=4}^{9} d_i^- + P_2 \sum_{i=1}^{3} d_i^- + P_3 \sum_{i=10}^{15} d_i^- + P_4 d_{16}^-$$

The solution is summarized in Table 3; it shows the number of students assigned from each tract and group to each school.

Table 3

School	Group	1	2	3	Group Totals	School Totals
1	1	0	450	0	450	750
	2	0	0	300	300	
2	1	450	0	50	500	900
	2	225	0	175	400	
3	1	0	150	0		
	2	0	0	225		
Totals		675	600	750		

As can be seen priority 1 was met completely with all students assigned to a school. Priority 2 (filling all schools) was not met. There was a deviation of 375, but that is exactly the amount of excess capacity for the three schools. The desire to meet the 40% to 60% composition for each group was met exactly in schools one and three. School two had a 44% to 56% group composition range which is still within the desired 40% to 60% range. Finally, priority 4 had a deviation of 295 which means the total busing distance for this situation is 4095 miles.

3. Job Factor Compensation

This example is a summary of J.O. Gunderson's doctoral dissertation (1975). It concerns the development of a model for determining job factor compensation for supervisory personnel under collective bargaining. The basic idea is to distribute wages to supervisory personnel where the dollar amounts desired exceed the dollar amounts available. The situation models collective bargaining between the supervisory personnel and the board of education of a school district. The supervisor's jobs were assumed to be composed of twelve variables. The variables can be summarized as follows:

Variable	Definition
X_1	District advisory committee participation
X_2	Administration of different collective bargaining contracts
X_3	Scope of work
X_4	Budget development involvement
X_5	Supervision of multiple programs
X_6	Supervision of other supervisory staff
X_7	Supervision of classified staff
X_8	Responsibility for capitol equipment
X_9	Direct contact with students
X_{10}	Supervision of staff under a fair dismissal law
X_{11}	Highest degree obtained
X_{12}	Years of supervisory experience

Thus each supervisor considered had a twelve item "job factor profile." This job factor profile determined the amount of special compensation an individual would receive beyond his base salary. Each variable was also scaled to reflect an internal hierarchy of importance within each factor. Each individual's salary was then the sum of his base salary plus the total dollar value of each variable times the individual's appropriate scale factor. The total budget for all supervisors' special compensation was the sum of the individual special compensation salaries. This is an important sum because limits placed on this total will affect the basic alignment between each individual's special compensation.

Six basic types of constraints were formulated to reflect the relationships between the variables. The first constraint was the total district resources allowed for special compensation. The second type were the variable value constraints used to force equality among the variables unless the goal priorities affected them otherwise. The third type was the negotiation constraint and it was used to balance the total value of variables 1-6 against variables 7-12. Fourth was the factor sum constraint which was used to provide overall model factor consistency. The fifth and sixth types of constraints were used to control the scale hierarchy widths and midpoints respectively. The total number of constraints (rows) was 23. Rows 1-13 dealt with individual job factors and rows 14-23 dealt with the relations of job factors, and personnel types to each other. After internal scaling of each variable there were 349 total factor weights.

Six priorities (goals) were established to reflect the overall view of how the job factor compensation model should work. Goal 1 was to use all of the resources allocated by the district for special compensation. The desired level was to limit underachievement of the total resources allocated. Goal 2 was to balance board initiated and supervisor initiated factors. Goal 3 was to balance the effect of the width and midpoint scale factors. Goal 4 was to maintain overall consistency of special compensation for the supervisors. Goal 5 was to maintain overall consistency and equality between each of the 12 variables. Goals 2-5 wanted then to limit both over and under achievement. Finally goal 6 was to allow the total resources spent to exceed the limit desired in Goal 1. That is, the desire was to allow overachievement within reason. This was done to allow the other goals a greater chance of affecting the final solution.

The initial district resources budget for special compensation was set a $58,395 (row 1) and each individual job factor (rows 2-13) was set at $167 ($58,395/349) for each scale level. The solution values of the variables then reflect the relative importance of each variable in view of the constraints and goals used.

The results are as follows:

Variable	Value (in dollars)
X_1	225.10
X_2	167.00
X_3	167.00
X_4	137.00
X_5	167.00
X_6	167.00
X_7	167.00
X_8	205.40
X_9	186.70
X_{10}	119.50
X_{11}	205.40
X_{12}	186.20

These results indicate that variables 1, 4, 8, 9, 11 and 12 were the most important since they exceeded the base value of $167. Variables 2, 3, 5 and 6 equal the base value and variable 10 was of least importance in this formulation.

Four similar models, formulated by changes in various priorities, weighting factors and goals, were tested as a part of the study. The result of model testing was a conclusion that a goal programming model was developed which did demonstrate the capability to develop a job factor compensation plan in a public school setting. The model was able to relate goal statements of a prioritized and weighted nature to a series of mathematical relationships and produce useful output for the decision-making process.

Conclusion

The adequacy of any single set of output is dependent upon environmental and human considerations that are beyond the scope of any model. However, by using a tool such as goal programming, a significant aid is provided to the decision-making process and the consequences of a given set of goals can be evaluated ahead of time.

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HUNTING BIG GAME--WITH A BOW AND ARROW

Dale Woods
Northeast Missouri State University, Kirksville, Missouri 63501

ABSTRACT: I will show how one may take a small computer (one that doesn't even have double precision), use mathematical ingenuity and determine whether a large number--say over 1000 digits--has a small factor (less than 1000000). I also will indicate how one may use a small computer in the search for large amicable pairs--over 1000 digits. Also, I will present some currently unpublished amicable pairs as a part of the lecture.

Most of you will recognize the title of this paper is similar to a previously published paper by Professor D. N. Lehmer. I do not mean to imply that the big game for which I am proposing to hunt is as large as that stalked by Professor Lehmer or that the speaker has equal to or greater than his mental acumen in order to trap the elusive big game. However, the speaker hopes that he will be able to inspire some promising student to go after big game in the future.

Obviously, the speaker does not have access to the hunting equipment currently being used by many other mathematicians (hunters), therefore, the subtitle "with a bow and arrow" seems to be appropriate.

If one goes on a hunting expedition, there are several things one must consider:

1. What sort of big game should one attempt to catch? Our environment, number theory, abounds with big game, unsolved problems, hence one must decide whether it is the "really big" animal you decide to try to catch or is one to be satisfied with a smaller trophy to hang in his den for a conversational piece.

2. Is there the game available or what is the probability that one could find an animal that has not already been captured by a previous hunter? There may be that the particular game you desire to capture is as extinct as a dinosaur or that all of this game is like the whooping crane whereby all are known and are protected.

3. What territory does the particular game inhabit? Would the animals probably be in a region you would be able to reach with your method of conveyance (mental and physical endurance). Most any amateur mathematician could have performed the factorization feat of Professor Cole but not many of us would have given up the Sunday golf or the Saturday night beer to devote his energies to the division of integers.

4. Do you have the proper equipment to capture the particular animal? An elephant could be a prize if one used an elephant gun or perhaps a poisoned dart, but one would be a bit bold to go on an elephant hunting safari with a muzzle loading gun.

5. After the previous questions have been considered, one should think through the following question. How does one make proper use of the environment one finds himself? Where does one use the computer at his command and where does one use his mental abilities with a paper and pencil to minimize the time spent and to maximize the output in trophies collected?

6. After a foraging expedition, does one come home with a prize? Could your "butterfly net" be empty or does one return home like the deer hunter with the prize atop his automobile for all the world to see?

Let us consider the above in greater detail in the remaining time that I have to discuss one particular safari with you. Perhaps I should say bore a captive audience with small talk.

Of all the unsolved problems (uncaptured game) in mathematics one of the most fascinating, to me, are the perfect numbers. Is there an odd perfect number? Are there infinitely many perfect numbers? Anyway, only twenty-four have been found (captured) and at that only twelve since the computer (post bow and arrow) era. Should one attempt to locate an odd perfect number? If one exists it must be greater than 10^{36}. From previous mathematical experience, it is indicated that if any odd perfect number exists it will be a very large number and not to be found by direct computer search. Should one attempt to find the twenty-fifth perfect number or attempt to prove an infinite number exists? Surely by use of a computer a rigorous proof of the number of perfect numbers is not probable and since the twenty-fourth perfect number $(2^{19936})*(2^{19937}-1)$ contains some 12003 digits it is very logical to shy away from a search (safari) for this type of game.

A generalization of a perfect number is the amicable pair. Any perfect number being amicable to itself. Are there infinitely many amicable pairs? Is there an amicable pair of opposite parity? At present, both of these questions are still unanswered. We do know, however, that more than 1100 pairs have been found and that if an odd pair exists then the product of the pairs must be divisible by at least twenty-one different primes.

Professor H. L. Rolf was the first to discover, in 1964, an amicable pair using a computer. Prior to this time, some five hundred thirty-five pairs were known (in May 1943--390 pairs). All, of course, were of the same parity. Four pairs were published in 1974 and at least three published in 1975. Since several others have located (been able to capture) amicable pairs very recently it seemed to me that this was the type of game I should attempt to capture for a trophy. Since there are many different varieties (classifications) of these beasts some decision had to be made as to just what type would be sought. I decided to limit my hunt to two very simple varieties.

All amicable numbers M, N must satisfy the relation S(M) = S(N) = M + N where, for the benefit of Donna, my secretary, S(K) is the sum of the divisors of K. Using this relation a systematic search is easily performed on a small computer. The first such search produced some new pairs but most of all, all pairs less than 10^6 were now located. The systematic search has later been extended so that it is believed that all pairs less than 10^8 have been tabulated. If we consider the special cases, then there is some possibility of locating some new pairs. First, we restrict M = Epq and N = Er. Contrary to some previous writers, I find that in studying this problem it is convenient to write solutions in the form

Q = C/D -1,   C = E*(P + 1),
D = E*P -(P + 1)*(S(E)-E),
R = (P + 1) * (Q + 1) -1.

then assign prime values for P and test the primality of Q and R. Now if E = 2^N and P = $2^{N-M}*(2^M + 1)-1$ we have Q = $2^N*(2^M + 1)-1$ and R = $2^{2*N-M}*(2^M + 1)^2-1$. For different values of M and N this form has been studied for many years. Several interesting theorems regarding the primality of the P, Q, and R for different values of M and N may be proven. I have found several interesting relationships that as yet have not been published so we will not discuss these at this time.

If M = 1 in the above we have the formula derived by a 9th century Arabian mathematician Korrah. To my knowledge he did not locate an amicable pair by use of this formula. It seems that Fermat found the first pair in 1636 from this formula. The most recent was found by Professor te Riele in 1974 using N = 40 and M = 11. This latest pair have forty digits each.

I first calculated the possible pairs for M = 1, N ≤ 200 not because I would hope to find any new pairs since it has been well-known for quite sometime that none existed. I did carry out the computations up to N = 400. According to my calculations, there are no pairs in this range. I then calculated all values of M and N up to M = 150. I must say that I did get the pair for N = 40 and M = 11 but unfortunately, Professor te Riele had found this pair some three or four months before my work was completed. In this instance, my "butterfly net" was empty. I do plan to publish the results of this work in the near future.

My next step was to let E = 2^N * S. Only five of this type had been found, however, I suspected there were more around. That is, game surely must be found of this type and in the range that the small computer could reach. The basic formula is Q = (E*S*(P + 1))/((P + 1)*(S + 1 - 2 * E)-E*S)-1. One now assigns prime values for S and P then computes Q and R. I restricted N to less than sixteen since on a small computer (Honeywell 1640) I found that I cannot work effectively with numbers greater than 8300000. A program was written with these restrictions. After using 28 seconds of computer time, I found only one amicable pair, the one known to Pythagoras. Obviously, the program needed to be altered. The next program was written to take advantage of the fact that the denominator should be a factor of E*(P+1). We then let Q=((E*(P+1)/((P+1)*(S+1-2*E)-E*S)/S)-1. I further restricted S=2*E-1+2^M for M = 1 to 2*N. This program produced five amicable pairs of which two were known. Those unpublished are

2^{11} * 4507 * 23039 * 811259
18691430399   and

2^{11} * 4099 * 2102783 * 1077413951
2265568819642367.

These have been forwarded to a journal for publication. The basic program has been altered so S=2*E-1+L for L=2 to 2*E. With this change, nine pairs were obtained of which five had previously been published. The other two unpublished numbers are:

2^{13} * 25423 * 23039 * 292872959
6747972998399   and

2^{15} * 66047 * 4359101 * 139491263
608056647884927.

If one has the big gun (a computer with integer double precision or a multiprecise arithmetic program) one would be encouraged to go after the bigger game. But without this equipment one must do some reflection before attempting a safari. One could, of course, do as one mathematician did in the past. Have his students (slaves if you dare) perform the tasks on a hand calculator which has a considerable number of digit precision. Anyway, one with no slaves and with only a bow and arrow must make other adjustments.

If one does not have the multiprecise arithmetic available one can create one by using bases, other than 10. After doing this (poisoning the arrow) one is ready to proceed. The basic idea is to simply use blocks of digits. For example, if n=853476 then we use N(2)=853 and N(1)=476. One now can easily perform the four basic arithmetic operations with numbers up to say 1000 digits quite easily. To add or subtract simply calculate C(L)=A(L)±B(L) then normalize with base 1000. To multiply calculate C(K)=C(K)+A(I)*B(J) where K=I+J-1 and I, J range over the numbers in the multiplier and multiplicand then normalize. To divide is just a bit more difficult if the divisor is greater than 1000, however, if the divisor is less than 1000 all one needs to do is to calculate Q(L)=INT(A(L)/D) then normalize. To generalize the divisor to numbers greater than 1000 but less than 1000000 we calculate N=A(L)*1E3+A(L-1) so Q(L)=INT(N/D) then follow the fundamental division algorithm. With numbers greater than 10^6 the trial quotient gives a bit more trouble. A further comment is that we are of course limited to the size of the computers memory for subscripting.

After calculations of the Q and R satisfying the equation for amicable pairs the next step is to determine if these computed values are prime or composite. We need then an efficient method of factorization for large numbers. To locate factors less than 1000 one of course just uses the division algorithm repeatedly. I will not dwell on the factorization process since this is very well covered in the recent work of Professors Selferage and Guy. I should, however, remark that Professor Shanks has developed a process to factor twenty-digit numbers on a hand held calculator. Since the Q and R for this second problem are quite small the method of Shanks is quite satisfactory.

As previously noted our "butterfly net" was not empty. Further expeditions for hunting big game probably will be quite productive. I suggest that you spend some Sunday afternoon (not as many Sundays as Cole) on a hunt. In my opinion, there are many trophies available. In fact, so many that they do not make a particularly good trophy (not many are published except in the NOTICES) any more. The major deterrant seems to be in the area of factorization. One might say-to determine if that which we have captured is not in season.

May I suggest that future computer oriented mathematicians continue working on more efficient methods of factorization. When this is accomplished I feel certain other big game will be brought in as trophies for all to view. This is especially true if we consider the case where $E = 2^N$. In my opinion, many more pairs may be found by considering

$$E = \prod_{i=1}^{K} P_i^{A_i} \quad \text{for } K \geq 10.$$

It has been said that the factorization of numbers up to 10^{80} will not be accomplished in this century. Perhaps this prediction is like one of the past whereby it was indicated that it would be quite sometime before numbers of 40 digits were factored. Surely the mathematicians of the next 20 years will be able to do much more in this area than the mathematicians have accomplished in these past 20 years. One mathematician has developed an interesting method of factorization by assuming Riemann's hypothesis.

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DATA PROCESSING AND SCHOOL MEDIA CENTERS

Don D. Shirley
Supervisor of Library Services
Shawnee Mission Public Schools, Shawnee Mission, Kansas 66204

ABSTRACT: Our district of 40,000 students is using data processing in the school media center programs for central library processing, data retrieval and acquisitions. The major function of the computer is central library processing. This is on-line through the use of four 3767 terminals, utilizing IBM's FASTER generalized software package and the district's IBM 360/40 computer. The retrieval aspects of the system include bibliographic data, inventory data and printing of extra cards and labels. Selected tapes are used to generate microfiche union catalogs for our high school collections of 80,000 items. Our data bank consists of 152,000 unique book and multimedia titles. The cost of the program has reduced from $4.30 (1969-70) to $2.18 (1974-75).

I. Introduction

Shawnee Mission (Kansas) Public Schools is located in the suburban portion of the Greater Kansas City Metropolitan area. The district enrollment is around 40,000 students; kindergarten through twelfth grade. There are 49 elementary schools, ten junior high schools and five senior high schools. The district was unified in 1969 from 12 elementary school districts of various sizes and one high school district which also included junior highs. The highest enrollment, almost 46,000 students, was during 1970-71 school year with a steady decline of several hundred students a year since then. During the 1974-75 school year, two schools were closed and it is anticipated over the next five years several more may be closed.

Each of the district's 64 schools have a school library media center. All but 18 school media centers have a full-time librarian. The collection sizes in the elementary schools range from 4000 to 16,000 books and 500 to 3500 multimedia (audiovisual) items: junior highs average 12,000 books and 2500 AV items; and the senior highs average 20,000 books and 3500 AV items.

The district has a Department of Library Services, which coordinates all of the library related activities. This department has three full-time administrators, 1.5 full-time certified cataloger, one classified cataloger, and 20 clerks. They are responsible for a district Film Library, Central Library Processing, Library Material Acquisitions, library related federal funds, Professional Library, preview and examination center, etc. The Central Library Processing Center receives, processes and ships to the media centers all of the library material purchased.

The main purpose of the policy of the Shawnee Mission Public Schools in regard to automated library processing is directed towards freeing the librarians from clerical-type functions and to increase the availability of resources for both students and teachers. The librarian's time can then be rechanneled towards working more closely with students and teachers. In addition, we draw statistical information which assists in guiding sound management procedures.

Immediacy is a key in providing quality library services to students and teachers. They require assistance in locating library resources when the need is felt, not two weeks later. Automated library processing provides the solution to this problem by releasing the librarian from clerical duties so she can help the students now and by making available data on resources in the entire district, thus providing maximum service for the student.

The day of the students or teachers using only their own school's library is quickly fading. Automated processing allows the students to gain access to all 64 libraries in the district.

The district utilizes Data Processing in many of their media functions. The primary use of the computer by the media centers is for the Central Library Processing (CLP) activities. Data Processing is also used for acquisitions, information retrieval, magazine ordering, overdue notices and business functions. This paper is designed to delineate all of these uses.

Technical aspects of the district's computer center and operation is given first to provide the reader with a basis to refer back to as the various data processing uses are explained.

Technical Aspects - Software

The software framework for the on-line cataloging is FASTER (Filing and Source Data Entry Techniques for Easier Retrieval). This was first developed in Alameda, California, for law enforcement. The designers of the school district's program observed this system in operation at the Kansas City (Missouri) Police Department and felt it would satisfy their needs. FASTER was selected as the basis for the on-line catalog system in January, 1970.

The main language for the other data processing activities related to the media centers in the district is COBOL. Batch work related to centralized library processing such as the printing of cards and labels utilizes COBOL also.

Hardware

The district's computer center consists of:

1 IBM 360/40 computer with DOS 384K
8 discs
4 2401 tape drive
1 2701 line control
1 2540 Card Reader/Card Punch Unit
2 2711 Modems
1 3747 Data convertor
1 optical mark scanner
2 3742-dual data stations
1 1403 N 1 Printer (with upper-lower case print train)

At the Central Library Processing Center(CLP) are four 3767 terminals.

The computer center system operates in three partitions. Partition F1 houses Power Spooling Support. FASTER is housed in partition F2. Partition BG is used for batch jobs (COBOL).

Files

There are two basic files for storing the Cataloging data. The first is the Title file consisting of full bibliographic data for each unique title in the school district. Table 1 displays the information in the Title file. Each unique Title record is 562 characters long.

TABLE 1 - Main Fields Input by Operators

Record	Field	Length	Comments
Title	Form code	2	Distinguishes
	Publication date	4	/physical format
	Copyright date	4	
	Author	35	
	Title	50	May be continued
	Annotation	105	/in Annotation
	Publisher	30	
	Edition	3	
	Price	5	
	Dewey number	8	
	Cutter number	10	
	Grade level	4	
	Collation	40	
	Series	35	
	Language code	3	Use MARC lang.
	LC card number	14	/abbrev. codes
	Subject heading 1	24	Use Sears headings
	Subject heading 2	46	Use Sears headings
	Subject heading 3	60	Use Sears headings
	Added entry	30	For name or title
Copy	Title number	7	
	Number of copies	4	
	Building code	5	
	Funding code	2	If other than gen.
	Volume-number	3	For vol./other seq.
	Print instructions	16	Kept only until /labels&cards print.

TABLE 1 (continued)

During on-line operations, 8 a.m. to 5 p.m., Monday-Friday, a modified Title file is being used. This modified Title file consists of a shortened title (first 50 characters), the author's name, physical format code and the unique title number. The modified file was developed so that additional disc packs could be released during the day for other uses. This Title file is stored on two disc packs and has the capability of handling 190,000 title records and 970,000 copy records. When printing or retrieval functions are in operation the full Title and Copy files are brought up and run on six-disk packs.

The second basic disc file record is the Copy file. The Copy file contains a 56 character record for each copy of a title, and comprises fixed-length fields for building number, special funding, volume information and circulation control. Copy and Title records are linked through the Title number.

A third file is the ISAM (indexed and sequential) title index, comprised of records with a phonetic code key for each title record. This file is called up by a terminal transaction containing title, the incoming phonetic code for the title is matched with any equal ones on the index.

In the cataloging files each unique title is assigned a unique title number. This title and copy number consists of six places to the left of the decimal and four places to the right. The title number is represented by the first 6 digits.

Example:

Book	Cat in the Hat	013469 (Title No.)
Filmstrip	Cat in the Hat	002387 (Title No.)

As schools add this book or filmstrip to their media collection the numbers to the right of the decimal are assigned automatically by the computer. Example:

Books

School		
Apache	Cat in the Hat	013469.0001
Oak Park	Cat in the Hat	013469.0002
Pawnee	Cat in the Hat	013469.0003
Apache	Cat in the Hat	013469.0004 (2nd copy)

Filmstrip

School		
Trailwood	Cat in the Hat	002387.0001
Brookridge	Cat in the Hat	002387.0002
Flint	Cat in the Hat	002387.0003

A complete and very detailed description of the technical aspects of our on-line cataloging system can be found in the following article:

Miller, Ellen Wasby and B.J. Hodges, "Shawnee Mission's Cataloging System", Journal of Library Automation, 4:1, March, 1971, pp 13-26.

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In addition to the cataloging system files there are separate files for the acquisition system, the overdue system, the magazine ordering system, and the business system. The information retrieval system utilizes the cataloging systems data bank.

II. Central Library Processing (CLP)

History

The year before unification, 1968, the High School District started an automated system for cataloging library material. This was batch system using an IBM/1401 computer. At the time of unification, 1969, only the high school and two other elementary school districts, of the 13 district, had centralized library processing.

With unification the new district committed itself to centralized library processing for the 65 schools. To facilitate the handling of the anticipated mass of library material to be processed, it was also decided to stay with an automated system. The high school district's batch system presented a number of problems, which would have to be overcome to establish an effective and efficient operation. Some of the problems were:

a. Limitations of the 1401 batch system to handle 100,000 items a year.
b. Only upper case letters on catalog cards.
c. Fixed length fields which resulted in abbreviations that could be difficult for the elementary age children.
d. High incidence of error. Need for more accurate data on cards and labels.
e. Compilations with paper handling; color code grid-forms for duplicate items, massive shelf list, etc.

After considerations of these problems by the district's personnel in both library and data processing it was decided to explore the possibility of some type of on-line system. The on-line system became a reality in mid-March 1970 on a pilot basis. By August, 1970, the total processing was converted to the on-line system. The on-line system solved most of the problems that existed in the batch system. A major breakthrough was scored with the capability of upper and lower case letters on the catalog cards, thus making reading of these cards more natural to the children using these cards in the school media centers.

The system has grown from one 2740 terminal to four 3767 terminals this year. At one time in 1971 the Central Library Processing Center (CLP) was using eight 2740 terminals. The data bank has gone from zero to 150,000 titles and over 500,000 copies. All library material purchased in the district for any school media center since August, 1970, has been processed by the on-line system of the CLP.

Present application

CLP receives, catalogs and processes all library material purchased for the school media centers. The items are checked via the terminals to determine whether we have other copies in the district. If it is a duplication, then the data bank is up-dated on-line to add this item to the bank.

If the item is not a duplication then it is sent to professional catalogers to be cataloged. After original cataloging, it is returned to the terminal operator to input the item's bibliographic data in the computer. A complete set of catalog cards is printed by batch operation in the computer center during the evening and night shifts. Also labels for the book pocket, check-out cards, and book spine are printed by batch. These cards and labels are then sent to CLP for the final processing.

The entire operation takes anywhere between five days to five weeks to complete depending on the time of year and volume of new material in CLP. The average amount of elapse time between receiving the material in the center and shipping it out to the building is between three and four weeks.

Data Bank

The data bank developed by adding this material to the media centers is the major involvement with the district's Data Processing Center. This cataloging data bank is growing at the monthly rate of approximately 1200 new titles and 7000 copies. Table 2 displays the data bank size as of February, 1976.

TABLE 2 - CATALOGING DATA BANK

Physical Format	Copies	Titles
BOOK	388801	106611
SOUNDFILM	19045	6351
DISC REC	12030	5293
TAPE	2035	1379
CASSETTE	9511	2847
SUPER 8	11058	3770
FILM 16	1965	1682
TRANSPRN	4612	1854
SLIDE	1994	831
FILMSTRIP	38173	10514
MODEL	305	222
MAP	184	124
CHART	290	205
FLASH CD	84	30
GLOBE	25	17
KIT	994	594
GAME	770	341
VIEWMSTR	382	231
PRINT AP	3875	2080
PRINT SP	5525	1455
REALIA	34	20
SD SLIDE	708	233
SD LOOP	27	8
MI SLIDE	57	48
8 MM LOOP	65	63
REPRINT	578	481
PAPER BK	15141	5167
PAPER BD	1320	778
Totals	519589	153229

The steady growth of this data bank can be seen in the four-year growth patterns of Table 3.

TABLE 3 - CATALOGING DATA BANK GROWTH PATTERN

Physical Format	March 1972		February 1976		Added in 4 yrs.	
	Copies	Titles	Copies	Titles	Copies	Titles
Books	153 055	57,500	405,262	112,556	252,207	55,056
Multimedia	47,280	20,613	114,327	40 673	67,047	20,060
TOTALS	200,335	78,113	519,229	153,229	319,254	75,116

A detailed analysis of this data bank, Table 4, indicates the overall duplication rate is about 3 to 1, with the largest duplication ratio in books 3.6 to 1 and filmstrips 3.4 to 1. This table also shows that 77% of the copy file and 73% of the title file is books and the others a wide variety of multimedia. The ratio of books to multimedia is fairly representative of our total media center collections.

TABLE 4 - ANALYSIS OF CATALOGING DATA BANK

Physical Format	No. of Copies	No. of Titles	% of all Copies	% of all Titles	Dup ratio Cps./Title	
Books	405,262	112,556	77%	73%	3.6	
Multimedia	114,327	40,673	23%	27%	2.8	
Selected Multimedia Format						Description of format
Filmstrips	57,218	16,865	11%	11%	3.4	Sound and Silent
16mm Films	1,965	1,652	.4%	1%	1.2	
Recordings	23,576	9,519	5%	6%	2.5	Disc, Tape, Cassette
8mm Films	11,123	3,833	2%	3%	2.9	Super and Regular
Prints	9,403	3,535	2%	2%	2.7	Art & Study

We do not presently have all of the library material on the computer. In May, 1975, we compared our data bank totals with our inventory figures. We had 651,366 books in all of our media centers and about 56% of these, or 362,141, were in the data bank. In the area of multimedia, the schools inventoried 126,490 in May and about 83% of these (105,000) were on the computer. In a May, 1972, comparison of these same figures, we had only 26% of the district's books on the computer and about 45% of the multimedia items in the data bank.

A long range projection of our data bank indicates we anticipate that the unique title count will level out at about 230,000 and the copy file to be almost 900,000. If all factors remain the same we are expecting to reach this level by May, 1981. This projection is based on several factors:

a. Four terminals inputting 85,000 items a year;
b. Keeping only 4 terminals;
c. Status quo of library budgets;
d. Cost of library material increase about 10% annually;
e. Annual deletion rate for the schools of about 3.5% of their collection size (lost, damaged, discarded material).

Retrospective Cataloging

As previously mentioned, everything purchased for the media centers since August, 1970, has been added to the data bank. Most media centers were established before this time and so plans had to be made to add these older items to the data bank. The term used for adding these pre-August, 1970, items to the data bank is called "retrospective cataloging."

At least four different methods of retrospective cataloging have been tried:

a. The shelf list card for each item is sent to CLP and this data is entered.
b. The actual physical items not on the computer are sent to CLP.
c. Cards of a selected section of the data bank are matched with the media center's shelf list. The cards that match are sent to CLP and the data entered.
d. A terminal is moved to a media center and the material entered at the building site.

Of these methods, the second one of having the actual material sent to CLP has been the most successful. This allows the terminal operator to actually compare the data on the material with the data bank information. It also allows CLP to finish processing the items completely so that when it is sent back to the school it is ready to be put on the shelf. The other methods require the librarian or building level clerk to attach the labels sent from CLP after the item has been put on computer.

The processing of new material takes priority over retrospective cataloging in CLP.

Two techniques of retrospective cataloging have been performed in the district. The first technique was to select a single school and complete retrospective cataloging on the entire school. During the 1974-75 school year a different approach was used. The district's Art Department wanted to know all the art material in all the media centers. All of this data was not in the data bank. The decision was made to do retrospection across the district in the Dewey Decimal classification (700-769), pertaining to Art. This was done and now we have all the art material in all 64 schools on the computer.

This year it was decided to continue with this approach. We are presently involved in entering the rest of the 700's to the data bank. It is anticipated that by the end of this year we will have all material, book and multimedia, in the Dewey classification 700-799.99 from all the schools in the data bank. Even while we are doing this, however, we are still at work on retrospective cataloging in several individual schools.

After a school adds its material to the computer, it normally receives a new set of catalog cards for this material. An alternate method most often used by buildings when their entire collection is added, is to request a new card catalog. The computer has the capability to generate a complete card catalog already alphabetized.

Presently in the district we have all the material from five high schools, three junior highs and five elementary schools completely in the data bank. All of the schools' 700-769 Dewey's are in. There are three junior highs and one elementary school working rapidly towards being on the computer. It is anticipated that by May, 1981, all of the media collections for all of the schools will have completed retrospective cataloging.

Problems

The system in general does not seem to

have any major drawbacks. The problems related to it are more similar to problems of Central Library Processing operations in general than related to Data Processing. The problems related to fixed length fields seem to be the main programming problem. Catalog card format bothers some librarians; particularly the lack of the ability to distinguish between a title and subject heading at the top of a card. Other problems are:

a. Limitation of having only three subject headings per entry.
b. Keeping price of material on catalog cards up-dated.
c. Keeping data bank current. If a library deletes an item from its collection, CLP must be notified so they can delete from data bank.
d. If a typographical error gets into the computer it can repeat itself over and over until it is caught.
e. If an item's classification number is changed for one school, then all schools having that item must change their spine labels, book pockets, check-out labels and catalog cards.

The district has an active Cataloging Committee made up of librarians from all grade levels, CLP catalogers and supervisor, and a Dept. of Library Services administrator. This committee must approve any changes in Dewey classification and other major decisions affecting cataloging and the data bank.

Cost Analysis

To determine the actual cost of processing is very difficult. Most data affecting this cost analysis can be collected, including cost of data processing and central library processing personnel, terminal and line rentals; and an estimate of the pro-rated computer cost, and this data can be analyzed fairly completely. The items which are more difficult to measure, if the decision is made to even include them in a cost analysis, are the building maintenance costs of the facility housing central library processing (including water, lights, gas, custodial help, and necessary repairs): the cost of developing the original computer program (over how many years do you pro-rate this expense; were accurate records kept in the beginning to show everyone's time involved in program development, etc.): should only the cost of processing new items be considered or should retrospective cataloging be included; should minor programming changes be computed in the cost analysis and for how many years should they be spread out; the cost of equipment (typewriters, embossing machine, etc.); the cost of the business office's time related to central library processing; and, saving of librarians', clerks', and administrators' time when the data bank is used to furnish necessary data.

The question also arises of whether to figure a cost analysis on the full capacity of the system, 100,000 items annually, or on the actual output within a given period of time (summer months, semi-annually, annually, or over several years). There may be extenuating circumstances which prevent full utilization of the capacity of the processing system, such as power failures, computer down-time, personnel problems, telephone line problems, loss of data due to computer problems, changing of programs, personnel turnover, training time for new personnel, duplication rate and type of material input (media items take longer to input than books), etc. So the question arises, should the cost analysis be based on actual output or on what the system was designed to produce?

Analyses of estimated costs that have been computed on the Shawnee Mission Public Schools' system over the last several years have been both on a full system capacity situation and actual output. This includes data processing and central library processing salaries and supplies, and an estimate of computer costs, terminal expenses, and other data processing expenses. During the 1969-70 school year, the system was on a batch system using keypunch to enter data: the estimated cost of processing a library item was $4.30.

Table 5 displays the cost analysis since 1969-70 and a projection of the current year, 1975-76. Records were not accurately kept for the 1970-71 or 1973-74 school years, so no cost analysis is given for these years. This table shows a constant decline in processing cost until this year.

TABLE 5 - COST ANALYSIS PATTERNS

	69-70	71-72	72-73	74-75	Proj. 75-76
cost per actual item processed	$4.24	$2.42	$2.56	$2.18	$2.44
cost per 100,000 items processed	------	$2.39	$2.34	$1.94	$2.20
number of items processed	22,000	98,788	91,107	89,188	90,000
system in operation	Batch	on-line	on-line	on-line	on-line

There are several factors which influenced the cost increase for this year. The major reasons for the increase are an adjustment in the salary of the CLP supervisory position, and a greater pro-rated amount of the computer charged to library processing. Last year the library system was run during the same time that a Computer Assisted Instruction (CAI) system for students and teachers was in operation. The pro-rated cost for each of these functions tended to balance the cost of the computer operation during this period of the day. This year the CAI activities have been dropped from the district's computer, so the library processing system must assume a larger portion of the computer cost. This year's on-line computer expense increased by 56% over the 1974-75 school year.

The increased cost for processing would have been even higher if it had not been for several changes. This year four 3767 terminals are in operation as compared to five 2732 terminals in 1974-75. In addition to saving on the cost of terminal rental we were also able to reduce one terminal operator's position. This person is now being used part time in the Film Library. Due to the high duplication rate and the size of the data bank we were also about to reduce the amount of professional cataloger's time.

Cost analyses by other districts having central library processing range from $.60 to $14.80 per library item. A study done by the library consultant from Bellevue, Washington, in 1968-69 showed that to catalog and process one book under ideal conditions would cost most districts at least $2.32, as reported in an American Library Association bulletin. As you probably suspect, with the very wide range in costs ($.60 to $14.80), the people computing the cost analysis are not talking about the same thing when they think about "central library processing." This same kind of communication gap exists when commercial library processing is considered to be the same as Shawnee Mission Public Schools' central library processing.

III. Information Retrieval

The present retrieval system is handled almost completely through batch operation in the computer center. The data bank used is the same as that developed from the processed items. Even though this is a large data base, 150,000 unique titles and over 500,000 copies, it does not represent the total collections of the district's media centers. As more schools or district-wide sections of the collection are added to the data bank, the retrieval utilization will increase. Some of the value of the retrieval system is represented in the following list of capabilities and services.

a. Provides bibliographies for specific teaching units or selected readings.
b. Provides bibliographies for use with curriculum development task forces or individual teachers.
c. Provides bibliographies on new material to the district in any specific time sequence.
d. Establishes if a district has a specific item and its location in specific media centers.
e. Provides data that assists teachers and librarians in selection of material for their media centers.
f. Provides bibliographies of material in specific physical formats (cassettes, films, games, prints, etc.) which can be used to develop interest centers, provide students with a variety of media experiences and allow students access to material best tailored to their learning style.
g. Provides statistical data.
h. Reduces paper handling through production of additional catalog cards and labels.

The information from the data bank can be retrieved by a number of ways. To date the most common retrieval requests have been by Dewey Classification or subject headings, or for a single building location. Over the past few years programs have been written as needed for special requests.

With individual bibliographies the data can be retrieved in any number of combinations related to special form codes, building locations, Dewey classifications and Subject Headings. There are about 3-5 such requests a week. These retrieval requests are handled by completing a preprinted grid sheet, which is keypunched. The computer then supplies the appropriate print-out, usually within 48 hours of the request.

Another retrieval technique which will probably expand greatly over the next few years is the request for single items. This is done on-line at our processing center. Usually once a day they are called by a librarian to determine if the district has a specific item and what media center has it. At this time this on-line retrieval can only be done if a specific author and title are known.

Special requests, usually resulting in large print-outs, are handled on an individual basis with direct communications between the Department of Library Services and the Data Processing Dept. Due to the amount of computer and print time required for these requests, they are planned for on a scheduled basis.

All of these retrieval requests are designed to provide teachers, students, librarians, and administrators with data as to the availability of resources and to save time in paper handling. The data processing cost for these requests for this year is anticipated to be about $15,000.00. The following are some specific examples of how the information retrieval system has been used.

1. Inventory Data

Each spring, immediately before inventory time, an inventory print-out is requested for each school. This tells the school exactly the number of books, filmstrips, or cassettes, etc., they should have in each Dewey Classification, 100's, 200's, fiction, etc. On request they have also received a shelf list print-out of specific sections to be used during inventory time.

2. Book Catalog

Three buildings have made use of book catalogs. The book catalog takes the place of the card catalog. It is an alphabetical listing of all the material in a single media center. The print-out is arranged in three sequences; author, title and subject heading. The advantage of the book catalog is its mobility. A student or teacher could take it to the classroom or have a section of the catalog for use and not be limited to using it only in the library. The disadvantage of the book catalog is keeping it updated. In our district library, material ordering is continuous, so the media center receives new material weekly.

3. Building Closings

Last year the district closed two elementary school buildings. To assist with the redistribution of the library material we requested special print-outs. The print-outs showed us which of the buildings receiving the relocated students had the same material as the closing schools. We were able to identify specific items which the closed school had and the other media centers didn't have. This saved us a great deal of time and we did not have to rely on the librarians receiving the material to try to recall which of the materials they already had, nor the need to bring the shelf list from their building to the closing building.

4. Printed Catalogs

A number of printed catalogs have been developed.

a. 16mm Film Library Catalog

Every year we request a print-out by title and subject heading of all the 16mm films in our District Film Library. This is sent to the printer to have 1500 copies made. These copies are then distributed in quantities to the schools. A teacher can then take this print-out of the films to their classroom or home for planning purposes.

b. Professional Library Catalog

This is handled similarly to the Film Catalog with a wide distribution. The teachers involved in college courses can carry this catalog with them to determine what the district has in the Professional Library appropriate to their classes.

c. Art Catalog

After the retrospective cataloging of all the art material in all the media centers last year, an art print-out by school level was requested. This print-out was printed and distributed to all art teachers and librarians in the district. This allows any elementary art teacher (or junior or senior high) to know what is available from any other elementary school in art. Next year the music and physical education teachers will have this type of print-out available.

5. Extra Catalog Cards

A number of schools are requesting extra catalog cards. One high school building has satellite libraries (resource centers) in science, foreign language and home economics. By requesting extra cards they can have a card in the main library's card catalog case and one in the satellite library. Two buildings receive cards for all 16mm films so their card catalog will reflect the holdings in the Film Library. In the case of vandalism or disaster, the computer could replace an entire card catalog.

6. Bibliographies

Several times a week librarians request individual bibliographies. The debate coach may want to know all the material in all the high schools on a topic, or a teacher may be writing a new unit on a selected topic and will need to know all of the available material on it in their own media centers. Every request reflects a different need.

7. Union Catalog

A union catalog is a catalog of all the material in a selected group of libraries. The first union catalog in Shawnee Mission was of all the high school library resources; this included material in all five of the district high schools. It was arranged with author, title, and subject heading indexes. The catalog is available in the libraries so that any interested student, teacher, parent, or librarian could consult it to determine the location in the district of needed resources. Essentially, this function, from the user's viewpoint, is as if each high school had a card catalog of the material in all the district high schools. It promotes greater utilization of material, provides the students and teachers with a one-stop source of all the material in the district's high schools, reduces the need for all the schools to buy exactly the same materials, thus reducing duplications and improving the buying power of the district, and would promote interlibrary loaning of materials.

Preliminary cost quotes for such a catalog in paper form ranged as high as $10,000. We were able to reduce this to less than $500 by going to a union catalog on microfiche. This cost was considerably below the $10,000 cost. The fiche are made directly from prepared computer tapes by a local company.

The original microfiche packet included 61 microfiche. This represents about 78,000 unique titles in three arrangements; author, title and subject heading. There are 27 fiche for the title index, 21 for the subject heading index and 13 for the author index. Each fiche has 260 pages plus one index frame. This interprets to 7119 pages of titles, 5392 pages of subject headings, and 3351 pages of authors. From the originals, ten copies of each packet were made. Each high school, the Johnson County Public Library, and the Dept. of Library Services will have a copy.

Ultimately this concept will be used in all buildings. It is anticipated that when all of the library resources are in the data bank, such a union catalog will be developed to show the total holdings of the district.

IV. Acquisition System

Purpose

The principal function of the acquisitions unit is to check, approve, and submit requests for books, audiovisual materials, periodicals, and library supplies to the computer or to the business office where these requests are transferred to purchase orders and mailed to vendors. All library resources for school libraries, for the district professional library, and for the district film library are submitted to the acquisitions department. Library materials for federally funded programs, such as Title II, Right-to-Read, etc., in the eleven private and parochial schools within the Shawnee Mission area, as well as District #512 schools are also ordered and processed.

Requests for ordering library material may be made by using one of three methods--the automated acquisitions listing, the library request card, or the regular district requisition--depending upon the type of material and whether or not it is to be processed.

Automated Acquisition System

The automated acquisition system was developed in 1973 with the first print-out generated in December, 1973. The acquisition system consists of a data bank of over 13,000 titles of material that has received favorable reviews in professional magazines or favorable preview by our district's staff.

Every month two clerks peruse 20-25 professional magazines and selection aids. They complete preprinted grid forms, supplying specific data on each item. These grid forms are then keypunched by the Data Processing Dept. and entered into the district's acquisition data bank. Three times a year the computer supplies a print-out of all the material input during that time. This print-out is then sent to the district printing deparment to duplicate enough copies to send to all media centers.

The print-out provides the librarians with the following data:

- a. Unique item number
- b. Physical form code (same as used in cataloging system)
- c. Author's name
- d. Title
- e. Publisher
- f. Copyright date
- g. Edition
- h. Suggested grade level
- i. Review Source (1. Magazine Title code: 2. Date of issue; 3. Page of review)
- j. General classification (Fiction, Non-fiction, Poetry, Biography)
- k. Number of volumes
- l. Price
- m. Vendor code and catalog number

Three separate print-outs are generated every four months. One for the elementary schools, one each for junior and senior highs. These are selected from the data bank by suggested grade levels so there is some overlapping. Each print-out is divided into two sections: one for books and one for AV items.

The librarians complete a grid-type order form when they want to order from the acquisition list. On the order form, besides some building and funding codes, they simply record the form code, item number, quantity desired, unit cost, and total cost. This form then goes to the Data Processing Dept. for keypunch and entering into the business files. The computer generates purchase orders for the material and cards showing what was ordered. The cards are returned to the librarian for the active order file. As material is received from CLP the librarian can remove the cards for the items received. The remaining cards tell what is still on order but has not been received.

Cost Analysis

The Data Processing Dept. yearly cost analysis for the acquisition system is about $6700. Two clerks maintain the input to the files and one library administrator works part time on acquisition. With the 3-times a year printing cost the total annual expenditure is less than $20,000. Where the system itself is only a little over two years old, it is difficult to determine the cost savings related to the system. Most librarians are now using the system to a great extent, but it is anticipated that this utilization will continue to increase significantly in the next four years.

V. Magazine Ordering System

The magazine ordering system was developed two years ago. It was designed to simplify orders, make them more accurate, provide data for bidding procedures, and create a master list of who is receiving what magazines in the district. The district's media centers subscribe to more than 600 different magazines. Most elementary schools order 30 to 50 titles, junior highs 50 to 150 titles, and senior highs between 100 to 250 titles. A data bank of these titles and other ordering information has been developed.

Once a year a print-out is generated for each media center listing the magazines in alphabetical order by title of those they subscribe to. In the late winter, the librarian is instructed to delete any title from this list which is not wanted for the next year, or change the quantity on any title. This corrected print-out, along with another form listing any new magazine(s) wanted is then sent to the Data Processing Dept. to update the files.

A composite list is printed from the corrected data bank and sent out to various subscription vendors for bids. Once a jobber has been selected, then all of the magazines the jobber can furnish are so marked in the data bank. Then, when it is time to generate purchase orders, the data bank can print those for the jobber and individual ones for those going directly to a publisher.

A list for the individual media centers is sent to them in the Fall so they can check off the magazines as they receive them.

A master print-out is produced in the Fall, also. This list allows anyone to identify which buildings have what magazines. This helps the students by allowing them access to over 600 different titles. Once a title has been identified as being received by one of the other media centers, it can be handled through inter-library loan. It also provides a librarian the opportunity to look at magazines or talk to librarians having specialized magazines before ordering for the media center.

VI. Overdue Notices

Several years ago a student in our SM South High School wrote a computer program to help the librarians. This program was designed to print overdue notices upon request. South has an enrollment of over 2000 students who actively use the library, so there is a great deal of paper work related to writing overdue notices. One of our other high school libraries will also be trying this program this semester.

Basically the system works as follows:

1. The librarians have a complete deck of keypunched cards on all students in the school. On this card is the student's name and room location for a special class hour. (2nd period at South)
2. As the student's material became overdue, the regular check-out card is matched with this keypunched card.
3. These keypunched cards, along with control cards, are sent to the computer center as batch work.
4. The computer center generates a number of

print-outs from these cards; a master alphabetized list for librarians, a class roster print-out for second hour by teacher of those students having overdue material, etc.
5. These lists are then used by the librarians and teachers to retrieve the overdue material.

The program is designed to provide several different types of print-outs and notices as required. This system saves the librarians a great deal of time and provides for more accurate record keeping.

VII. Business Functions

The district's business and fiscal control functions are totally computerized. Purchase orders, audits, checks, etc., are all automated. Monthly the librarians receive a print-out showing the budgets and expenditure records. The business records interface with the library's acquisition and magazine ordering systems.

VIII. Future of Data Processing

Continued refinement and improvements will be made on the existing data processing programs. As mentioned previously, by at least May, 1981, all of the media centers items will be in the data bank. This alone will create a greater demand on the retrieval aspects of data processing.

Union Catalogs

Once retrospective cataloging is complete for all media centers it is anticipated that a master union catalog will be generated. This will list all of the library material in the district and be indexed by author, title and subject headings. The catalog will be on microfiche. This will allow any student, teacher, librarian, or administrator in the district to know the availability and location of over 200,000 unique library resources.

Search and Circulation System

A program will be developed in the future to try an on-line, in-building circulation and research system at the secondary school library level. This system will provide the library with a check-in, check-out system and a search system to locate material anywhere in the district. These procedures will allow the students and teachers to ask the librarian for a specific resource (book, film, record, tape, etc.) or a general area (Kansas government and history, effects of water pollution, etc.). The librarian will immediately request and receive from the computer via a terminal in their media center, the location in the district's high schools of this material and whether it is checked out and if so, who has it and when it is due back in that library. This system will also save the librarians and clerks time by checking material in and out, and by printing overdue notices, fine lists, and other lists. It will also produce statistical reports, circulation records, inventory records, data for state reports, specialized circulation data which will assist in accountability and utilization of materials and services, and for purchasing and selection activities.

16mm Film Scheduling Program

The district's 16mm Film Library has grown during the past years from 700 films to about 1800 films. The scheduling has grown from 12,444 films booked in 1971-72 to 25,000 films booked during 1974-75. A district the size of the Shawnee Mission Public Schools could easily effectively use over 3000 films. The booking schedule will continue to increase over the next few years. It requires a great amount of personnel time to book these films and send confirmation notices back to teachers. It is anticipated that eventually a computerized program will be developed to handle this booking, providing a speedier, more accurate, and time-saving system.

Summary

As knowledge and information expands, so must the libraries in a school district. It will not be sufficient to have access only to the material within your own school library. The students and the teachers must be able to "tap" the resources of all libraries in the district, other libraries of all types in the immediate region, state libraries, libraries of higher institutions, and even data bases at the national level. Retrieval capabilities and interlibrary loan activities will increase significantly through inter-library communication systems such as computerized search and circulation programs, getting all library material in all libraries in the district in the computer's bank through retrospective cataloging, union catalogs of all material showing location which any student or teacher can look at, and improved inter-library loan procedures.

It is hoped that someday all of the library resources in Johnson County might be linked by computer. This would mean a student, teacher, or patron could go to a library and ask for a book or other material and the computer could immediately determine if the material was available in any of the school libraries, Johnson County Public Libraries, or the Johnson County Community College library. Ultimately this network could include other agencies (such as universities, medical libraries, etc.) in the state of Kansas, in neighboring states, or even in the nation. This type of service would make greater utilization of resources, save the students, teachers, patrons time, and improve the buying power of the libraries by reducing the need for a large number of material duplications, thus giving the taxpayers more for their money.

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TEACHING TEACHERS COMPUTING: A PRGAMATIC APPROACH

A. R. Kaled

Miami University, Oxford, Ohio 45056

ABSTRACT: A framework for teaching teachers about computing is described. An approach is presented which examines a methodology to provide teachers with the necessary knowledge and skills to use computers in an instructional environment.

Computers have begun to play a greater role in education. Results from the last biennial survey of programs and practices conducted among public school systems in 1974 by the National Education Association (NEA) illustrates the trend of computer use in education. According to this survey, comprising a sample of 839 school systems, it is estimated that about 20 percent of the school systems provide computers for student use in some of their schools. This is an increase of ten percent from 1972. Some of this increase may well be attributed to the advance of technology both from a hardware and software point of view. The development of microprocessors, minicomputers, and the associated software packages related directly to educational applications has played a major role in the introduction of computers into the public school curriculum and the public school administration. Administrative uses of the computer such as scheduling, budget reporting, and record-keeping have been widely developed and are very common. The development of computer applications for instruction has not progressed as readily. According to some educational observers, the use of computers in the public school curriculum has been somewhat inhibited by 1) the number of teachers trained to use computers in the classroom, and 2) the cost of equipment. With the trend toward miniturization of components, the cost of equipment has been decreasing. Although still important, cost has become in some areas less of a consideration. The major area of concern is the training of teachers. As computers come to be introduced more into the public school systems, teachers will be expected to utilize this "new" technology for classroom instruction. Presently, there appears to be an inadequate program in computer education for teachers during pre-service training (1, 2).

Certain barriers or obstacles seem to exist which inhibits the learning of computing. By removing or minimizing these obstacles, learning computing should be facilitated.

What then are these obstacles or hinderances? One of the major hinderances seems to be the translation of one's thinking about a problem into symbols and statements understood by the computer. The student is suddenly required to pay close attention to details and to be rigorous in his thinking about the steps that will solve a given problem. Associated very closely with this phenomenon is the often expressed thought that mathematics is a prerequisite to learning computer programming. A student needs to be assured that his present knowledge is adequate for learning computing. The presentation of material can avoid many fears by drawing upon the experiences and knowledge that students already possess. It is not necessary to speak in detail of the inner workings of computers or the binary system of numbers. The beginning student need only know that he can communicate his problem to the computer through the use of a high-level language. It can be further explained to the student that a translation or interpretive process takes place to make his programming statements understood by the machine. At this stage of learning, simplicity is important.

Another common fear has been the "device replacing teacher" syndrome. Although, probably not as prevalent today, this fear nevertheless seems to operate as a threat or barrier to learning. Much of this attitude could be dissipated by demonstrating how the computer can be utilized in the classroom as an instructional tool. The computer, it can be explained, is one of many technologies that can be used in the course of instruction. Other technologies such as filmstrips, overhead projectors, video tapes, and movies are now in common use.

Being cognizant of student anxieties about computing and minimizing these hinderances represents the first step to teaching teachers computing. Learning computing is somewhat similar to the learning of a foreign language. Certain basics such as noun and verb forms must be mastered before the more complex language structures can be learned. In programming, the basics include reading, writing, and arithmetic. Once these elementary concepts are understood and the student has had sufficient time to test his knowledge using these concepts, then he may progress to the more difficult concepts such as decision-making, iterative processes, and list processing. Figure 1 illustrates this flow of learning.

As with any other course of instruction, there are certain objectives which computing instruction should meet for teachers. The minimal objectives are 1) to identify those areas where the computer can be of assistance in the learning process, and 2) to provide teachers with the knowledge to select between the proper and improper use of computers in the classroom.

Some of the emphasis in teaching centralizes upon the questions of what should be taught (content) and how should

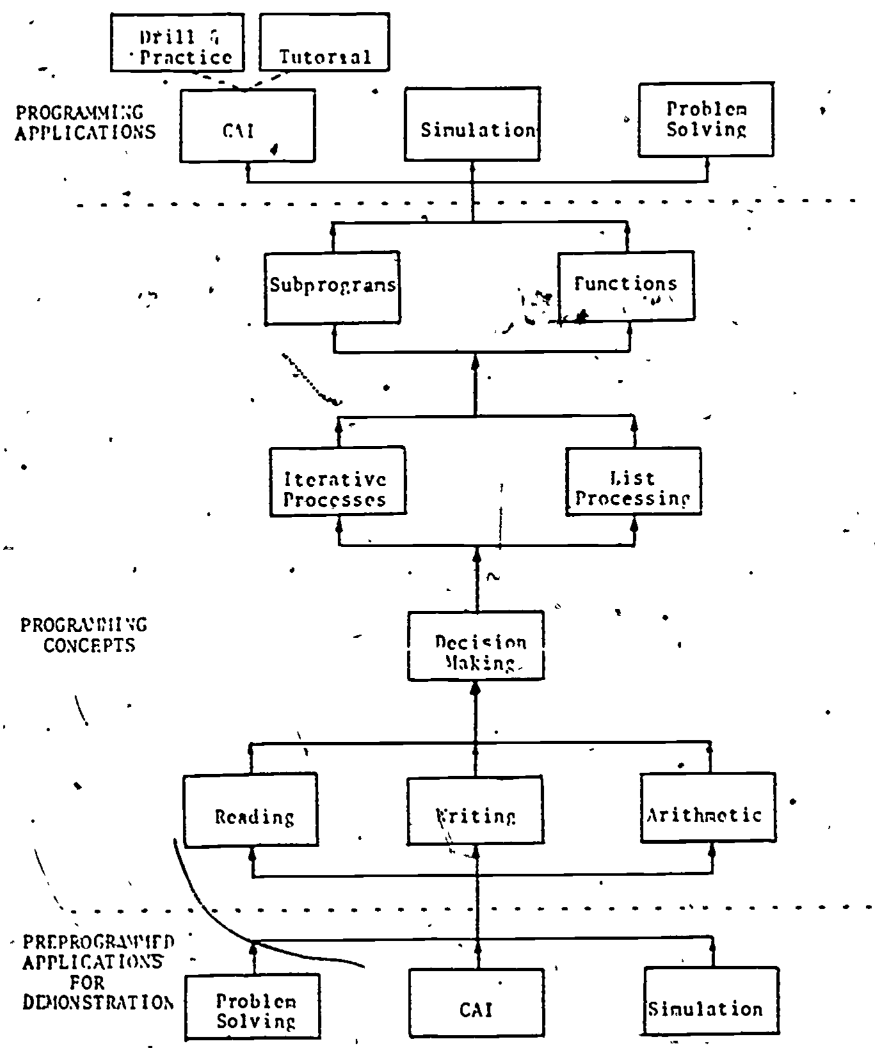

FIGURE 1. A STRUCTURE OF LEARNING FOR TEACHING TEACHERS COMPUTING.

it be taught (methodology). The content of an introductory computing course should consist of three major components: 1) a survey of computer applications, 2) programming fundamentals, and 3) writing application programs. More specifically, it would seem that the following items should generally be included in an introductory course:

- A survey of computing applications to education
- Sources of assistance/information on computing
- Computing terminology
- Fundamental programming concepts
- Exposure to the practical applications of computing related to instruction
- "hands on" experience

This list although not all inclusive should nevertheless serve as a basis for the design of an introductory course. The emphasis that can be given to any one item will vary according to the amount of course time available and the amount of importance a course instructor would place upon each item. Some of these items might be comfortably covered in one class session.

After a discussion of computer applications, it should be apparent to the learner what use the computer can be in an instructional environment. The student should realize:

- The computer can be very useful as a drill and practice resource thus relieving a teacher from routine tasks.
- The computer can provide clerical support for individualized instruction i.e. computer-assisted-instruction (CAI) where a concept or skill is taught (tutorial).
- The computer is an aid to test construction, testscoring, test analysis, and record keeping.
- The computer can be used to amplify and extend the curriculum. Many more problems can be solved with the aid of the computer than what is humanly possible in the classroom.

Another examination of Figure 1, indicates what may be the content of the second major component of instruction: programming concepts. Starting with the basics, the student is introduced to the concepts of reading/inputing data, writing data/information, and performing computations. Instruction at this point remains simple with explanation being supplemented by many examples. The student after completing this frame of instruction should be able to write a program whereby data is read, computation is performed, and the results printed and labeled appropriately. This simple process is flowcharted in

Figure 2.

FIGURE 2. A SIMPLE PROGRAMMING PROCEDURE

From the basics, instruction progresses to the next level of complexity: decision-making. Based upon the comparison of two quantities, the student learns how to inform the computer what course of action to pursue. The concept of branching is explained with examples. Discussion includes such topics as relational operators and true-false conditions. After completing this portion of instruction, the student should be able to write a program to solve the following type of problem:

> A survey was conducted on the question: Teachers need improved facilities to do a better job. Agree? Disagree? The agree responses are coded as 1's and the disagree responses are coded as 2's. Write a program which will total all the agree and the disagree responses for a given set of data and display the results appropriately labeled.

The student can now write simple programs with some amount of flexibility. The next step of learning will include the concepts of looping (iterative processes) and the processing of lists. A discussion of iterative processes should include loop construction, transfer of control (decision-making) within/outside a loop, use of the loop index, and types of loops. In discussing the concept of a list, one should include list characteristics, the purpose of lists, and the specification of lists in a program. Here the student learns about repetitive processes and the procedures to efficently program such processes. The student also learns how to set aside storage area in his program and read information into this storage area through the use of a loop. Once an array of information is established, the student learns how to manipulate this information in many different ways. The different functions of lists and how lists can be used for instructional applications are explained in detail. This information, for example, may be sorted or rearranged in some other manner or may be searched for a particular value or piece of information. After completing this level of instruction the student should be able to write a program of the drill and practice type. An example of a problem and the expected results follows:

> Write a program to drill a student on the capitals of ten states you select. Use the following procedures for giving feedback and keeping score:
> -If the first response is correct, give the learner two points.
> -If the first response is incorrect, print a message such as, "WRONG, PLEASE TRY AGAIN".
> -If the learner does not respond correctly after the second try, then no points are given. Print a message such as, "THE CAPITAL IS" followed by the correct response.
>
> Print a message indicating the score attained. If the student attains a score greater than 85, then print a rewarding message such as "YOU HAVE DONE WELL" followed by the learner's name. If the score does not meet this performance, then print a message informing the learner that he should review.
>
> A sample session follows illustrating how the output might appear.

```
WHAT IS YOUR NAME?
?CONNIE
NAME THE CAPITAL OF THE FOLLOWING
STATES
NEW YORK?ALBANY

ARIZONA?PHOENIX

MICHIGAN?LANSING

OHIO?TOLEDO
TRY AGAIN PLEASE
OHIO?COLUMBUS

VERMONT?MONTPELIER

IOWA?DES MOINES

YOUR SCORE IS 92
YOU HAVE DONE WELL CONNIE
DO YOU WANT TO TRY AGAIN?  TYPE
YES OR NO
?NO
```

The next level of programming includes the concepts of functions and subprograms. The student learns what comprises functions and subprograms, their use, and how they are specified in a program. After a discussion of functions and subprograms, the student should be prepared to begin programming instructional applications. Relevant programs would include problem-solving, CAI, or simulation applications. The student should now be able to design a drill and practice unit or a simulation. If a drill and practice unit is programmed, the student should meet the following criteria:

> -The program should be applicable to the student's discipline.
> -The learner's name should be requested.
> -Unanticipated responses as well as anticipated responses should be accounted for and the appropriate feedback should be provided.
> -The learner should be provided with a score or percentage correct based upon the performance. If the learner's performance is below an acceptable score, then prescribe further work. If the learner's performance is acceptable, then provide positive feedback.

The foregoing discussion has focused primarily upon content. From a methodological point of view, this instructional approach has assumed that the teacher will be working in a timesharing or interactive computing mode. As part of the learning process, this approach expects students to begin by actually participating in a terminal session. In the first assignment, a student should be confronted with the experience of interacting with a computer. The student after a formal orientation and demonstration of terminal procedures should sit at a terminal and participate in a CAI session or a simulation. Through "hands on" experience, a student should quickly realize the uses and the benefits of computers. It is important that students achieve success in interacting with computers very early in the learning process.

To enhance the communication of programming concepts, it is suggested that the full-range of audio-visual media be employed wherever possible. This would include overhead projection, video tapes, terminal demonstrations, and other media. "Foolproof" terminal exercises that demonstrate concepts should be regularly assigned. Included in the classroom discussion should be short problems/exercises demonstrating various concepts. Students should be encouraged to work with others in solving problems during class periods.

This course structure and approach has been designed to introduce teachers to computing without the necessity of expending a great amount of time and effort. Acquired experience with this approach has demonstrated that it is feasible, practical, and can be accomplished in a minimum number of classroom hours of instruction.

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COMPUTER SUPPORT FOR A SYSTEM APPROACH TO INSTRUCTION PROBLEM STATEMENT AND DATA ENTRY TECHNIQUES

by Eugene A. Collins and Dean C. Larsen

ABSTRACT. The Jefferson County Public School System with the National Science Foundation is conducting a study which implements a digital time-shared computer as support for a systems approach to instruction. This study presently involves one elementary school but will support a total of 13 schools in the future. The computer support includes computer generated criterion test forms. The items for the test forms are randomly selected from a test-item bank. Additional computer support includes the use of a remote document reader for test scoring and updating student academic records. The records are updated using test results and teacher certification of mastery. Data from academic records is being studied to determine its usefulness for formation of instructional groups in a multi-unit elementary school. The design of feedback reports to teachers is being studied in order to optimize the report's usefulness in instructional processes. The effects on teacher's roles caused by the computer support of an existing instructional system are being observed.

Many programs for individualizing education have been developed during the last ten years. An outcome of these experiences has been the identification of a problem which is common to all attempts to individualize. The problem is one of data management. At any given time students in a particular group may be at many different places in the curriculum, each student in the group having different learning needs. Information about the learning needs of each individual is usually available. However, techniques have not been developed for effectively managing this information for optimizing the instruction for each student.

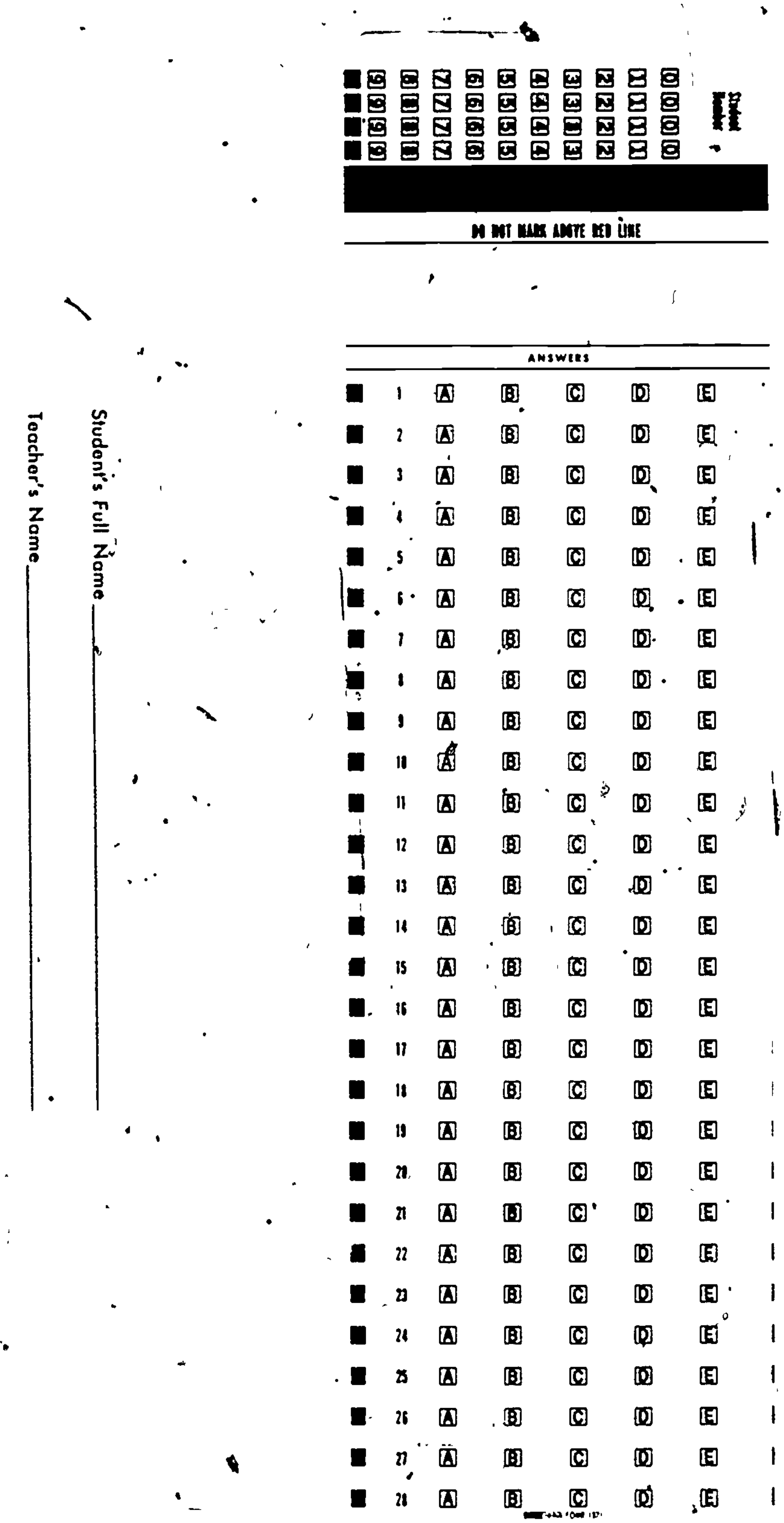
This paper is a description of a National Science Foundation[1] project located in the Jefferson County Public Schools, Jefferson County, Colorado. The project is designed to develop computer support for an existing instructional management information system in schools attempting to individualize instruction. The primary purpose of the project is to develop the data management techniques required to group students with similar learning needs.

The Jefferson County Public School district has defined curriculum in language arts, mathematics, and reading by stating explicit student performance objectives. Procedures for monitoring student progress against these objectives have been identified. The programs have been implemented through grade 8. In mathematics, criterion test items have been developed parallel to the objectives. Levels of mastery have been established. Dependency hierarchies between objectives have been identified, and multiple learning activities have been designed which relate to these objectives.

Teachers are keeping records on individual student performance against the objectives. However, these records on individual student performance are not generally used as a basis for selecting appropriate learning activities. Furthermore, in most schools, the formation of student groups for instruction is not accomplished through use of past performance records. That is to say that student records are not widely used as input into the formation of groups of students for instruction or into design of instructional strategies. As a result, effective grouping of students for experience with appropriate learning activities does not always occur. Students may be provided instruction in skills which they have previously mastered or for which they do not have the necessary prerequisite behaviors.

While systematic diagnosis of student's individual needs may occur, this diagnostic information is not always available in a useable form when students are grouped for instruction. This is due primarily to the fact that instructional decision makers have too much data. They do not have the procedures nor the time necessary to process it.

[1]The work reported in this paper was performed pursuant to Grant Number GY 11109 with the National Science Foundation, Experimental Programs Group, Office of Experimental Projects and Programs. Any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of N.S.F.


Student Number

DO NOT MARK ABOVE RED LINE

ANSWERS

1	A	B	C	D	E
2	A	B	C	D	E
3	A	B	C	D	E
4	A	B	C	D	E
5	A	B	C	D	E
6	A	B	C	D	E
7	A	B	C	D	E
8	A	B	C	D	E
9	A	B	C	D	E
10	A	B	C	D	E
11	A	B	C	D	E
12	A	B	C	D	E
13	A	B	C	D	E
14	A	B	C	D	E
15	A	B	C	D	E
16	A	B	C	D	E
17	A	B	C	D	E
18	A	B	C	D	E
19	A	B	C	D	E
20	A	B	C	D	E
21	A	B	C	D	E
22	A	B	C	D	E
23	A	B	C	D	E
24	A	B	C	D	E
25	A	B	C	D	E
26	A	B	C	D	E
27	A	B	C	D	E
28	A	B	C	D	E

Student's Full Name ____________

Teacher's Name ____________

Figure 1

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The project described here is developing a solution to this problem. Funded by The National Science Foundation Office of Experimental Projects and Programs, Experimental Program Group, the project is titled The Computer Support for a Systems Approach to Instruction. A computer system which will allow instructional decision makers to process records on student performance is presently being developed. The outcome of the application of this system will be the formation of student groups for instruction.

The system is being developed on a Hewlett-Packard 2000 series time-shared computer. Communication and remote data entry are handled over telephone lines with a General Electric Terminet 300 terminal and a Bell and Howell Mark Document Reader.

Development is taking place at Normandy Elementary School. After refinement and field testing the system will be installed in a total of eleven schools in the Bear Creek/Columbine Area of Jefferson County. These schools will be added in two waves over a period of four years after the system implementation is completed in the development school.

The system is being developed in a manner which will provide for the maintenance of performance information on children in any discipline. Currently, mathematics performance records of students in the development school are being managed on the computer. Four years of performance history are being maintained on each individual. In order to insure that these performance records are current, two system components for updating them have been developed. The first component provides update by application of criterion referenced testing for mastery. The second component allows update by teacher certification.

When teachers are interested in testing students over any subset of objectives, in mathematics, they call for a test using the test generation subsystem. This subsystem generates a recipe for the test by randomly selecting items for each objective from an item bank. The item bank contains approximately 80% multiple choice items. The recipe produced by the computer lists the items to be used on the test, the order in which they are to appear, and the correct answer. Mulitple choice items are listed first followed by items requiring more detailed student responses. This recipe is used by an aide who constructs the test by drawing items from the item bank.

The decision has been made to use only two test items per objective. The criteria for mastery is that both items must be answered correctly.

The test is administered to students. They respond to multiple choice items on an answer card shown in figure 1. Students respond to non-multiple choice items on their test paper. These non-multiple choice items are then graded and transcribed to the answer card by an adult. An answer key is filled out from the test recipe. This key is entered through the mark document reader along with the student answer cards. Grading of the test is done by computer. The student's academic performance records are automatically updated by the system. A summary of test results is printed out for teacher analysis.

The advantages of this procedure are numerous. First of all, there is total flexibility regarding which objectives are tested together. Random selection of items from the item bank is also assured. More than one form of each test can be generated, and there is no need for computer storage of the answer keys. Automated grading and record update is provided along with enough human interface to allow for non-multiple choice items.

A second component of the system allows for update of student records through teacher observation and subsequent certification of mastery. This is a necessary component of the system because many mathematics objectives through the second grade are not appropriately measured using paper and pencil. Student behavior described by these objectives includes verbal response and application of manipulative devices. These behaviors must be observed and recorded by the teacher. Furthermore, this teacher observation and certification is an appropriate assessment of student behavior beyond second grade.

The need to update records by teacher observation and certification is being supported by the form shown in figure 2. The form is initially blank on the left side. The heading, containing student name, system number, mathematics level, etc. is printed by the terminal. Forms for each student in a particular group are kept together in a folder. Teachers observe individual student behavior. Mastery of particular objectives is then certified by marking the appropriate code on the computer readable part of the form on the right side. These forms are read periodically by the mark document reader which has the capability of reading both 3½" and 8½" width forms. Student records are updated accordingly.

As mentioned before, the form in figure 2 is initially blank on the left side. Alternative types of individual student profiles are being printed remotely by the terminal in this space. The project staff and teachers are working together to determine which forms of the individual student profile are most helpful to the teachers in supporting their efforts in observing students.

Now that many of the mass data entry problems have been solved, the primary task of the project is being pursued. The task is to increase the useability of the data for teachers, using it to form instructional groups. The development school, as well as many of the other project schools, is implementing Individually Guided Education. Under this model, schools are organized on a multi-unit basis. Each unit is composed of 100 to 150 students with up to three years age difference. The formation of such multi-age

Name
GERNST, ED

Student Number
180

Date
DECEMBER 11, 1975

Teacher
BRADFDRD

Level	Dbjective	Mastery	# of Masters in Group
D	41	X	15
D	38	X	13
D	37		11
D	36	X	15
D	7	X	15
D	3	X	14
E	45		D
E	25		D
E	19		D
E	7	X	2
E	6		D
E	5		5

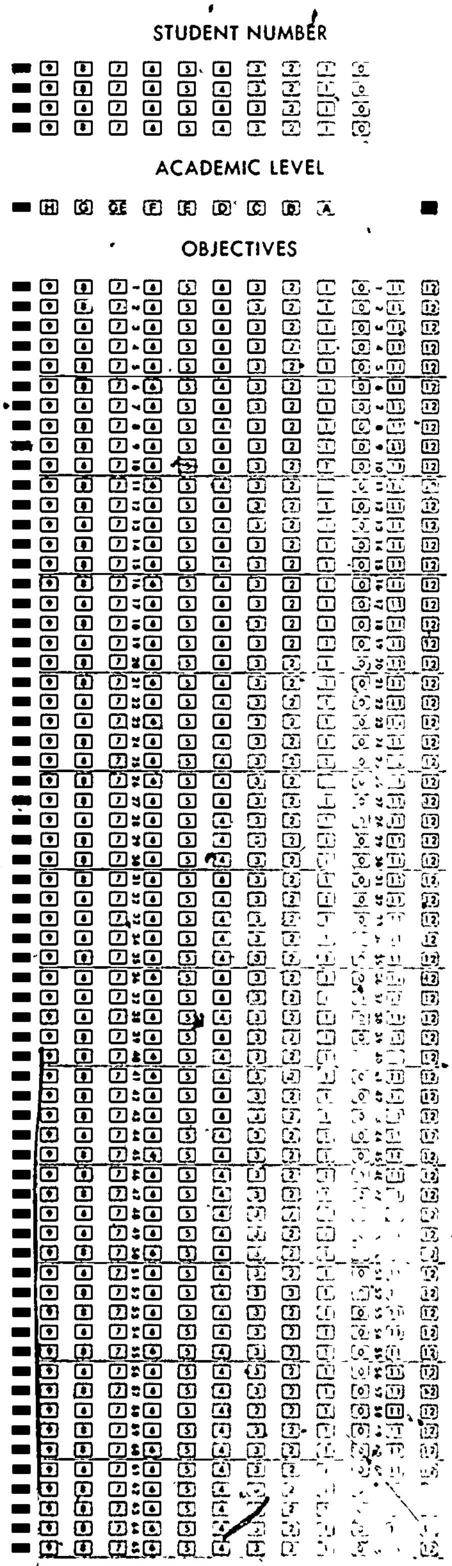

Figure 2

units increases the heterogeneity of the unit with regard to student's previous background and experience. This increased variety enriches the learning experience which can be brought to any instructional subgroup formed within the unit. This heterogeneity is important to learning in any discipline.

Within a multi-age unit, instructional subgroups are formed in the skill disciplines on the basis of common, student learning need. These skill disciplines are typically mathematics, reading, and language arts. Based on their observations and previous experience with students, teachers identify clusters of objectives for which they think instruction is needed. Student's needs with regard to these objectives are assessed. If instruction is needed, appropriate student groups are formed.

The multi-age unit organization along with the procedure for subgrouping on the basis of skill needs has the following advantages. Some of the heterogeneity present in the total unit is maintained in the instructional subgroups. Furthermore, variability in student achievement in any subgroup is reduced. This allows the opportunity for planning an optimal learning experience for each subgroup.

Student learning needs related to any cluster of objectives in mathematics are assessed in two ways, through diagnostic test procedures and through the analysis of historical records of student performance.

When a team of teachers feels the need to regroup within their unit, the objectives for potential instruction, during the next instructional period, are identified. A pretest is constructed over prerequisite objectives using items from the test item bank. After administration of the pretest, the results are analyzed by the teachers and the project staff. Subsequently, student subgroups are formed. The criteria for this subgroup formation are recorded as precisely as possible.

While the teachers are providing instruction, the project staff uses the computer to probe the historical performance data in an attempt to form similar groups. The stated grouping criteria are used as a guide for developing alternative algorithms for subgrouping. These algorithms are programmed and executed. The composition of the suggested groups which result is then compared with the composition of groups actually receiving instruction. In the future this procedure will be repeated regularly. The desired outcome is the discovery of generalized algorithms for probing historical performance data to produce instructional groups which are similar in composition to those obtained through pretesting.

Any successful application of computer technology to support instruction requires attention to the interface problems which exist between the user system and the technical system. The level of technical literacy on the part of educators is of primary concern. They need enough technical literacy to understand both the power and limitations of the computer and to communicate precisely with it. The required level of technical literacy may be different for each educator. This depends on the educator's role in the schools and the person's relation to the information system. The various roles and relations must be observed. The necessary level of technical literacy must be identified and provided.

The problem of understanding and precisely modeling the users original information system is of equal importance. Technical staff members must recognize their role as one of modeling the users information system rather than redesigning it to meet some external constraints. Only if a precise computer model is produced will meaningful computer service be provided.

These interface problems are much more severe than generally recognized. They are solved only through well planned procedures which increase person to person communication. In order to increase person to person communication, the project has chosen the procedure of on-site development and slow expansion to other schools over a period of several years.

COMPUTER BASED EDUCATION IN TEACHER EDUCATION: AN INSTITUTIONAL DEVELOPMENT STRATEGY

RAY MUSTON

RITA WAGSTAFF

UNIVERSITY OF IOWA
COLLEGE OF EDUCATION
IOWA CITY, IOWA 52242

ABSTRACT: A 2 year pilot study of interactive computing in teacher education began in 1973 at the University of Iowa. Included is a discussion of the organization, cooperation of university units, goals, implementation, results, and future plans involved in integrating human and hardware technology.

INTRODUCTION

C. F. Hoban, in his discussion of the management of educational technology, noted "...technology, in its modern usage, involves the management of ideas, procedures, money machines and people in the instructional process." (Hoban, 1968). Even so, many who would introduce computer based instruction into the curriculum focus on machines and the "technical language" and give limited, if any, attention to the needs and motives of those they intend to serve. Consequently, meaningful efforts are often doomed to failure even before they are presented to students and faculty directly concerned with curriculum development.

The purpose of this paper is to present one college's effort to systematically develop a plan to introduce computer based education in the ongoing curriculum. Through the planning process, a concerted effort was made to integrate hardware acquisition and the design of technical support systems with a more fundamental commitment to faculty development. Institutional development was viewed as the product of systematic integration of collective contributions of creative faculty, staff and students to new applications of ideas, material and hardware for improved learning.

DEVELOPMENT OF INSTITUTIONAL COMMITMENT

An analysis of computing applications at the University of Iowa conducted in 1972 revealed that only 15 percent of total computer usage was committed to instruction. Most instructional applications were designed to teach research methodology with practically none targeted for undergraduate instruction. A preliminary plan was developed to introduce interactive computing in undergraduate curricula throughout the campus. The preliminary plan included recognition of the critical necessity for attention to each of the following support systems:

1) A system to facilitate faculty involvement in the planning and development process,
2) A system to provide necessary technical support,
3) A system to provide essential communication among participating groups and activities,

and,

4) A system of hardware and facilities to support emerging development and implementation.

The initial plan for an experimental project was visibly supported by the Director of the Computer Center and the Vice President for Educational Development and Research. Together, they acknowledged the need for collegiate faculty involvement and support and announced a commitment to the acquisition of an integrated system of mini-computers to provide hardware support. At the same time, support staff of the Computer Center were designated to assist collegiate units in their systems development. (Weeg, 1972)

Selected colleges were invited to participate in the project. If a unit elected to participate, the Dean was asked to designate a planning committee to work with the Office of the Vice President for Educational Development and Research and the Computer Center. Each collegiate planning committee was to have responsibility for site planning, necessary training and development, and evaluation of project development.

The procedure for initial planning provided several essential ingredients for effecting change or development in academic organizations.

1. The proposed project had visible support from the University central administration.
2. A commitment to technical staff support was assured.
3. Collegiate systems received a commitment of support from the dean through the designation of a planning committee.
4. An integrated system of hardware support was committed.
5. A system of communications among university administration, computer center support staff, and collegiate units was established through interlocking planning committees.
6. Above all, a vehicle for faculty involvement in the planning and development process was identified in the form of planning committees at the collegiate level. The substance and direction of program development efforts were the responsibility of faculty planning committees.

DEVELOPING FACULTY INVOLVEMENT AND COMMITMENT

Numerous studies have shown that the inclusion of those most directly affected by plans and decisions leads to better input and ultimate results. Similarly, involved professionals are also more committed to goals and programs they have helped develop. Above all, innovative development of instructional programs is most effectively and efficiently realized through the effort of those with greatest expertise - the faculty. Thus, responsibility for early planning effort was assigned to representative faculty and staff committees at the collegiate level.

Representatives named to the College of Education Computer Based Education Committee included:

-A senior professor with a strong computer background,
-A senior professor with a strong background in learning theory and instructional design,
-A junior professor from secondary education with prior experience in computer assisted instruction,
-A junior professor from educational media and instructional development,
-A junior professor from elementary education,
-A graduate student in educational psychology,
-An undergraduate student in elementary education, and
-An assistant dean.

The college committee was strategically selected to include staff with prior experience in the use of the computer, instructional design and development, and positive approaches to faculty development. Also, the two largest undergraduate programs (elementary and secondary education) were represented as well as the office of the dean. The committee was structured to facilitate complementary input of students, faculty, and administrative staff.

Nominations to the committee were made from a list of individuals who had responded positively to a survey of interest in computer assisted instruction.

The charge of the committee included responsibility for site planning, a plan for systematic program development, and articulation of procedures for project evaluation.

ARTICULATION OF PROJECT OBJECTIVES

The college planning committee focused its initial attention to the development of project objectives which were to serve as guidelines for project development as well as a reference point for coordinated direction for interested faculty and staff.

The recognized goal of the experimental project was to make a significant impact on the use of computer based education in undergraduate curricula. The committee recognized that improved instructional effectiveness and acceptance of products developed would be contingent upon deliberate examination of each step of the instructional design process. If the total development process was to succeed, committed faculty would need time, technical support and recognition for instructional design, software development and evaluation efforts. Emphasis was given to the reality that significant contributions would result from programs which were developed from deliberate analysis of instructional needs rather than CAI packages constructed as ends in themselves in search of a problem.

The following general objectives were articulated by the planning committee.

1. Stimulate Faculty Development: Identify a core of committed faculty to develop specific computer based education programs and provide sufficient released time for program planning, development, and evaluation. Those selected would become the nucleus for continuing program development.

2. Maximize Student Impact: Select and develop projects which could result in immediate impact on a significant number of students in the undergraduate teacher education program.
3. Integration of Instructional Media: Explore and develop the potential of computer based technology as a complement to existing media and methodologies. Concurrently, the plan called for establishment of a support lab to provide continuing hardware, software, and technical support to faculty and students.
4. Promote the Acceptance of Computer Based Education: Through project design, field testing, and evaluation, provide a support base for computer based education programs as effective learning strategies.
5. Development of Generalizable Products: Through all of the above, the College committee was committed to develop programs and products which could be transferred and implemented at sister institutions throughout the country.
6. Continuing Faculty Development: As a part of the total plan, it was intended that the total project would provide an incentive and example for continuing faculty development and utilization of computer based education programs and materials.

These objectives were intended to integrate the commitment to hardware accessibility, faculty support and development, and broad student access.

IMPLEMENTATION PLANS AND STRATEGIES

Through a statement of project goals and objectives, the planning committee sought to clarify expectations for the project. Still, plans to identify and assure necessary space, hardware, personnel and software support remained to be developed.

Physical Facilities: The committee emphasized three criteria in their plan for physical facilities for the computer based education project. 1) A space large enough to accomodate a critical mass of terminals was essential. Efficiency of student utilization was not to be constricted by thin distribution of available hardware. 2) Space for the computer based laboratory should be in close proximity with other elements of instructional resources in the Learning Resources Center. 3) Facilities should be provided in an environmental setting which would be pleasing to users.

Space adjacent to the existing Curriculum Laboratory was reassigned for use as a Computer Based Education Laboratory. An interior designer from a local architectural firm was engaged in a plan to renovate and furnish the reassigned space.

The laboratory was carpeted, walls and ceiling treated with acoustical tile and complimentary colors, and furniture was selected to complete the decor. A partition was designed to give privacy to a work space for a lab coordinator.

Facilities have proven to be functional and attractive.

Hardware: Because the basic support system had already been selected by the central planning committee and eight terminals (four CRTs and four TTYs) assigned to the College of Education, the primary concern of the college committee focused on proper distribution and functional assignment of available terminal hardware. The committee expressed commitment to optimum accessability for student users, special support for restricted faculty development, and flexibility.

Six terminals were clustered in the Computer Based Education Laboratory and hardwired to the central system. Two terminals were designated for faculty development and placed in locations isolated from the lab for uninterrupted faculty use (one CRT and one Teletype). Thus, no direct supervision or technical support was available with development terminals. Two of the eight ports assigned to the college were maintained as tele-ports to assure hardware mobility and flexibility.

During the first year of the project, data showed that the faculty development terminals were receiving little use. It was decided to bring the CRT into the student lab and trade the TTY for a variable speed portable Texas Instrument Silent 700 which could be taken into public schools for demonstration and to other campuses for extension courses. The portable terminal has also received substantial use in faculty development.

Within six months, it became apparent that developers would be able to accomplish more if they were not interrupted by laboratory activity. An office isolated from the student lab, but nearby, was designated as a development office and a CRT terminal was moved to provide a quiet place for both student and faculty development.

The TTYs are now over two and one-half years old. They receive one-third to one-half the use of CRTs. Only people who must have hard-copy are willing to use the slower TTYs. Because the TTYs have depreciated over half their expected five year life, maintenance is becoming a problem. Also because of their slow speed and high noise level, consideration is being given to replacing the TTYs with DEC writers or some similar device one at a time over the next three years. Some hardcopy devices are necessary for developers who need listings and for users who want print-out. There is presently no plan to replace the Beehive CRTs which have provided good service while receiving more use than the TTYs.

Personnel-Faculty Resources: The committee recognized faculty and staff support as being the most crucial element of their effort to develop an ongoing computer based education program. Few faculty had prior experience in instructional applications of the computer; software directly applicable to teacher education was not immediately available; and no systematic program for staff development had been identified. Thus, the committee outlined steps to:

1) Create an awareness of the potential role of computer based education in teacher education.
2) Provide resource support for faculty who expressed interest in the project.

3) Provide access to available software, and
4) Encourage recognition for development efforts.

A survey of all faculty in the college was designed to solicit expressions of interest. Responses from the survey were used to identify projects which could lead to early success and implementation. An early effort was made to develop a proposal for external funding to support project development throughout the university. Internal resources of the college were identified and reallocated to support selected development projects.

Probably the single most effective event in stimulating C.A.I. development was the intercollegiate sponsorship of a simulation designers workshop presented in the fall, 1974. Dr. James Bobula of the University of Illinois Medical Education Center spent two and one-half days assisting designers in developing paper and pencil simulations. Some of the paper and pencil simulations were later expanded and implemented on the computer. Some of these modules become the core research for Ph. D. dissertations as well as other research studies.

Other major events include summer grants given by the University Computer Center and University Council in Teaching to professors to develop C.A.I. materials. Courses in C.A.I. languages and more general Computers in Education courses have aroused interest in students which frequently results in development modules. Local newspaper and University press releases have devoted articles to computing and its impact on education and to individual faculty projects being developed at the University.

A day-long faculty retreat was held off-campus which focused on the innovative use of instructional technology. The Dean encouraged faculty members to dismiss classes for the day so all faculty and students who wished to would be able to attend.

Continuing interest in computer simulation has led to two additional simulation designers workshops presented locally by participants of earlier workshops who progressed into more sophisticated computer application techniques.

An information exchange with the other Regents institutions led to additional interest in development. A similar exchange with the University of Nebraska at Lincoln should also stimulate development.

There has been a great deal of promotional activity in order to create an awareness of computing and its value as an instructional aid. A number of users and developers are involved and regularly utilize the facilities provided. Attention is now being turned to those users who are interested but who do not have the time or expertise to complete projects who are in areas which have made little use of computing. There is a core of sophisticated users who assist their faculty colleagues with new development. In this way, the expertise of a few can be viewed as a multiplier throughout the college.

The Computer Based Education Committee has formally recommended recognition for faculty development of software in promotion and tenure decisions.

An analysis of our brief history has shown a positive relationship between developmental events and the incidence of usage.

Personnel-Staff Support An early commitment was made by the College administration and the faculty developers and student users. Resources were thus committed to basic support positions. The goal of the computer lab staff was to provide basic development support and general continuity to lab users and developers.

The initial personnel consisted of a half-time graduate assistant who had five years batch programming experience. General direction came from the Associate Dean of the College. Later, another half-time graduate assistant programmer was added. The two students split the responsibilities into promotion-administration and programming. The students shared responsibility for assisting lab users.

A year and a half into the project, the status of both graduate assistants was changed from half-time to three-fourths-time. Another half-time graduate student was added temporarily for development of a specific project. A work study programming assistant was added for a summer project. Concurrent support was provided for graduate student input as content specialists in selected projects.

After three years the staff was expanded to incorporate a full-time coordinator, a half-time graduate assistant programmer, a student programming assistant, a secretary shared with the adjacent Media Lab, and a student typist also shared with the Media Lab. The coordinator reports to the Associate Dean of the College and serves as an ex-officio member of the College Computer Advisory Committee.

Throughout the project, the advice of C.A.I. consultation at the University Computer Center has been invaluable. The Computer Center has also provided BASIC and IDF language workshops as well as other workshops related to computer usage.

As part of the Learning Resource Center which also includes Curriculum and Media Laboratories, and the Education-Psychology Library, the Computer Laboratory is able to draw on the expertise and technology of these resources for multimedia module development.

The combined efforts of many people have gone into making the Computer lab operational.

Software The coordinator of the Computer Lab assumed responsibility for the identification and preview of software packages external to the College which might prove beneficial in the teacher education program.

New package titles developed by students and faculty within the College are listed below. (A complete description of projects is available upon request.)

DRILL AND PRACTICE

Math - Basic math review and remediation.
Media - Review questions for midterm and final exams.
Spanish - A brief program reviewing grammar of the present tense in Spanish.

TUTORIAL

Systems Approach - An introduction to the systems approach as it pertains to education.
Learning Theory - To teach political science students the implications and applications of learning theory to socialization.
Interaction Analysis - Teaches students the category system of Flander's analysis; applies the knowledge using audio tape conversations of students and teachers which students learn to evaluate.
Behavioral Objectives - A tutorial introduction to writing behavioral objectives.
Photosynthesis - A tutorial on the photosynthetic reaction.
Math - A series of programs on complex numbers.
Computer Programming - An IDF program to teach IDF users who have had no computer experience.
Photography - A tutorial which leads beginning students through the meaning and use of depth field.
Educational Administration - A tutorial program which teaches the basic concepts, conditions, formulas, and types of queues.
Statistics - A teaching module which stresses key points in statistics and allows students to build sampling distributions using simulated data.

SIMULATION

Photography - This program teaches students how to process Ektachrome film using a simulated darkroom.
Photography - Instructs beginning photography students in the process of making black and white prints.
Statistics - Computation modules in Bayesian Statistics where students input data and are able to observe the results.
Computers in Education - Introductory program dealing with different aspects of interactive computing in instruction.
Math Education - Teaches prospective elementary school teachers the basic vocabulary and nomenclature.
Classroom Test Development - Teaches how to compose effective classroom tests from a pool of 100 items. Gives statistics from the test produced.
Elementary Science - A 4-lesson simulation on force and motion accompanied by film loops.
Delphi Inquiry Method - Program on the Delphi technique with simulation and tutorial modes.
Sociological Game - GHETTO, where students are presented situations encountered by ghetto-dwellers and try to improve the ghetto conditions through their decisions.
Law - Two simulations which teach problem solving in civil procedure. These are being used in first year civil procedure classes at University of Iowa law school.
Teacher Education - A set of classroom management simulations for student teachers of elementary grades.
Teacher Education - Series of management simulations which confront science education student teachers with classroom situations about which they must make decisions.
Counseling - Simulation for counseling education students where the student is faced with a client and the student must make decisions about the problems.
Teacher Education - Questioning Techniques --A simulation in which student teachers "ask" questions to gain skill in achieving teaching objectives through questioning.
Teacher Education - Elementary Math -- Elementary math simulation -- a course to assist teachers in diagnosing and tailoring elementary math to meet the special needs of the students.

COMPUTER-MANAGED INSTRUCTION

Instructional Design - 12 CMI modules which test over readings in instructional design.
Computers in Education - Eight CMI modules which survey computer application in education.
Teaching of Reading - A CMI diagnosis and prescription reading program.
Counseling - Two testing modules for counseling students.
Media - A test item pool containing more than 2000 items to generate tests covering a range of experience in educational media. For IBM 360 system.

EVALUATION

Evaluation of the project, and products which emerged from the development effort, focused on four primary concerns.

1) Have development efforts resulted in increased student use of computer based instruction?
2) How have students reacted to the introduction of computer-based units in their classes?
3) How can support facilities and services be improved?
4) Above all, can any measurable indicators of improved learning effectiveness be identified?

In the academic year prior to the arrival of the Hewlett-Packard interactive system, (1972-1973) 344 graduate and upper division students used the IBM 360/65 system primarily for research in 11 classes. The first semester that the H-P was available, there were 582 undergraduate and graduate students in nine courses using the H-P system. There has been a continual increase in H-P use by both undergraduate and graduate students.

Student and faculty development has remained fairly constant since the beginning of the H-P project. Currently there are 28 major instructional modules completed and three still in development.

Table I reports the use data since the beginning of the project.

TABLE 1

USE SUMMARY

	1973 Fall	1974 Spring	1974 Summer	1974 Fall	1975 Spring	1975 Summer	1975* Fall	TOTAL
# courses	9	17	10	17	12	13	12	90
# students								
Users	582	681	118	786	558	246	583	3554
Developers	11	4	4	7	8	4	2	44
# faculty								
Users	9	18	10	15	9	12	14	87
Developers	7	2	4	2	4	2	2	22
Terminal Time (minutes)	52617	141079	59680	133241	144401	69705	81792	682515
# sign-ons	1943	3844	1663	3931	5044	2823	2668	21916

* December, 1975, estimated from December, 1974

Currently, conditions, costs, and distrubution of materials are concerns with developers. The Computer Laboratory, is cooperating with CONDUIT, an established distributor of computer materials. CONDUIT is just beginning to handle education and interactive modules.

It has been the policy of the lab to maintain records of events and/or strategies of promotion and note the result in terms of operation, development, and student use. For example, the isolated development terminals intended for faculty use sat idle much of the time. The faculty seldom directly programmed or entered their materials. Students who assisted faculty often needed programming assistance so when the development terminals were relocated nearer the lab programming assistants, their use increased.

Students were exposed to both instructional programs and computing as an instructional aid. An attitudinal survey regarding several facets of the computer and computer related applications was thus administered to a sampling of all students. The attitude survey polled 19 undergraduate and graduate students in the summer of 1974; 142 in fall, 1974; and 125 in spring, 1975.

Results of the largest sample (142) indicated that 90 percent of the students had never used a computer before. Ninety percent agree that the computer was a useful tool of instruction. Although 85% said they had no knowledge of programming languages, 70% reported that they would like to take more courses using the computer though not necessarily to program for it. About 50% said if a computer were available, they would use it in their own teaching. However, 50% felt that a computer course should not be required for either a degree or teacher certification.

Process evaluation of plans for support facilities and services was conducted throughout the project. Thus, developmental terminals were relocated to better serve user needs and staff allocations were adjusted according to emerging demand.

Evaluation of cognitive gains and learning effectiveness has been a structured objective within all projects. One complete module reports results of a multimedia series which teaches Flanders' Interaction Analysis to undergraduate social studies methods students. This module shows that of a possible 22 post-test responses, the experimental computer group (N=14) had six perfect scores and five scoring 21. The lowest score was 19. In the control group (N=13) matched to the experimental group on ACT and cumulative grade point average, the high score was 20 and the low was 13. Time compression was also significant. The experimental group spent 2.2 hours in instruction, the control group 3.3. It also appears that students with low ACT and GPA generally performed better via C.A.I. than with the traditional method.

Similar results were obtained in a series of four film loop and computer simulations to teach the relationship of force and motion according to Newton's Second Law. Three groups were used. One group viewed the films and used the computer simulation, a second group studied the same material using non-computerized simulation materials and a science lab, and a third received the usual lab and class instruction. The computer group spent a minimum of one hour and forty minutes on the terminals. They did no outside work on the material. The student who had benefit of the lab and simulation material spent six forty-minute periods on the material plus 45 minutes for each student outside class. The regular lab group spent between nine and eleven fifty-minute periods on the material plus twenty to thirty minutes on homework. The ratio of concept learning for the computer group compared to the regular lab group was 8:3 to 1. The group which received access to the simulation materials and film but not via the computer fell between both other groups in achievement and time spent. Retention after a six month period was significant for all groups, but especially for the computer and regular lab group.

Other results have not used control group designs but have used pre-post test comparisons, all of which show learning was accomplished with the C.A.I. modules.

CONCLUSION & FUTURE PLANS

The University of Iowa College of Education Computer Based Education project has had a significant impact on both student users and faculty developers. The project was the result of a cooperative effort which included the University administration, College administration, College faculty, Computer Center, Computer Lab staff, and students in the College.

This integration of human hardware technology has made possible instructional development which otherwise would not exist. One result of this integration has been to provide a new mode of instruction to students in the teacher education programs at The University of Iowa. Perhaps the most exciting results have been where learning was more effectively achieved through C.A.I. than through traditional classroom methods.

Future plans include commitments to:

1) Continuing support for faculty development,
2) Special workshops to train secretarial and part-time staff in IDF and user assistance,
3) A program of student orientation to the lab and its resources is being revised,
4) Distribution of products through CONDUIT is being negotiated and,
5) Continuing evaluation of project results.

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THE TANGLED TRIANGLE: COOPERATION, COMPUTER BASED EDUCATION AND PERSONALIZED SYSTEMS OF INSTRUCTION

Kenneth L. Modesitt
Mathematical Sciences Department
Indiana University-Purdue University
Fort Wayne, Indiana, 46805

ABSTRACT. A community of knowledgeable adults is a desirable and attainable goal of education. The concepts of community, knowledge, and adult are discussed, as well as how they are related to the corresponding processes of cooperation, computer based education, and personalized systems of instruction. Cooperation is suggested as a valuable aid in preventing the interpersonal isolation which may result from exclusive reliance on individualization. However, models for cooperation in a content-based education are sparse. Computer science courses will be the content area from which specific examples are drawn.

Introduction

A community of knowledgeable adults is a desirable and attainable goal of education. This paper will discuss the three concepts of community, knowledge, and adult; and how they are related to the corresponding processes of cooperation, computer-based education, and personalized systems of instruction. We will also explore methods whereby cooperation can aid in bridging the isolation gulf which is a serious side-effect of many computer-based education systems and personalized systems of instruction. Computer science courses will be the content area from which specific examples are drawn.

Motivation

Historically, formal education owes a great deal to religion. However, in recent centuries, much of education has intentionally minimized any reference to a god, spirit, soul, etc. Unfortunately, in so doing, we are now left with a state of formal education which is almost solely cerebral (preferably left-sided) in nature. Whereas, in the past, slavish attention was usually given to religious concerns, now most educators concentrate on intellectual needs of students almost exclusively. This is particularly true in higher education, although the fact is certainly evident in lower grades. Now, intellectual growth is obviously a very desirable quality, but, in my opinion, it is most certainly not enough. I believe that a community of knowledgeable responsible persons actively working on a mutual end represents an invaluable goal for education.

Computer-based education (CBE) and personalized systems of instruction (PSI) are both remarkably successful tools for instructional delivery in content-based courses. I have utilized both in a variety of computer science courses over the past several years. Each tool will be discussed more fully in later sections. However, CBE and PSI are both primarily designed to minister to the intellect of the student. That is appropriate within the university, but it is not sufficient.

Both CBE and PSI are addressed to the concept of individualization. Usually this means mastery-level learning for each individual, often carried out in a self-pacing manner. This process, I firmly believe, is a far better alternative than an entire term of the "me talk-you listen (and learn?)" professorial syndrome. The lecture as a tool for content delivery and acquisition by all students is hardly adequate to the task.

For all the many real advantages of both CBE and PSI however, they share a common side-effect I believe undesirable. They both promote the likelihood of an individual working in isolation. If one believes, as I do, that a community of responsible informed persons is important both to each individual and to the solution of many serious current problems, then such isolation should not be an exclusive mode of education.

Cooperation via working on a common goal represents a positive resource in combatting the possibility of individual isolation resulting from CBE and PSI frameworks. Meaningful joint efforts provide an arena in which the person can exercise her knowledge, perhaps gained in a CBE environment, with a responsible attitude, perhaps gained in a PSI environment. The individual's intellect and maturity provide a foundation for significant individual and mutual action. Each of these vital educational elements: intellect, maturity, and community, will be discussed in the following sections as they relate to CBE, PSI, and cooperation, respectively.

Computer-Based Education

Computer-based education (CBE), also known as computer-assisted instruction (CAI), has a firm foothold in higher education today. I believe that its greatest potential lies in an increase in the quality of cognitive education (difficult to measure) and secondarily in cost reduction (easier to measure) [3]. However, money being what it is, the second benefit is receiving more attention, much of it negative. Stories abound of how CBE System X was suppose to cost N cents/student hour, and really costs 2*N or 10*N cents/student hour. The latter figures usually incorporate research and development costs; the former is usually one meant for production systems. The forthcoming evaluations by Educational Testing Service for the large PLATO and TICCIT CBE systems should help mitigate the altercations [10]. In any case, it is becoming less an act of faith and more a fact of education, that CBE systems are increasingly widespread. Future generations of students will be hard-pressed to remain unexposed to computers in their courses. I believe this is primarily good because it introduces them to one of the most remarkable inventions ever known, as well as permitting them to learn many subjects by doing rather than listening, and often at their own pace. The increased quality of cognitive skills is the desired and, I believe, attainable goal.

In the past, CBE has been considered the domain of computer science departments, with a smattering of mathematics, engineering, and business courses also involved. I believe this attitude held, until recently, primarily because CBE was equated with having students write programs. However, this use of computers will probably not involve a large majority of students. This problem-solving mode is just one of several types of CBE.

CBE now includes the use of computers in education for: problem-solving, drill-and-practice, tutorial, simulation, games, inquiry, and Socratic or tutorial [18]. These divisions are not well-defined, and several workers in the field have a different set of categories [4, 5]. Nevertheless, it is becoming clear that computers will impact far more individuals in the "student" mode, i.e., taking a lesson, than will probably use the computer in an "author" mode, i.e. constructing a lesson. The trite analogy of "drivers of cars" versus "builders of cars" is not far afield.

It is evident that a variety of organizations: governments, universities, and industries, are convinced that the time is ripe for introducing an increasingly larger number of students to computers. Funding of various CBE efforts by the National Science Foundation is well known [10]. The PLATO nationwide network cosponsored by the University of Illinois and Control Data Corporation has received a great deal of publicity [1, 8]. The introduction of the CLASSIC minicomputer system of Digital Equipment Corporation into school systems holds considerable promise. And the availability of low-cost terminals is providing pre-university school systems a realistic option for widespread computer use.

Faced with the honestly exciting prospect of "coming of age" (the first issue of a CBE journal will soon appear), CBE has not seriously investigated the more sobering aspect of potential increased isolation of its users. Yet the phenomenon is not unknown. And as CBE continues to be espoused as a tool for individualization, I believe care must be exercised lest education concentrate solely on the individual to the detriment of the community.

Personalized System of Instruction

PSI, also known as the Keller Plan, is one of the most promising approaches to content-based education now available. The literature on PSI is ample and growing rapidly [6, 15, 16]. A journal will soon appear, and the national conferences are attended by a wide diversity of educators intensely involved with the learning process. An informal and informative newsletter is available from the Center for PSI [14].

Briefly, PSI concentrates on mastery-based learning, essential to self-respect and professional competence. In a previous paper, I discussed how the use of PSI requires the integration of freedom and responsibility [13]. An "adult" was defined as one who takes responsibility for her own actions, regardless of chronological age.

For those not familiar with PSI, the following terse summary should suffice. It is excerpted from the paper referenced above. Briefly, PSI is characterized by five attributes:

a) mastery-based
b) self-pacing
c) non-lecture
d) written materials
e) peer tutors.

The argument in favor of PSI runs something like this. Students can gain in self-respect, and justifiably so, when they demonstrate they can master the material (a). But since students grasp material at widely varying rates, such mastery will occur only if the students are primarily responsible for pacing themselves (b). However, if they pace themselves, there is no way any lecturer could possible speak to all students at their individual points of progress (c). But if the information is not transmitted verbally, how can it be done? Written material provides a partial answer (d). With the widely varying rates of progress through a course, there is no way one instructor could manage the evaluation process for thirty students working on twenty units of material, each with its own multi-version unit test. Hence, peer tutors become invaluable (e). They each, including the instructor, take responsibility for about ten students. That is, they go over the unit tests, answer questions, suggest resources, etc.

As indicated, the desired course content is split into 15-20 units, where each unit consists of:

a) an introduction
b) statement of objectives
c) suggested procedure for achieving the objectives
d) supplemental discussion
e) sample problem/answers
f) multi-version repeatable unit tests.

In previous papers [11, 12], I discussed the components in more detail. For example, the objectives are listed by knowledge levels. And the suggested procedure involves any of the resources we've discussed earlier, e.g., taking PLATO lessons, in addition to reading the text, or constructing structured procedures.

At this time, I have utilized a PSI framework six times, four of them in an Introduction to Algorithmic Processes course for freshmen through graduate students. PSI has also been used in a dual-level Algorithmic Languages course. Results are consistent with PSI studies reported elsewhere [7]: procrastination is a problem, 80% of the students prefer it to lecture, and the same ones do well on final exams, retention, desire for another PSI course, etc. In recent terms, the peer tutors have been utilized more heavily by helping to prepare clarifications to unit material and unit questions. The classes are not yet sufficiently large to use computer-generated exams. Also, incompletes are not given unless the student has completed the number of units for a B. Completion rates during the second term for incompletes given under looser criteria were extremely low.

The major change to the PSI framework is to introduce cooperation explicitly. I am, of course, aware that the instructor and peer tutors "cooperate," after a fashion, with the student to master the course material. Yet, individualization is one of the avowed assets of PSI. As mentioned earlier, this mode is a far better alternative to instructional delivery than the standard lecture, in my opinion. It offers real hope for mitigating the debilitating atmosphere of competition based on grades, which are themselves often based on speed. The use of PSI to lessen such rivalry is one of its greatest assets. However, as I hope to show in the next section, replacing a competitive-based classroom by one devoted exclusively to the individual is neither necessary nor desirable.

Cooperation

Webster's dictionary defines cooperate as "to act or operate jointly with another" [19]. The idea of a common goal is also usually associated with cooperation. Now common goals are hardly a new phenomenon, even when common goals such as cooperating to beat the other team are specifically excluded. Cooperation to end wars, poverty, pollution, starvation and other critical problems is publicized daily. Cooperation within a family unit to nurture oneself, perhaps a spouse, and possibly children is a good and often-realized ideal. And yet where does one find cooperation in the educational process--a process devoted to discovering more of oneself, each other, what the world is like, and how to make a valued contribution? Why this dearth, when students enrolled in the same course supposedly have some common goals?

Yet, looking about the world of education, there is little difficulty encountered in finding models of competition. What does Webster's have to say about competition? Competition is a "contest between rivals," where a rival is "one of two or more striving to reach that which only one can possess." Sound familiar? Of course it does at the Astrodome or Orange Bowl. But what about the normal bell-shaped curve exhibited after so many hour exams, finals, and courses? What percentage of your students know 90-100% of the material you expect of them? Is that rarified level reserved for only a few, say 10% of the class? Do you "reward" only the fastest to master your course objectives? As indicated in the last section, I believe one of the greatest assets of PSI is the lessening of such competition based on speed.

Consequently, if PSI does in fact reduce the "what'jde get" syndrome, what replaces the vacuum in the realm of interpersonal relationships? I believe it is too often indifference. If every student is tutored as "a class of one," we are going to raise some very socially-impoverished students. The need and desire to relate to other students could diminish drastically with increased individualization brought on by more widespread use of PSI and CBE.

I believe that the usual competition-based class, as well as the completely individualized class can be replaced by the class based on a knowledgeable (CBE), mature (PSI) community of learners. The community arises from cooperative efforts in a broad spectrum of sharing activities and thoughts. The following examples of such cooperation are drawn from the introductory computer science course.

Perhaps the most major cooperative effort derives its genesis from an exercise in the excellent reference, Values Clarification [17]. The exercise has the students form their own lists of "What I know about X, and what I want to know about X." X is computers in our case. From the latter lists, groups of 3-4 are formed based on a common interest. The assignment of each group is then to research their common interest for presentation to the rest of the class at the end of the term. The presentation is not having someone read a research paper. Rather, they are often multi-media in nature: video tapes, interactive computer programs, stories, photographs, plays, music, etc. And the topics chosen cover a very broad range: medicine, graphics, weather, mathematics, landscaping, traffic control, building a computer, consumer indexes, etc. As our campus happens to be non-residential, one class hour a week is devoted to "project day" for those who wish to work in their groups. Other students may wish to take or go over unit tests, study, or clarify a point with the instructor. This is a normal mode in PSI classes. Other cooperative efforts vary widely, depending upon the ingenuity of the instructor and the students. The Values Clarification reference mentioned earlier contains a wide variety of such exercises. The course includes a sizeable number of films dealing with computer applications, moral-ethical questions, and technological concerns of computers. A sample list is in Appendix A. Round-table discussion follows each film with all people sharing their values, if they wish.

Other cooperative efforts during class time include taking undocumented procedures written by other students, and working together to analyze what problem is being solved. Also, since students do not have a sense of competition during the course, they offer and accept help from other students who may be a unit or so ahead at the time. Such aid could be on content questions, or on how to obtain a listing at a remote batch terminal by submitting a job from an interactive CRT terminal. One of the most challenging cooperative efforts is for a small group to design an interactive computer game based on cooperation, rather than competition, e.g., Star Trek, Moonwar, Battleship, etc. One of their strongest responses is that they have not had any models for games which are cooperative in nature. How many do you know?? This fact alone says a great deal about the value systems espoused today. The desirability and need for cooperative efforts rather than competitive ones in the world and in education today is very great, in my opinion.

Problems

The students are hardly alone when they complain they have few models for designing a game based on cooperation. I have a difficult time discovering or creating methods to promote cooperation within a course. The few mentioned previously are not many, but they represent a large increase over my original virtually null supply. The design of content-based courses to include cooperative interpersonal relationships is a fertile research area, in my opinion. It does not appear, for example, in The Yellow Pages of Undergraduate Innovations [9] which is a handy reference for many other experimental appraoches to education.

The belief persists, nonetheless, that cooperation within the classroom is not only highly desirable, but also possible. A recent article in Psychology Today [2] dealt with such concepts at elementary grade levels. The article was written in the context surrounding the forced busing for integrated education issue. References to additional sources of information would be greatly appreciated.

The introduction of PSI and CBE into the classroom has done a great deal to alter the concept of a professor as the person standing at the front of the room dispensing information. There are many educators who are excited about forming a new role for themselves, but also many who are not so interested. The incorporation of cooperative efforts to help build a community within the structure of a course will also change the role of the instructor. I believe it is too early to say how.

Summary

A community of knowledgeable adults is a very desirable goal for education. Computer-based education can do a great deal to improve the quality of intellectual content (knowledge) gained by students. Personalized systems of instruction give the student the opportunity to take responsibility for her actions which involve considerable freedom (adult). Cooperation based on common goals is a substantial aid to building a community of students. Moreover, cooperation is not just a frill. I believe that cooperative efforts are necessary to prevent the increased isolation of the student involved with the individualized instruction espoused in both CBE and PSI. Unfortunately, far too many of us, educators and students alike, have a multitude of models for competitive efforts and a dearth of models for cooperative efforts. I sincerely hope this effort will prompt more interest and work in the design of content-based courses which include cooperation as an essential component.

Appendix A

Ken Modesitt — Fall, 1975

Computer Science Film Schedule

Sept. 3	(Wed.)	The Computer Revolution: Good overview of computer applications as of late 1960's. Part of Cronkhite's 21st Century Series.
Sept. 10	(Wed.)	Computers at Work: Good application Flick (cakes, toys, etc.) Comput-Her Baby: Graphic spoof of computer dating.
Sept. 24	(Wed.)	Incredible Machine: Bell Telephone plug for computer music, graphics, motion pictures.
Oct. 1	(Wed.)	The Right of Privacy: Superb account of ways in which institutions invade the rights of individuals. And how the computer can "help".
Oct. 15	(Wed.)	Computer Sketchpad: Good early film of applications and methods of computer graphics (CRT-based). Bart Automatic Train Control: Short animated promo
Oct. 22	(Wed.)	The Leading Edge: Excellent in-depth coverage of computers in aircraft manufacturing: modelling, production control, management systems. The Catalyst: Univac promotional film on potpourri of applications--somewhat sensational.
Nov. 5	(Wed.)	Discovering Electronic Music: Great film for music lovers. Shows how synthesizers are constructed and how computers aid composers. Far out sounds.
Nov. 12	(Wed.)	Thinking??Machines: Good Bell Telephone Flick on different types of "thinking" and how well computers do with each type. Robots Get Smarter: Late 60's account of artificial intelligence work on hand-eye and mobile robots.
Nov. 26	(Wed.)	Spires/Ballots: Review of work in information (document) retrieval in a computer-based system at Stanford.
Dec. 3	(Wed.)	Matter of Survival: Scare film of how one man is affected by his company becoming automated.
Dec. 10	(Wed.)	CAI in New York: The use of prototype computer-assisted instruction (CAI) in a New York City elementary school. Quite a contrast to standard modes as well as to PLATO efforts.

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THE CALCULATOR : A BOON TO EDUCATION

Pearl A. Skoll

Project Director , "The Mobile Computer Math Lab "

Los Angeles Unified School District , Area K

8111 Calhoun Ave., Panorama City, Ca 91402.

ABSTRACT: The impact of the computer revolution has been upon us for several decades and will continue to affect our lives for generations to come. Miniaturization of electronic components has been responsible for the devlopment of the minicalculator. The economics of our country has made this a product available to the consumer at a very reasonable price. Thus the minicalculator has become a responsibility of the educator. It is necessary that we learn to cope with the calculator and create ways to use this highly motivational device as an instructional tool in the classroom. Documentation of the success of students in mathematical achievement was made possible under grant awards from Title III, ESEA, from 1971-1974, for the "Mobile Computer Mathematics Laboratory". The project developed for grades 5-12 in five schools of Area K, LAUSD, has now expanded to 40 schools, grades K-12. Students use a variety of calculators, from desk-top programmables to the hand-held minicalculator to learn the concepts of mathematics and to improve basic computational skills and understanding of numbers. One vital component of a calculator program is the training of teachers in proper techniques for using mini-calculators in the mathematics class. Administrators, teachers, parents and students are involved in setting local policy regarding the utilization of calculators in math classes, within the framework of the mathematics program. Thus, through creative teaching strategies, and students' proper use of the calculator - - - the calculator is, indeed, a boon to education !

There is no doubt that the computer will continue to affect society and the world in which we live. Due to technological advances and miniaturization of electronic components, the size of computing equipment has become so relatively small that calculators with a great deal of mathematical skill fit in the palm of your hand.

Industry has developed a product that is available to the general public. I refer, of course, to the minicalculator. Due to the economic situation in our country, the calculator has become a "thing" of interest, excitement, and pleasure to individuals of all ages in all walks of life. When a calculator is used correctly, a problem is solved accurately, in a minimum amount of time. Thus the drudgery of laborious calculations does not stand in the way of understanding, and learning develops. The emotional feelings one derives from "success" cannot be written down - for there are varying degrees of reactions.

Thus, it is the responsibility of educators to offer "success" to their students in a maximum number of learning situations in a given time period. A student's "curriculum" refers to everything that affects his daily life. Whether one names a subject area "science", "home economics", "driver education", "music", "art", or whatever; when numbers, size and shape, measurement, relationships, and logical analysis of a problem require an accurate numerical solution, it is the arithmetic of mathematical procedures that does determine whether this answer has been calculated correctly.

The minicalculator has been built to do this. Correct answers "pop out" on a display screen. Fantastic!? Not really! This is true only if an individual enters the correct numbers in a correct procedure, within the capabilities and capacity of the particular calculator.

Now a variety of problems and concerns face administrators, teachers, parents and students. The calculator - a boon to education - must not be misused; for abuse of the calculator is more detrimental to education than not using it at all. The power of this tool must be contained within the framework of a meaningful instructional program, that will continue to offer students the opportunity to improve their basic computational skills while learning and understanding the concepts of mathematics.

Thus it is the responsibility of the educator to expose students to the various types of calculators in meaningful ways. One must devise, create, cope with, or develop situations of the world in which we live, to which the calculator can be adapted."

The calculator is a highly motivational device. Everyone wants to at least touch one. Thus the educator must channel this enthusiasm toward learning experiences. Then the calculator will take its place in the classroom, along with paper and pencil, chalkboard, books, and multi-media materials and equipment, to fulfill its role as an instructional aid and learning tool.

Similar to the developmental processes required for a baby to proceed from crawling to walking and running, are the levels of abilities of students to work with and use calculators, as they progress up the ladder of learning and understanding. Although a calculator will compute an answer, it will be the decision of the student whether to accept this value or not, as a reasonable answer to the problem. Thus students develop a "number awareness" through the ability to estimate answers and consequently accept or reject the figure that appears on the display.

Students become interested and involved in their mathematical studies. Enthusiasm is generated to explore, think, deduce, predict, and solve problems - for the fear of mathematics and the failure previously felt because one does not know the entire "multiplication table",(as one of many illustrations), no longer stands in the way of understanding. The calculator fills the gap between understanding what to do to solve a problem, and the actual computation of the numerical answer.

The creative, astute educator will find that the calculator may be used as an aid in improving perceptual skills of the psycho-motor domain; and behavioral attitudes of the affective domain; all this simultaneously during the period of mathematical growth. With reference to perceptual skills, educators agree that some mathematical errors might appear because a youngster has a vision problem, or reverses numbers, or has poor handwriting, or poor motor development, or many other types of problems that have nothing to do with the rules of arithmetic. Through a variety of activities on the mini-calculator, many perceptual problems can be corrected - and mathematical skills eventually improved.

Educators also agree that learning is difficult when poor behavioral patterns and attitudes exist within the educational environment. Since we find that students are anxious to use calculators for the study of mathematics, what simpler way is there to develop self-discipline within a child than to take a calculator away and deprive him or her of using one until one can show self-control and respect for property? Once again the calculator has come to the aid of the educator in the growth and development of the child. Now the students wants to learn, and so he will -- and mathematical skills are again eventually improved.

Do not take this statement lightly ! It is not intended to mean that the "magic" of the calculator always works wonders, or even very quickly ; but rather that it possibly can do something where other efforts have failed.

This year, we are finding that our work with kindergarten youngsters is correcting recognition difficulties. Children had been reading the numeral "2" as a "5", or vice-versa; and even read the number "5" as the letter "S". We are convinced that the earlier these types of errors are corrected, or at least made "cognitive", then they can be corrected and no longer cause the child to experience failure in school.

Many of our students find that they can compute certain problems faster than the calculator. The challenge then becomes one of using larger numbers, or problems of higher difficulty. Students begin to understand the "how" and "why" of mathematical computation through reasoning, rather than by rote memorization of a technique told to them by a teacher.

The low and underachieving students are encouraged to study arithmetic because they are now successful and understand the underlying concepts. The gifted students are challenged to higher levels of analysis in their understanding of mathematics.

An underlying ingredient for the acceptance of the minicalculator by society is the fact that it is simple to operate. Anyone can push the keys and have numbers appear on the display.

Now the controversy is heard ! "Children are cheating when they use a calculator." . . . .

"It's a great gimmick." . . ."The calculator is so cheap now we can buy a class set." . . ."Why should the schools buy calculators if everyone is buying his/her own?" . . ."When you learn the basic facts, then you may use the calculator in school." . . ."If my child uses a calculator now, he won't be able to balance his checkbook." . . . "Do you allow the use of calculators during a test?" . . ."Don't you ever bring a calculator into my classroom!" . . ."Show me what this gadget can do, and then maybe I'll use it in my class." . . ."What security measures can we take to prevent theft and vandalism?" . . ." Is this calculator electrically safe for the children?" . . .etc.etc.

These are but some of the concerns to society. Educators across the nation are attempting to deal with the "popularity" of the calculator. Its impact and existence cannot be ignored. There is no doubt that the calculator has a role to perform within an educational program. The calculator in itself is not a panacea. Staff development is an important component of a calculator program.

A teacher should feel "comfortable" in how to use a calculator to achieve definite goals and objectives. . . for, no matter how "cheap" a calculator is, it is too expensive to be used solely as a check to see if calculating was done correctly by paper and pencil. An answer sheet serves this purpose very well.

Our program, "The Mobile Computer Math Lab", funded from 1971-1974 under Title III, started in five schools in the San Fernando Valley (grades 5-12). There were twenty classes involved in the program.

Test scores over a three-year period, 1969-1971, indicated a need for concentrated mathematical instruction. In two of the five schools targeted to receive services under the project, test scores were 22 and 21 percentile points lower for 6th and 12th grades, respectively, than the average of all schools in the district.

A van was purchased and converted into a mobile mathematics center. Equipment and educational materials were rotated amongst the schools as the project director traveled to each school. A variety of calculators included desk-top programmables, memory-type calculators, and those that used either paper-tape or had a nixi-display screen. An x-y plotter was also used with the programmable calculators. Equipment was limited, so a variety of filmstrips, slides, cassettes, math kits and games were also used to supplement and enrich the mathematics programs at the project schools.

Staff development and community involvement were components vital to the success of the project. Once the teachers and students learned the real value of proper use of the calculators in the teaching and learning of mathematics, their enthusiasm for this type of learning situation soared.

The final report in June 1974 contains the following information on effectiveness:

" 81.6 % of all students who took both the pre- and post-test were enrolled in grades in which statistically significant progress was made, (in terms of pre-post "Z" scores of the applicable norm group); 11.9 % of students were on grade levels in which no statistically significant progress was made; and 6.5 % of students were in a grade level in which progress was significantly negative."

In addition, this final report includes some very important, though unanticipated findings. These are:

(a) Student attendance improved.
(b) Parent interest increased.
(c) Teachers at the project schools used techniques they learned in demonstrations with students who were not officially included in the program and/or evaluation design.
(d) Teachers in the project schools who were not included in the demonstrations took the time to learn our techniques and used them with their students.
(e) Teachers in schools, not included in the project, but who had similar types of equipment, picked up the techniques used in this program.
(f) Articulation heightened amongst teachers of various grade levels from the elementary and secondary schools. "

With the decrease in the cost of the minicalculator, many schools began to purchase their own types of equipment. Requests for proper techniques for using calculators to teach the concepts of mathematics were received from many schools in LAUSD. Title III funding was no longer available - - yet Area K decided to continue this project. For the school year 1974-1975, our services were expanded to include 23 schools. The 1975-1976 school year shows a further expansion. . . for we now travel to 40 schools in Area K. Occasional demonstrations are held in other Areas of LAUSD, as requested. (There are 12 Areas in LAUSD.) Our expertise is also requested at professional mathematics conferences across the nation. . . and as an extension instructor at UCLA, CSUN, CSU-LA, Pepperdine University and a Community Adult School.

Thus, we feel that the calculator is "not a gimmick, nor a crutch". . . but rather a valuable, exciting tool that, when used properly and wisely, can help children to learn what mathematics really is !

Further conclusions discovered as the minicalculator continues to invade our classrooms are:

" (1) Calculators take the drudgery out of computing.

(2) Calculators cannot "think", and consequently do only what they are told to do - - thus, students have to know their mathematics, and press the right keys on the machine to get a correct answer.

(3) Much more number awareness and critical thinking are required when using a calculator correctly and efficiently for the study and learning of mathematical concepts.

(4) The low and underachieving students are encouraged to study arithmetic because of the success factor in their learning of concepts. The gifted students are challenged to higher levels of analysis in their understanding of mathematics.

(5) Students have a great respect for the calculator's efficiency and capabilities. Enthusiasm for mathematics ranks very high in a class where calculators are being used. "

Most teachers take pride in their profession and receive many rewards through the success of their students.

The calculator has the potential to help "turn youngsters on" to education. . . in this case, through the learning and understanding of mathematics.

It is, therefore, the responsibility of each local school's administration, teachers, parents and students to discuss the implications of the existence of the calculator; and to develop a policy concerning the utilization of calculators within their educational program.

Through creative teaching strategies, and students' proper use of the calculator - - - the calculator is, indeed, a boon to education !!

* From the book, "Coping With The Calculator", by P.A. Skoll

FACULTY RATING POLICIES OF COMMUNITY COLLEGE MATHEMATICS STUDENTS

Vernon M. Guymon Jr.

Scottsdale Community College, Scottsdale, Arizona 85251

ABSTRACT: The purpose of the study was to determine what faculty rating policy or policies selected subsets of MCCCD mathematics students used during the 1975-1976 academic year.

The intent of this study was to determine what faculty rating policy or policies selected subsets of Maricopa County Community College District (MCCCD) students used during the 1975-1976 academic year.

Faculty evaluation by students is an area of great concern and the focus of much educational research. In 1974, the MCCCD governing board directed the district faculty to develop a faculty evaluation process which would include student evaluations of faculty. A faculty committee was commissioned to create a proposal to be submitted for district faculty approval. In December, 1975, the committee's proposal was presented and voted upon on a campus by campus basis. Two of the 5 district campuses approved the proposal. Each campus which rejected the proposal was given until March, 1977, to develop an evaluation procedure with the stipulation that the procedure include student evaluations of faculty.

Student evaluations of teaching effectiveness have been found to be related in terms of student rating policies. Identifying these rating policies has been a problem. However, a technique for capturing and clustering raters' policies, Judgement Analysis (JAN), was suggested by Bottenberg and Christal (1) and Christal (3). In a study at the University of Northern Colorado, Houstan (5) used JAN as a vehicle for identifying different judgmental policies used by various subsets of student raters. Regardless of the grouping of students (grade level, reasons for taking the course, school or college in which the students were enrolled), one faculty rating policy emerged for the student groups. The policy was described as student concern for the personal characteristics of the instructor (instructor's interest and enthusiasm, inter-personal relationships, ability to communicate the subject, ability to communicate the subject, ability to interest and motivate students). The instructor's classroom management characteristics and professional qualities (attitude, knowledge, and preparation) did not make a significant contribution to the students' policy.

Following the procedures used in the Houstan study (5), JAN was used in a pilot study to identify different judgmental policies used by various groups of mathematics students attending Glendale Community College and Scottsdale Community College during the 1974-1975 academic year. When students were grouped by the campus which they attended, one faculty rating policy emerged. However, when the students were grouped by their mathematics instructors two faculty rating policies were obtained.

PURPOSE OF THE STUDY: The purpose of the study was to determine what faculty rating policy or policies selected subsets of MCCCD mathematics students used during the 1975-1976 academic year. Three grouping methods were used. Specifically, students were grouped by campuses, mathematics courses, and by mathematics instructors. By the use of JAN, the identification of the minimum number of different judgmental policies was made for each of the student groupings. Student evaluations of faculty were conducted in December, 1975, and in May 1976, to determine if the faculty rating policy or policies of the various student groupings varied from semester to semester.

HYPOTHESES: The following hypotheses were tested in this study:

H1. A single faculty rating policy is obtained when students are grouped by campuses in the December evaluation.

H2. A single faculty rating policy is obtained when students are grouped by mathematics courses in the December evaluation.

H3. A single faculty rating policy is obtained when students are grouped by mathematics instrutors in the December evaluation.

H4. A single faculty rating policy is obtained when students are grouped by [illegible] the May evaluation.

... A single faculty rating policy [illegible] attained when students [illegible]

... A single faculty rating policy [illegible] attained when students [illegible] instructor [illegible]

[illegible]

Cattell's parametric notation as follows:

b - for bivariate. Multiple regression studies are actually the midpoint between bivariate and multivariate work but are considered as bivariate for classification purposes.

f - for "freely happening." The variables measured in this study were not manipulated nor interfered with.

d - for "dated." Variable 1 was measured before variable 2, variable 2 was measured before variable 3, etc.

u - for "uncontrolled." All of the possibly involved variables left unmeasured and unobserved (classroom facilities, time of day of classes, etc.) were allowed to differ as they will.

a - for "abstractive." The researcher chose which variables to observe according to a specific hypothesis about relations among a set of variables of interest.

k - for "keyed to a biased sample." Faculty members who volunteered to participate in this study were selective in determining which classes evaluated their performance.

INSTRUMENTATION: Students were asked to rank their mathematics instructors on each item of the following instrument.

EVALUATION OF INSTRUCTION

Please rate only this instructor in this particular course in accordance with this rating scale:
(1) Poor (2) Fair (3) Average (4) Good (5) Excellent

1.	Instructor's interest and enthusiasm for course.	1 2 3 4 5
2.	Ability to adequately answer questions.	1 2 3 4 5
3.	Ability to communicate the subject matter effectively.	1 2 3 4 5
4.	Ability to interest and motivate students.	1 2 3 4 5
5.	Fairness in testing and grading.	1 2 3 4 5
6.	Personal interest and adaptation to student's needs.	1 2 3 4 5
7.	Course objectives are clearly stated.	1 2 3 4 5
8.	Course objectives are met.	1 2 3 4 5
9.	Everything considered, including strengths and weaknesses, I would rate the teacher.	1 2 3 4 5

This instrument was used by Houston(5) to determine what policies existed for various subsets of student raters at the University of Northern Colorado. Since the instrument is not widely used or recognized, it is very important to consider its reliability and validity.

Reliability - The reliability of an

instrument refers to the stability, repeatability, or the precision of the data collected from the instrument. The responses on the first 8 items on the instrument were considered as predictor variables for the response on item 9. In the Houston study, the R^2 (multiple R squared) values exceeded .74. This indicated a high degree of intrareliability for the Northern Colorado students. When data were collected using this instrument at [illegible] and [illegible] in the pilot study during the 1974-1975 school year, the R^2 values exceeded .6[illegible]. These results indicate an adequate degree of reliability for the instrument.

Validity - The validity of an instrument refers to the extent to which data from the instrument measure what they were intended to measure. Any estimate of the extent to which an instrument is valid requires an already existing instrument or measure which has sufficient relevance, reliability and validity to be used as a criterion measure. In the domain of teacher effectiveness such a criterion is not yet available. However, [illegible]ats (4) used a 11 item questionnaire to determine the number and nature of the factors which underlie student perceptions of teachers. A single factor accounted for 61.5% of the variance in test items. The highest loadings of this factor were on (a) "clarity of explanations", (b) "fairness", (c) "attitude toward students", (d) "Stimulates interest", (e) "attitude toward subject", (f) "attitude toward student opinions", (g) "encouragement of student participation". Items 1 through 6 on the instrument used in this study are addressed to these concerns. Items 7 and 8, while apparently not significantly related to student perceptions of teachers, were retained for comparison with the Houston study.

DATA COLLECTION: A prepared packet of questionnaires and answer sheets was given to each participating faculty member for each of his classes. The packets were distributed to the faculty during the weeks of November 24th and April 19th. All packets were collected prior to finals at the end of each semester. On the front of each packet was a code for the specific class and instructor and a set of instructions regarding the administering of the questionnaire. Briefly, the teacher was instructed to chose a student in the room to adminster the survey and then leave the room while the survey was completed. The packet was then delivered by the student in charge to the mathematics office.

TREATMENT OF THE DATA: The students were grouped into three selected subsets. The first grouping was made by campuses within the MC[illegible] and resulted in 4 subsets or groups of students. The researcher treated each of the individual groups as a judge of mathematics teaching performance in the first JAN investigation. The second grouping resulted in 10 groups each of which was treated as a judge in the second JAN analysis. The third grouping of students was made on the basis of mathematics instructors. This grouping resulted in 26 groups which were treated as individual judges in the thrid JAN analysis.

JAN utilizes a multiple regression model and a hierarchial grouping technique which clusters reaters on the basis of the homogeneity of their prediction equations. The procedure relates each of k dimensions of the stimuli (the predictors) to the responses (criteria) made by a rater through a least-squares regression equation. Once ratings for all stimuli have been obtained, the JAN technique uses an interative method of clustering criteria which retains optimum predictive efficiency.

As described by Houston, "the JAN technique starts with the assumption that each judge has an individual policy. It gives an R^2 (multiple R coefficient squared) for the initial stage consisting of all the judges, each one treated as an individual system. Two policies are selected and combined on the basis of having the most homogeneous prediction equations, therefore resulting in the least possible loss in predictive efficiency. This reduces the number of original policies by one and and gives a new R^2 value for this stage. The loss in predictive efficiency can be measured by finding the drop in R^2 between the two stages. The grouping procedure continues reducing the number of policies by one at each stage until finally all of the judges have been clustered into a single group." (6)

Following the procedure used by Houston, the researcher examined the successive drops in R^2 at each stage of the JAN process. The determination of whether one or more policies were present among the judges was made on the basis of the stage-by-stage drop in R^2. It was determined a priori by the researcher that a slippage greater than .05 between successive stages represented to great a loss in predictability. (According to Houston, a .05 drop in R^2 usually coincides with a departure from linearity in the R^2 drops.) By employing this procedure it was possible to determine the December and May evaluations for each of the student groupings.

Supplementing the JAN procedure the researcher used stepwise multiple regression (BMDO2R) in an effort to explain the policies identified by the JAN technique. The researcher determined the unique contribution of proper subsets of the predictor variables, 1-8, to the prediction of the criterion (variable 9). The contribution of a set of variables to the prediction of the criterion can be measured in terms of the difference between the full model (FM) R^2 (all predictor variables included) and the restricted model (RM) R^2 (some variables omitted). This difference may be tested for statistical significance by using an F-ratio or by establishing an [illegible] maximum [illegible] ... the researcher [illegible] procedure and established [illegible] maximum acceptable drop in R [illegible] R^2_{RV} [illegible] .05 the researcher [illegible] that the omitted variables were [illegible] criterion.

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VARIETIES OF INTERACTIVE COMPUTER-BASED TESTING

David B. Thomas

University of Iowa, Iowa City, Iowa 52242

ABSTRACT: Computer-based instruction has spread from the obscure laboratories of the 1960's to often extensive usage by colleges and universities, public schools, business and industry, the military, and government. A recent accompaniment to the growing use of computers for instruction has been the development and use of computer-managed test item banks and computer generated tests. Further developments have included procedures whereby students are tested while seated at computer terminals. This review will focus on the varieties of interactive tests and on research which has suggested alternative methods for presenting and scoring tests presented by computer. Particular emphasis will be placed on a comparison of sequential, branching, linear, and multi-staged item selection and presentation models for interactive computer-based testing.

Computer-based tests have generally been characterized as groups of test items which are stored, constructed, or generated by means of a computer system. Such is the focus given by the systems described in a volume edited by Lippey (1974) in which test items reside in item banks stored within the computer systems and in some cases on tab cards retained by individual instructors. These models of computer assisted test construction provide for automated item selection (according to criteria such as content, difficulty, discrimination, and the like), item generation (using item forms), and printing of tests and alternative forms. Statistics relating to item and test usage and item analysis data are also usually retained by the computer system for evaluation of the items or for use by item selection algorithms.

An almost universal characteristic of the computerized test construction systems is the necessity for off-line administration of the tests. The applications for such test construction systems are widespread, and usage of the systems is increasing. Recent work has begun to extend the applicability of such automated systems to testing which takes place at an interactive terminal so that the testing situation may be uniquely and dynamically structured for the individual student.

An interactive test may be defined for present purposes as a test administered at a computer terminal, such as a teletype or cathode ray tube display, in which the student's response to each question is immediately evaluated by the computer, a testing decision may be made, feedback to the student may be provided, and another item may be selected for presentation to the student. The interactive process is then repeated as often as necessary until the testing session is concluded. A distinction needs to be made between the concept of an interactive test and some forms of computer assisted instruction (CAI). In certain varieties of CAI test questions play a major role. Drill and practice programs consist almost entirely of questions; tutorial programs intersperse questions with text; simulations and inquiry systems often use test-like questions as part of a dialogue. Groups of test questions such as these are not considered interactive tests within the present discussion even though these uses properly fall within the definitions provided. The interactive test as used here provides guidance useful <u>between</u> units of instruction whereas the CAI usage generally provides guidance <u>within</u> the unit.

In the interactive testing situation the examinee is presented with a test item through a computer terminal. The response to the item is evaluated as to its correctness and this information, together with other information which may be available (difficulty of the item, response latency, prior test or item scores for the student, for example) is employed in a decision model which may permit or select the next item to be presented or may even terminate the testing session.

The interactive testing models which have been developed may be classified according to four points of view representing the procedure employed as the student proceeds from item to item through the test. These procedures, or models, have been classified as (1) linear, (2) branched or tailored, (3) sequential, or (4) multi-staged.

<u>Linear interactive tests</u> - The linear interactive test is one which is translated directly from a paper-and-pencil format to computer presentation. In such a test an item is presented to the student and a response is elicited. The correctness of the response is determined either through reference to a key or by comparison of the students' response to a generated answer if the item is dynamically composed. A key characteristic of the

linear test is the general absence of a decision function which would alter the length of the test or route the examinee from item to item. Items are presented in a predetermined order without exception. Linear interactive tests are common in computer-managed instruction (CMI) courses such as those at Florida State University and the University of Iowa. (cf. Hagerty 1970). The student enrolled in CMI courses at the University of Iowa signs on to a computer terminal, is presented with a short linear test, the test is immediately scored and the student receives feedback as to whether the instructional unit has been passed. In the Florida State University system, the same model is followed, except that the short linear tests are composed of items randomly selected from an item pool. A more complex mode of interactive testing and one providing a higher degree of individualization is the branched testing mode.

Branched testing models - Test items presented under a branched format resemble the form of interaction seen in a programmed instruction text. The student responding to a branched test is presented with an item, an answer is elicited, the answer is evaluated, and the next item is selected for presentation on the basis of the answer evaluation. Typically, the next item selected is determined on the basis of item difficulty. The difficulty level of the previous item and the examinee's answer are determinants of the difficulty of the succeeding item. It is desirable that items employed in aptitude and ability tests have difficulty levels of approximately .50 (about 1/2 the examinees answer the item correctly) for the population of students for whom the test is designed. For the individual, the objective is to design a test with difficulty level nearly the same as the examinee's ability, and to do so in a way that the test has difficulty level of .50 for that individual. The branched test is designed to do this by presenting a more difficult item after an item answered correctly and presenting a less difficult item following an item answered incorrectly. The items in the item pool making up the branched test are calibrated to determine their difficulty levels prior to their being administered to examinees for whom branching is to occur. An examinee typically begins the test by answering an item of moderate difficulty.

Within this framework, Bayroff and Seeley (1967) constructed branching tests of eight and nine items for use with Army enlisted men. The initial item presented had a difficulty level of .60 and each subsequent item differed from the item preceeding it by .05 on the difficulty scale. These investigators found correlations between scores on the branched tests and 40-50 item linear tests of .79 and .83. Reliabilities were found to exceed those predicted for the linear tests of similar length. Hansen (1969) constructed similar tests for use with students in a college physics course. High reliability was reported as well as a reduction in testing time.

If prior information regarding an examinee is available, such as a teacher rating, reliable self reports, or prior test scores, then the difficulty level of the first item to be administered may be selected in a manner consistent with this prior information. Weiss (1973) describes a branched testing procedure (stratified-adaptive or stradaptive) in which items are grouped into nine strata representing approximately equal difficulty levels. Items of difficulty level approximately .05 form the first stratum, items with difficulties of about .15 form the second, and so on. The examinee is first administered an item from the stratum closest to the ability level suggested by the prior information available. Correctly answered items are followed by administration of the next available unanswered item selected from the stratum of higher difficulty. Items answered incorrectly are followed by the next available item in the lower difficulty stratum. Testing continues until both basal and ceiling strata are identified. Over a dozen scoring formulae are being investigated to derive the actual ability level obtained. Weiss has shown that for the stradaptive test the difficulty level for the individual is very nearly the optimal level of p = .50.

Other procedures for branched testing have been proposed, some involving paper-and-pencil versions utilizing programmed booklets and special answer sheets. Alternative item selection strategies have also been investigated, notably Bayesian methods.

Sequential testing models - The branched testing models described previously are procedures for routing the examinee to items in a test which are appropriate to his or her ability level. With the exception of the stradaptive test, all of the tests described are of a fixed length. Even though the item makeup and branching rules differ, a specific test will typically be designed to contain a fixed number of items for each examinee. Only the stradaptive test employs a termination rule which results in tests of potentially different length. The sequential testing models to be described employ either a fixed item sequence or a rule for generating homogeneous items. A scoring and termination rule delimits the number of items presented during the interactive test.

The sequential testing procedure is implemented as follows: the student is administered a test item; the response to the item is evaluated according to the specific requirements of the model; the examinee is tentatively assigned to one of a number of classes representative of the ability estimate obtained at that point. The risk of incorrectly assigning the examinee is evaluated in reference to the amount of information available at that point in the test, and to parameters supplied by the test administrator. If the risk of assignment to an incorrect class is acceptably low, the test will be terminated, but if the risk exceeds an acceptable level another item is administered and the decision process is continued. Three major differences between the sequential and branched tests should be apparent. Firstly, the number of items in the sequential test is variable compared to the generally fixed number of items in the branched test. Secondly, the items themselves are fixed in the sequential test. Every examinee who completes ten items, say, will have been presented the same items in the same order (unless homogeneous items have been generated). Thirdly, whereas the branched tests are designed to directly estimate the examinee's ability level, on a continuous scale, the sequential tests are designed to <u>classify</u> the examinee into a group which is representative of the ability level. Alternatively, classification may be made into groups of other kinds. Examples of such groups are pass-fail, high-middle-low aptitude, accept-reject, program 1 - program 2- program 3, and so on. For many applications, such class designations may be sufficient and perhaps preferable to traditional ability scores.

A sequential testing model has been developed by Thomas (1975) which employs repeated applications of discriminant functions to classify examinees into one of four ability groupings. As items are presented to the student, a previously derived discriminant function is entered using the complete response protocol for the present and all previous items. The discriminant function indicates the class to which the examinee most likely should be assigned, given the response protocol at that point in time. When a small number of items have been presented, the probability associated with the "most likely class" is typically small enough so that one would not be highly confident of a decision to assign the student to the identified class. Thus, the probability of membership in each class is employed as a termination rule. After each item has been evaluated, the highest probability (i.e., that associated with the "most likely class") is compared with a minimum acceptable probability. If the minimum is exceeded, then testing stops; otherwise testing continues until some previously specified maximum number of items have been administered. Thomas found that only 1/2 to 1/3 the normal number of items were required for classifications and that 70% of the examinees were correctly classified. "Major" errors of classification occurred for only 5% of the examinees.

Ferguson (1971) employed a hierarchical model of criterion-referenced measurement in conjunction with a sequential probability ratio test (Wald, 1947). Homogeneous items were individually generated through the use of item forms. Examinees were evaluated relative to course objectives by administering an item and applying the sequential probability ratio test to determine whether the student had achieved mastery, failed to achieve mastery, or whether judgment should be suspended. A non-mastery decision terminated testing. In the case of suspended judgment, another item was generated, the item was administered to the examinee, and the sequential probability ratio test was repeated. A mastery decision led to testing of the next objective in the hierarchy. As a result of having to test fewer objectives in the hierarchy, the author found high reliability and a total testing time reduction.

Linn, Rock, and Cleary (1972) employed a similar model of sequential testing with three scales of the College Board's College Level Examination Program. The items were administered in the same order as in the original scale. These authors found that one-half the traditional number of items were required for the sequential testing model to identify students who should be placed into one of two categories.

The sequential testing models have not enjoyed the attention nor have they been the subject of as extensive research interest as the branching tests. This is primarily because they are inherently concerned with <u>selection</u> rather than measurement, <u>per se</u>. The sequential procedures as a group require the development of fewer items than the branching procedures and may ultimately emerge for this reason. Perhaps the selection function necessary for the multi-staged tests, described next, will provide the stimulus for more interest in this procedure.

<u>Multi-staged models</u> - The final variety of interactive tests to be presented are the multi-staged tests. This testing strategy requires two or more sub-strategies on sub-tests. The first stage consists of a routing test which is administered to the examinee to ascertain a general level of ability. This level may be characterized as broadly as high-middle-low, or may be somewhat more precise in nature. The routing test is typically followed by a "measurement" test which is peaked at the ability level indicated by the routing test which preceeded it. Characteristic of the multi-staged tests are those which have been investigated by Cleary, Linn and Rock (1968) using simulation techniques and existing item data. Four procedures were studied which divided examinees into four ability groups. Each of the four ability groups was then administered the measurement test of the appropriate ability level. The four routing procedures were:

1. Two-stage routing test - Ten items were selected which had difficulty values of approximately p = .50. The examinees were divided into two groups on the basis of scores on this first ten-item routing test. Each group was then administered a second routing test of ten items selected in the same manner within each ability range. Four ability groups were thus formed which could be administered the appropriate measurement tests.
2. Broad range routing test - Twenty items were selected which represented a broad range of difficulty. Examinees were administered these twenty items and divided into four groups on the basis of scores.
3. Group discrimination routing test - Twenty items were selected which showed the largest range of within-group difficulty indices (i.e., difficulty values computed for each of four ability groups). The score on these twenty items was used to form four ability groups.
4. Sequential routing test - Twenty-three items were selected for use in a sequential test as described in the previous section. Four ability classes resulted.

These investigators, in a series of studies, have showed that a procedure of sequential routing to the measurement test showed highest correlations with the total test score, but that the group-discrimination routing test showed higher correlations with external criteria such as achievement scores in History and English.

Application or Research? - The varieties of interactive computer-based testing which have been reviewed are largely confined to the research laboratory. Researchers are not presently prepared to recommend specific models for wide-spread adoption - indeed could not do so without significantly expanding research with students in a non-laboratory setting. The interactive computer-based testing which does occur within the context of ongoing instruction and which is relatively free from user concern for examinee welfare relates to one model only: the linear test. Yet even the linear test is not free of affects related to the computer terminal situation. Some research, for example, seems to indicate that black students perform better on a terminal-oriented test than on a traditionally administered test. Findings of this nature lead to speculations as to the equivalence of alternate forms of the test and to the errors of measurement - whether stimulated by computer or by paper-and-pencil testing.

The use of computers for interactions of any kind with students lead to considerations of costs vs. benefits. Consideration of the relative worth of teacher and student time also needs to be made. In those situations where student time is important and costly, as in the military, for example, computerized tests may be administered on demand within an individualized instruction framework. Even if administrative costs are not lessened, cost-effectiveness may be improved.

In situations where many different tests are given or where fast scoring is desirable, computer-based tests may be an attractive alternative. Where testing occurs at different times for different students and item security may be a factor, the computerized test may be valuable; an item on a CRT display leaves no hard copy for possible compromise.

In summary, let it be said that computer-based interactive tests are being actively explored by measurement specialists, educational researchers, and instructional technologists. Much testing has been taking place at computer terminals, primarily of a linear sort, and the trend to increase computerized testing applications will continue. The techniques described here, which individualize the testing interaction, will certainly be developed to the stage that will permit their educational use within a very few years.

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THE CONSOLIDATION OF SOCRATES*:

GROWING PAINS IN A LARGE COMPUTERIZED TEST GENERATION NETWORK

Lisa Gray-Shellberg, California State College, Dominguez Hills
W. Van Willis, California State University, Fullerton
Oliver Seely, Jr., California State College, Dominguez Hills

State-Wide Project Directors

SOCRATES Computer Assisted Test Construction

Substantial increases in the number of users, number of item banks, and item bank sizes have occurred in the past year. These changes, coupled with feedback from teachers and support personnel, have provided valuable input for consolidating SOCRATES from a pilot or demonstration phase to a routine operational phase. The experience gained in this task should provide invaluable input to educators interested in developing and implementing computer based test generation, scoring, and analysis (CTG) packages for classroom support. Five areas of experience are discussed as especially important to any such project: design of item banks for maximum selectivity and item retrieval, design of items and processing them into the banks, user attitudes, habits, and training, hardware and software constraints; effective use of CTG as a classroom resource.

Introduction

Notice!!! Test preparation is no longer a laborious task. The timesharing Exam Program enables an instructor to prepare a test by entering the following simple commands into an office terminal.

Exam test request (identifying the test generation Program)
General chemistry (identifying the question bank to be used)
Stoichiometry, volume calculations - 10 items (identifying category and quantity of items to be selected)
Chemical equations, predicting products - 10 items
Nomenclature, binary compounds - 10 items
Redox, determination of oxidation numbers - 5 items
Keyword: test 23, chapter 3, 4 (questions to be limited to those from a particular text and chapter)
Mixed difficulty levels, 4 versions

The screen displays the requested items sequentially, allowing the teacher to accept or reject them. Five different output options are provided: (1) the test may be placed on floppy disc at the test center for students taking the course on a self-paced basis; (2) the test may be printed on the electrostatic copier in the department office (1-10 copies); (3) the test may be printed on spirit duplicating masters at the teacher's office terminal with a 50% linear reduction (11-200 copies); (4) the test may be copied automatically onto microfiche cards with tri-color diagrams to accompany the text of the questions (11-200 copies); (5) the test may be transmitted to a queque at the duplicating center to be processed on its computer controlled multilith machine (100-5000 copies).

Sound like science fiction? It is if the teacher is employed by any public or private institution of learning in the U. S. Yet the technology required to retrieve tests and deliver them by any of these five options has been available for over a decade.

The development of SOCRATES began in 1972. Since that time many people have contributed to its growth. Our task this year has been to consolidate the progress to date. We have observed certain problems associated with the application of computer technology to the educational process. We present some of our experiences here for others who plan to develop a similar test generation and scoring service.

The teaching/learning process contains two major components: (1) the delivery of subject matter to the student and (2) the evaluation of student progress. Although the number of ways in which these two components can interact is large, the relationship is often in one direction only; the nature of the second is determined by the nature of the first, but not vice-versa. Following a period of learning, the student is examined for acquired knowledge. The examination serves as an evaluative tool only and not as a guide for the delivery of more course material. As long as the level of delivery is aimed at the average student and the exams are normed on the class average, this method is considered to be a success. That some students excell and others fall further and further behind is considered simply to be a peculiarity of "the system". Over the years, this commonly observed shortcoming gained greater prominence and educators began to suggest methods that were more sensitive to students' needs.

Today we see many outgrowths of this early desire to improve the system: programmed instruction, computer assisted instruction, self-paced learning, personalized instruction to name just a few. All of these methods tend to focus on the students' needs in determining the level and the speed of course work. Unfortunately, they have the fault of requiring the teacher to spend excessive amounts of time preparing and/or evaluating course work for students at various levels of progress. It is the evaluation of student progress which proves to be particularly burdensome: most of the personalized methods use a modular approach, with each module being concluded by a test over its contents. Some teachers administer a pre-test and a post-test as well as repeated post-tests until a certain mark is attained. It is here that the computer offers a solution to a very real educational problem. It can generate and print tests quickly, score the results, maintain student records, and compile item statistics for future test development.

Of course, educational administrators ask for more than that a new method, medium, or gadget be able to solve or alleviate a recognized educational problem. First, it must be just as accessible as the method earlier used for the same purpose. Second, it must be competitive in price. These two additional criteria pose larger problems.

A comparison of manual preparation and scoring of equal numbers of exams vs. computer generation and scoring will doubtless show the automatic method to be cheaper. To compare the generation and scoring of large numbers of tests for individual students, even by the computer, with the manual assembly of perhaps, a one-hour midterm examination and a three- hour final examination each term, the cost comparison becomes somewhat less favorable. There is another problem. Even if one were to compare the cost of generating and scoring equal numbers of examinations by both methods, the cost of the computer generation is added to existing educational costs rather than replacing them.

The teacher is still paid the salary of a full-time faculty member. The secretarial staff is not reduced. That the teachers and secretaries can now redirect their efforts toward more useful endeavors thereby improving the educational process cannot be denied; it is not, however, an argument for reducing costs.

Then, there is the matter of accessibility. In the early days of this century when the automobile first made its appearance, people worried about the problem of refueling on long journeys. The automobile enthusiasts of the time went out on a limb in predicting that refueling would be no problem at all as someday there would be one gasoline station in every large city.

Most educational institutions, in contradiction to the state of the art, find themselves still very much at the beginning of a new age. It is one thing to paint rosy pictures of automatic test retrieval as we have at the beginning of this article, but quite another to attempt to convince financial officers of the educational efficacy of computer assisted test construction when the system is plagued by any of the following problems:

The terminal which prints the tests is more than five hundred miles away (for some of our campuses).

The terminal which prints the tests is half-way across campus (for the rest of our campuses).

Your local campus ADP director will support the printing of tests on the local high-speed printer, but will not supply them on continuous form reproduction masters.

The reproduction of tests printed on white paper requires an advance notice of two weeks at the duplicating center.

The local campus ADP director will not support the SOCRATES system because he is already understaffed.

The test request (telephone-oral) gets garbled in transmission.

The test request (punch card via cable) is mis punched.

The computer breaks down.

The ADP director is supportive of the system, but the print chain on his terminal is the wrong one.

The teacher discovers during the duplicating process that the ditto masters were mounted backwards on the high-speed printer.

The test arrives on standard white forms, but the print is too light to produce decent optical masters.

The test arrives by first class mail ten days after it was postmarked.

The Organizational Structure of SOCRATES

The Division of Information Systems of the California State University and Colleges is centralized at the Chancellor's Office in Los Angeles. A dual CDC3300 computer services the needs of all nineteen campuses, though each campus has a smaller computer which can handle small jobs with quick turn-around. The organizational structure of project SOCRATES is shown in Figure 1. The role of the major components in the diagram are described below.

User-Contributors

There are slightly over three hundred users registered to request tests through SOCRATES. These users are distributed over the nineteen campuses of the California State University and Colleges. The potential user group within the system is roughly sixteen thousand. If the SOCRATES system remains centralized and its use is opened to faculty of the community colleges as well, then this potential user group would expand to over thirty thousand individual teachers. The daily request rate varies from one to three percent of the total registered users. In the month of November, 1975, there were 151 test requests processed. Users request tests from banks covering sixteen subject matter areas in one of two ways: directly by telephone to a clerical assistant hired to take test requests at the Chancellor's Office or by remote-job-entry at one's local campus computer center. The component labeled "communications interface" accounts for either of these functions. From the very beginning, our users were encouraged to submit their own items to existing banks and to develop new banks in other disciplines. As contributors, they are exposed to the finer details of cross-classification: categories, keywords, difficulty levels, behavior levels and special characteristics. Six of our existing banks and five new ones have been built by faculty who welcomed this opportunity and immediately saw advantages of using computer assisted test construction in their disciplines.

Bank Coordinators

Excluding the U. S. History bank which was developed by a large number of teachers in the Los Angeles Unified School District, each SOCRATES bank was developed by one or two faculty members in the CSUC system. Development included writing appropriate category indices, gathering items for inclusion, classifying the items according to category, difficulty and behavior level and certain cross-references. In the early stages of development, SOCRATES bank coordinators were from our Southern California campuses. Only recently, as the system has begun to be better publicized, are coordinators from the northern campuses beginning to volunteer their efforts. After a bank has passed through its initial development, users begin to ask if they may submit their own items to the bank. Dedication to this task varies greatly, but the overall effect is to change the role of the bank coordinator from innovative developer to that of manager. As new groups of items are received, they must be logged in and checked against earlier contributions to guard against duplication. Keypunch operators need to be kept informed on changes in notation conventions for each bank. As the volume of submitted items increases, coordinators find it impossible to undertake the task of coding them: those faculty who have submitted items are generally assigned this task. It is the coordinator's job to keep these individuals informed of changes in the category index and conventions on keyword and special characteristics. Finally, it is the coordinator's job to set standards of reliability based on the item statistics and periodically to edit the bank on the basis of these standards.

Campus Coordinators

Each campus has a testing officer whose traditional duties have included the administration of personal aptitude inventory tests, the coordination of periodic college board exams held on the campus, advising the local academic senate on the establishment of standards for teaching effectiveness surveys and assistance to faculty with research requiring expertise in the area of tests and measurement. The development of project SOCRATES, the availability of automatic scoring packages locally and the renewed awareness among faculty toward reliability of tests has given these testing officers the added responsibility of becoming the local SOCRATES expert. The response from the testing officers ranges from enthusiastic support to premeditated ignorance. The former generally see the role of their office to be that of service to faculty, whatever the need may be. The latter are often employed by the counseling centers on their campuses and they traditionally have not been involved in classroom testing. Nevertheless, as SOCRATES grows, we shall look more and more to these individuals to take on the task of maintaining a local supply of documentation and assisting faculty to order tests.

Project Directors

As the SOCRATES system grows, the role of the project directors changes from that of inspired (possessed?) innovator to that of evangelist. In the beginning, it is necessary to secure some programming support to write the prototype retrieval system and a few dedicated (hoodwinked?) faculty to develop the first item banks. After the first few banks are operating, and with the assistance of the workshop coordinator, the directors travel from campus to campus, spreading the gospel and distributing dumps of item banks like Gideon Bibles.

Systems Analyst - Programmers

Project SOCRATES employs one part-time systems analyst and a full-time programmer. The systems analyst and the project directors together evaluate desires and suggestions made by users, bank coordinators and ADP directors on the various campuses. After much discussion and establishment of priorities each year, the programmer tackles the job of implementation. The programmer also serves as troubleshooter when requests for tests fail for reasons beyond the knowledge of the clerical assistant who takes the request, or the user who submits the request by remote-job-entry.

Local ADP Directors

The SOCRATES system represents a very minor part of the job responsibility of the local ADP directors, whose attention is focused on supporting the registration, accounting, grade reporting, and a broad spectrum of instructional computing services. Nevertheless, most ADP directors see SOCRATES as a way of giving instructional computing a larger voice in the determination of campus policies affecting computer services. The ADP directors, through their support personnel assist users in generating examinations by remote-job-entry and having them printed on schedule at the local campus high-speed printer. The bad news is that there is a widespread reluctance to have SOCRATES tests printed locally. Faculty are reluctant because the local character set is slightly different from that used at the Chancellor's Office; ADP directors are reluctant because the line speed is only 3600 baud--any significant use of SOCRATES by faculty would swamp local campus systems. Practically all ADP directors refuse to support the local use of ditto masters, partly because of the expense involved and partly because of the static they get from their operators.

Summary

The reader might wonder what has happened to the rest of the connecting lines of command in Figure 1. The answer is that there are none. Each circle in the diagram represents a person who works for and is paid by a different administrative unit. The bank coordinators are largely faculty members on separte campuses, unpaid for their dedication to SOCRATES. The same is true for the user-contributors. The keypunch support for this year has been donated by the ADP director on one campus. The project directors and workshop coordinators are employed by the Office of New Programs and Evaluation. The computer operators are employed by the Division of Information Systems. The campus test officers are usually professors of tests and measurement on the various campuses. The systems analyst and programmer work for the Instructional Support Group of the Division of Information Systems.

The administrative structure of SOCRATES is a manager's nightmare and an academician's dream. With the exception of the keypunch operator and the computer operators, who answer directly to their supervisors, everyone else is free to do as he or she pleases within some very loose philosophical boundaries and the programmed constraints of the system. The campus testing officers are free to encourage or not to encourage faculty on their campuses to use the system. The bank coordinators are free to use many forms of cross-references in developing their banks or none at all; they are free to work closely with users who wish to contribute their own items or to let those users work directly through the project directors in getting their items coded and loaded. Users are encouraged to use existing banks and to develop new ones in different disciplines and specialties. Although they are encouraged to use the SOCRATES scoring package in order to add to the item statistics file, they are free to use scoring packages available at their own campuses or to use more accessible self-contained scoring machines. The workshop coordinator maintains an active schedule of meetings with interested faculty on the various campuses, assisting in the request of initial tests. The project directors maintain an office which serves as a clearinghouse of ideas and documentation. Suggestions which are deemed suitable for serious consideration are discussed by all concerned at a monthly coordinator's meeting. The office maintains current copies of all system documentation for users, coordinators and interested correspondents alike. At this early stage, the directors' job is to extend an open invitation to faculty both to participate and contribute to the banks.

There are at least two advantages to such a loose structure. First, the system will grow through faculty initiative rather than administrative directive. The charge that SOCRATES is being used as a means of controlling all classroom curricula centrally will be groundless. Secondly, expansion of the system to include the community colleges of California when the public agency data processing network is implemented will require little change in its administration; there will be some new banks, some extra money for hiring additional support personnel and a greatly expanded group of user-contributors. There is still widespread uncertainty and outright fear and ignorance among faculty and administrators about applications of computer technology to the educational process. The development of systems such as SOCRATES is better served by a loose structure, because its slow, natural growth threatens no one. It has the added advantage of buying us time to improve the system.

On the other hand, it is imperative that we recognize that the key to success is to continue to strive, through effective management, to achieve "the greatest good for the greatest number". The question is not whether to give permanent support to computer assisted test construction, thereby assuring its continued development. The observation that the computer has become an indispensable tool in supporting routine operations of educational institutions, including the maintenance of records on registration, grades, library holdings, and payroll, forces one to realize that the real question is whether to allow computer assisted test construction to develop on nineteen campuses in nineteen different ways with hundreds of programmers duplicating each other's efforts and thousands of professors submitting tens of thousands of test items, many of which are the same items that are being submitted by their colleagues, to hundreds of keypunch operators, all punching them in different formats. Can we afford to let professors keypunch their own items - to be used in their own private banks with primitive retrieval systems written by them in the evenings and on weekends with no coordination with a single other professor in the whole CSUC system?

That the final success of computer assisted test construction is inevitable, there can be no question, judging from the increasing demand for more rapid and efficient information retrieval from many sectors of society. Its usefulness will continue to be hampered though until the computer becomes as reliable as the department secretary or the office typewriter, until teachers place the same trust in the computer to produce tests as they do in a textbook to produce ideas for test questions and until users begin to demand the same quality of information retrieval service as they can now get from their campus librarians.

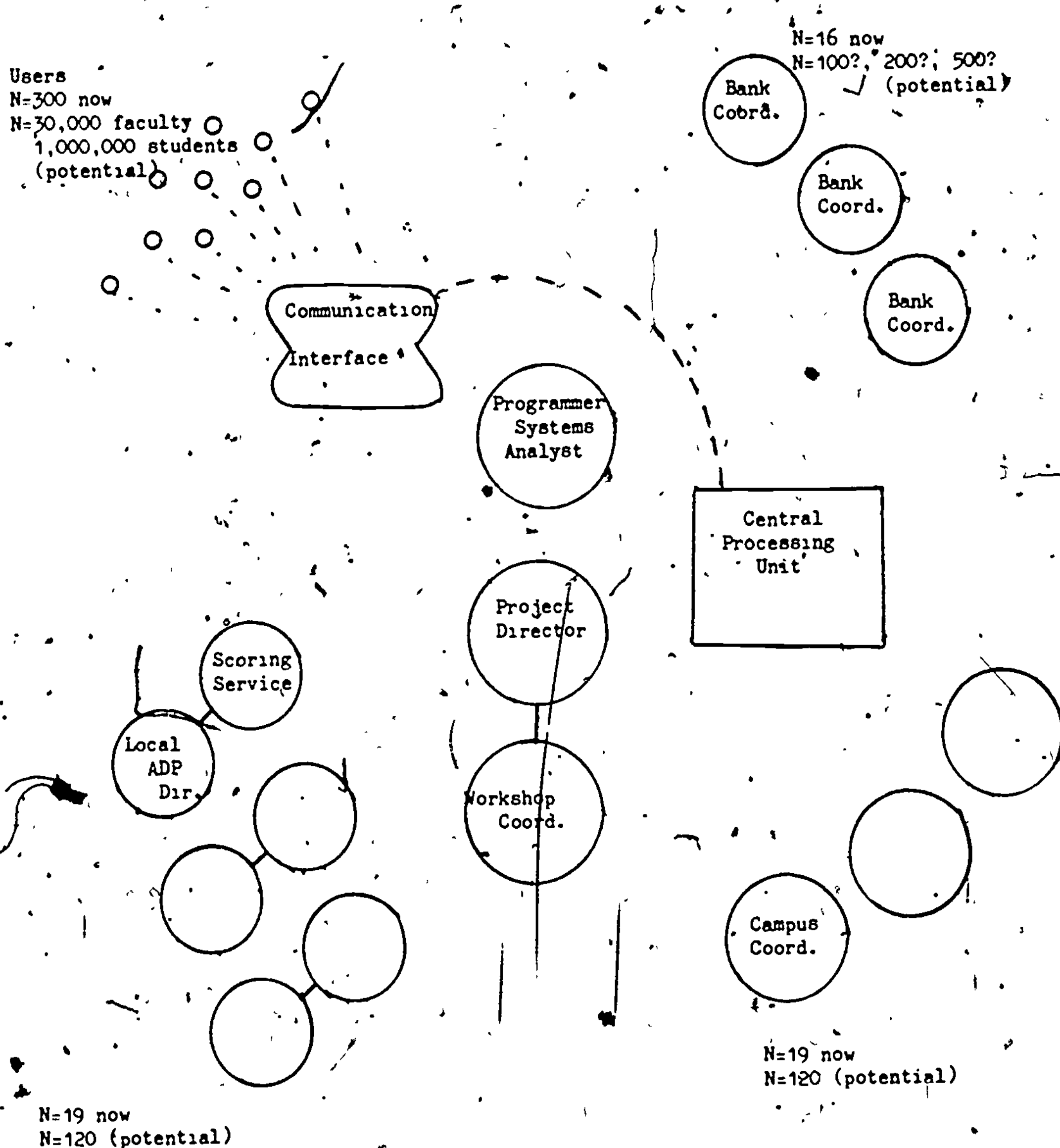
Users
N=300 now
N=30,000 faculty
1,000,000 students
(potential)
N=16 now
N=100?, 200?, 500?
(potential)
Bank Coord.
Bank Coord.
Bank Coord.
Communication Interface
Programmer Systems Analyst
Central Processing Unit
Project Director
Scoring Service
Local ADP Dir.
Workshop Coord.
Campus Coord.
N=19 now
N=120 (potential)
N=19 now
N=120 (potential)

Figure 1

COMPUTER-ASSISTED TESTING IN THERMODYNAMICS AT U. S. NAVAL ACADEMY

Chih Wu

United States Naval Academy, Annapolis, Maryland 21402

ABSTRACT: The objective of computer-assisted testing in thermodynamics is to present questions as efficiently and as accurately as possible, with the minimum feedback to the students at time of question presentation and the maximum evaluation of student's knowledge in thermodynamics. Questions from a computer test is selected from the computer-assisted-instruction in thermodynamics developed by the author and other professors at U. S. Naval Academy from 1967 to 1971. The questions can be selected by students on the basis of behavioral objective. Feedback is given at the end of the test as to what the student missed and what work needs to be prescribed for him. The more feedback loops used in the testing program, the closer the testing approaches to computer-assisted instruction.

1. Introduction

From 1967 to 1971, the Division of Engineering and Weapons, together with the Academic Computing Center of the U. S. Naval Academy engaged in a joint computer assisted instruction project(1) to produce teaching materials in thermodynamics for adaptation on the IBM 1500 instructional system. Four experimental sections consisting of sixty-two midshipmen taught by the author and Lieutenant Commander M. Tuft used segments of the completed CAI material in the thermodynamics course during the 1968-1969 and 1969-1970 academic years. The project was set up in three phases:

(a) Development Phase - To be used to write all the CAI materials and to program them into the computer. The preparation of each unit of the course material in instructional form is described by Wu and Lee(2).

(b) Validation Phase - To be used to conduct classes, to determine whether the objectives are met, and to make revisions where needed(3).

(c) Evaluation Phase - To be used to conduct classes, to determine the CAI presentation as compared to the non-CAI presentation, and to make revisions and recommendations regarding implementations. A general survey(4) and a statistical survey(5) on the CAI thermodynamics have been reported.

The CAI thermodynamics course has specified to be "total immersion," i.e., all the materials of the course are to be taught by CAI. However, the results of the students' performance and responses in the CAI classes and the experience gained by the author(6) and other professors who taught CAI or non-CAI thermodynamics from 1967 to 1971 pointed to the fact that due to limitation of the CAI material authors' time, the CAI instructional material could not be as thorough as the professors desired, thus causing the concept of "total immersion" of the CAI thermodynamics course to be dropped.

To make use of the existing CAI thermodynamics material, students who enroll in the thermodynamics course will be encouraged to take testing of those segments in which they may experience difficulties.

2. Equipment

The computer-assisted teaching unit is the IBM 1500 system which is comprised of an 1800 process control computer, a 1502 multiplexer, five 2310 disk drives, two 2400 tape drives, a 1442 card reader/punch, and an 1132 printer.

Each student station consists of:

(a) A light pen and a typewriter keyboard, which allows a midshipman to control the machine's presentation of testing questions and also to submit his answers to the testing questions.

(b) An image projector and a 1515 cathode ray tube which enables the system to communicate with the midshipmen. The testing questions are presented on the cathode ray tube and figures or graphs are displayed by means of the 1512 image projector.

3. Testing Logic

The computer-assisted testing materials in thermodynamics are made in many segments. Each segment consists of a test which is corresponding to the post test of a CAI segment. The midshipman who passes the test is considered to have completed the specific segment and achieved the desired objectives of the segment. The testing segment requires the midshipmen to go through a certain sequence of questions and to answer correctly each question posted in this sequence. He is told that he is wrong when an incorrect answer is picked. However, the correct answer to a question is not provided in the test. The midshipman who fails the test, twice in a row, is given the information "cut off, and see your instructor." The problem is either that the midshipman needs some additional instruction or there is an information gap in the testing segment. Some improvement to the testing segment should be made.

4. Discussion

Tutorial learning, especially under total immersion is too ambitious considering the present state of computer usage as an educational learning device. Material appropriate for computer-assisted testing seems most effectively in the area of training such as use of steam tables, gas tables, etc.

5. References:

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CREAM: A REALISTIC CATC SYSTEM FOR USE IN PUBLIC SCHOOLS

Kenneth Kayser, Data Processing Manager
and
Jeffrey Klein, Mathematics Supervisor

Manalapan-Englishtown Regional Schools, Englishtown, New Jersey 07726

In [illegible], the development of a district-wide [illegible] mathematics curriculum was undertaken. The approach decided upon for achievement assessment was criterion reference testing. Students would be tested on each objective using test items taken from an item bank based on the curriculum objectives. To this end, a committee of teachers was commissioned to create such a bank of test questions or items. The next problem was the logistics of presenting the test items to the students. Tests containing groups of objectives that were likely to be tested together were created. Two difficulties ensued. First, the cost of having these tests printed, across all grade levels, was prohibitive. Second, the objectives on a particular test were not necessarily the exact ones a teacher might want to test since the objectives could be taught in different sequences depending on the student and teacher. This paper will describe how these problems were solved by utilizing a Computer Assisted Test Construction System, acronymed CREAM for Computer Referenced Evaluation and Assessment in Mathematics, developed totally "in house" for the district's IBM System/3 Model 10. Both the systems design and software will be described.

INTRODUCTION

Seeking answers to the question "How effective is one's instructional program?" usually proves to be a thoroughly frustrating experience for boards of education, administrators, supervisors and teachers alike. The four-step procedure outlined below represents a simplified model which can be utilized when planning a program designed to objectively evaluate the instructional program of a given school:

1. Identify the specific objectives of the instructional program
2. Create evaluation instruments that can be used to obtain information about student achievement as related to the objectives of the instructional program
3. Develop and implement procedures for administering the tests (or other evaluative instruments)
4. Collect data and interpret results

This presentation will be concerned primarily with points 2 and 3 of the above model. However, before proceeding to these aspects, a digression into the philosophy underlying point 1 is necessary.

INSTRUCTIONAL OBJECTIVES

The pros and cons concerning the controversy over the desirability (or undersirability) of delineating instructional objectives (also known as performance or behavioral objectives) will not be reiterated within the scope of this presentation. The specificity and completeness of instructional objectives has been a point of debate for many years. Theoretically, a well written instructional objective should state (1) what is it that the student who has mastered the concept or skill identified in each objective will be able to do, (2) under what conditions will he be able to do this, and (3) to what extent will he be able to do this.

In practical usage, suffice it to say that one major advantage of an instructional objective is derived from the simple fact that it is written. Once it is written, it is visible. Once it is visible, it can be reviewed, evaluated, modified and improved. As the movement for accountability in education increases, this necessity for increased visibility and specificity in objectives will become apparent. No longer will education be able to cloak inadequacies, incompetencies, and mediocrity behind the guise of vaguely stated, unmeasurable goals and objectives.

The rather obvious purpose of an instructional objective should be to make clear to teachers, students and other interested persons what students should be able to do as a result of the instructional program. Unfortunately, school systems commonly lack a comprehensive and reasonably consistent set of instructional objectives.

CRITERION-REFERENCED TESTING

The method of evaluation commonly associated with instructional objectives is known as criterion-referenced testing. In this mode of evaluation (in contrast to norm-referenced testing), no attempt is made to compare the performance of an individual with that of others. Rather, one seeks to evaluate performance in terms of whether an individual has achieved or has failed to achieve specific instructional objectives. It seeks to answer the question, "What specific skills, knowledge, and understandings has a pupil acquired?" In its most elemental form, the response of each pupil to each test item is evaluated as correct or incorrect; the skill or ability measured by an individual test item has either been mastered or it has not.

Perhaps the most fundamental assumption implicit in criterion-referenced testing is that there exists a generally agreed upon hierarchy of skills or knowledge in the field in which one wants to test. Basically, the criterion-referenced approach is of little value unless the assumption is made that mastery of one skill or bit of knowledge is essential for mastering another skill or bit of knowledge of a somewhat similar character at a higher level of difficulty or complexity.

THE PROBLEM

Based upon these precepts and philosophies, the development of a district-wide kindergarten through eighth grade mathematics curriculum was undertaken. This objective based curriculum was to be developed in-house by a committee of teachers representing the various grade levels. The actual content of the curriculum was to be comprised of a compilation of generally acceptable mathematics objectives from various sources, including textbooks and currently available listings of objectives. These objectives would then be edited and modified to best meet the needs of our school district.

This objective based mathematics system was to be comprised of three components: (1) a curriculum guide which delineated the appropriate instructional objectives for each grade level, (2) a record keeping component designed to chart and profile individual and group progress through the specified objectives, and (3) a criterion-referenced evaluation component. The first two components of this system became operational and effective within twelve months of their inception. The assessment component proved to be more difficult to put into effective operational format.

The philosophy regarding the assessment component was in concert with criterion-referenced testing. To develop the necessary test items for the objectives that were developed during the previous year, a committee of teachers was commissioned to create a bank of test items or questions. These test items would then be used to test for student mastery of the specified objectives. After the test items were developed, they were organized into packets or groups of items which were considered to be most likely to be tested at the same time. The original intent was to have these packets printed and made available for use for all teachers with all their students. The high costs of printing prevented this particular strategy. In lieu of this procedure, tests were placed on ditto masters (on a one-shot basis) and as many copies of the tests as possible were distributed to the teachers. Teacher reaction to these tests was quite positive. However, certain problems arose. Most importantly, the objectives which were grouped for a particular test were not necessarily the exact ones a teacher might want to test since the objectives could be taught in different sequences depending on the needs of the student. Secondly, after the first year of use, the supply of test was depleted and were no longer available for teacher or student use.

The need for a more flexible and economically available method of reproducing the criterion-referenced test items was apparent. Flexibility was necessary in terms of grouping test items, number of test items per objective, number of test items per test, pre-tests and interim assessment tests. A readily available method of reproducing the tests was necessary in terms of quantity of tests required, various purposes of testing and economy of reproduction.

It was to meet these needs and maintain the criterion-referenced portion of the mathematics curriculum that CREAM, acronym for Computer Referenced Evaluation and Assessment in Mathematics, was developed.

DESIGN CRITERIA AND SYSTEM DESIGN

The design criteria for CREAM was developed under the direction of the Mathematics Supervisor. The initial requirements of the system were relatively simple: provide a method for storage and retrieval of text-type information. In addition, several parameters for format of input and output were established. For example, it was decided that only short answer type questions would be used (multiple choice, fill-in, true-false). Maximum item (question) sizes were established as well as output formats. In the final (but tentative) design the system would operate as follows. For each grade level, a bank of items would be established. This bank would contain approximately ten questions per objective (roughly 100 objectives per grade) although the actual number of items per objective could vary from objective to objective. When a classroom teacher decided to test a class, group of students, or individual student, he/she would submit a form specifying the grade level and the number of items desired for each objective required e.g. three items in objective 29, seven in objective 32, etc. The computer would then randomly select from its item banks, items to fulfill the stated requirements and output a test on a "ditto" master ready for reproduction. Minimum turn around time was an important design criteria. It was also required that a teacher be able to retrieve alternate forms of the same type test (different questions for the same objectives). The task of systems design was then turned over to the Data Processing Manager.

File structure and access techniques were the first items considered. The restrictions imposed by the limited hardware (IBM System/3 Model 10) were of major consideration. After several iterations, it was decided that two files would be used for the item bank. The primary, or main data file would be direct random access and contain the actual item text. This file would be "mapped" by a second file which would provide retrieval information for the main file. This procedure will be described in more detail later.

The next phase of design was the selection of a programming language. FORTRAN was initially selected due to the logical type operations which were necessary in item selection (random selection of a specified number of specific type items from a larger group) as well as character string manipulation. However, the inefficiencies of System/3 FORTRAN soon caused the limits of our hardware to be exceeded (we were working with 16K of main storage). The system was then converted to RPG II (the System/3's most efficient high level language) and it has evolved in that environment. This choice did pose some technical problems, however, we were able to write the software without the expense of a hardware upgrade. Specific techniques used in the coding will be described under "software design." The selection of RPG II did offer some substantial advantages. Its ease of file access and its facilities for table and array handling provided the ability to write the main test generator utilizing less than 12k of main storage. The entire system will run on a System/3 (any model) with 16K of main storage, 96 print position printer and one 5440 type disk drive. It can, in fact, be run in 12K, however, the required overlays significantly downgrade system throughput.

SOFTWARE DESIGN

As previously mentioned, two files are used in the bank-retrieval system. They are created as follows. The text file (ITEMBANK) is loaded from a unit record device. Each record contains the text of one item along with the objective number to which the item applies. The record length of this file is 190 bytes. All but five characters are available for text and control characters, (control characters indicate format considerations such as skip a line, suppress spacing, end of item, etc.). After this file has been loaded, it is sorted into ascending order by objective number. At this stage, the item map file (ITEMMAP) is created as follows. The main text file is processed and the records per objective number are counted. A record is written in ITEMMAP containing the objective number, the number of items found in ITEMBANK for that objective, and the "relative record number" or relative disk address of the first item for that objective in ITEMBANK. Therefore, by accessing a record in ITEMMAP (which is Indexed Sequential with the objective number as the Key), the system "knows" how many items are stored for that objective and where to find the first one.

The system evolved in a mathematics environment which is possibly the most difficult subject (along with chemistry) which could have been chosen. This is true due to the special signs and symbols as well as the use of exponents, subscripts and superscripts. To accommodate these features, a type of "sub" or mini language was constructed. In actuality, it is more a format discipline than a language. Exponentiation, for example, is achieved by writing the base, skipping a line (*), and then writing the exponent after counting the appropriate number of spaces.

This has proved a most viable method of handling this problem. In this way, long hand addition, subtraction, and multiplication examples can be constructed in the traditional column format and we can even create such symbols as long division (/‾‾‾‾‾‾).

Returning to the item selection process, items are selected randomly from the group for the specified objective. The random number generator is of the "power residue" type and generates evenly distributed decimal numbers on the interval 0-1 (approximately). The procedure for item selection is as follows. Let us assume that the request which the machine is currently servicing calls for three items from objective number 37. After proper editing has taken place, objective number 37's record is accessed in ITEMMAP. The system determines from this lookup, the number of items which are contained in ITEMBANK for objective 37 (assume 10) and the relative record number of the first item for objective 37 (assume 567). The program now invokes the random number generator and retrieves a decimal number (8 places) on the interval 0-1 (assume .87325951). (Actually, the interval for the random number is 0-.99999999 since only decimal positions are allocated). Next, the random number is multiplied by the number of items contained for the objective, the decimal is truncated, and 1 is added to this product giving the item to be selected (.87325951 X 10 = 8; 8+ 1 = 9 ie. select the ninth item for objective 37). The system now must find the position (relative record number) of this item. Well, it "knows" the position of the first item for object 37 (567). It simply adds 8 to this giving the position of the desired (ninth) record (567 + 8 = 575). (The reader may ponder the necessity of adding 1 to the product of the random number and number of items and then subtracting 1 to find the relative record number. In actuality, these self cancelling steps are not performed by the machine and are included here for the sake of clarity.) Now that the relative record number of the desired item is known, it can be quickly retrieved. However, first it is checked against a "memory" array to determine if it has been used already in this run. If it has, the program returns to the random number generator and computes a new item number. If it has not been used in this run, it is recorded in the "memory" array (so it will not be used again) and the text is then retrieved.

All that remains to be done is to format the selected item for output and print it. This is accomplished by simple character string manipulation as guided by the imbedded control characters. Several editing considerations take place such as assuring that a given test item does not cause page overflow (having a question split over two pages may cause sufficient confusion to a primary grade youngster as to invalidate the item). The item is then printed and the system returns to select the next item (in the above example two more items from objective 37 must be selected. It will then process the other requested objectives if any). Further details concerning the actual code may be obtained by contacting the authors.

BELLS AND WHISTLES

The procedures outlined above represent a basic CATC system. There are several enhancements that may be undertaken based on the needs of the individual user. Some of these will be described in this section.

1. Machine Scoring - The logical extension of machine generated tests is machine scoring. The computer can easily generate and store an answer key for each test it generates. This key may be used in conjunction with an optical mark reader to supply complete scoring and analysis services.
2. Item Validation - Once machine scoring has been implemented, analysis of the test items may be undertaken. The most popular type is the point-biserial correlation technique in which the validity of multiple choice questions may be established. This type of data is extremely useful in updating the item bank.
3. Student Progress Profile - Another off-shoot of machine scoring, students' progress through the curriculum may be charted and fed back to the student, parents, and teacher on a periodic basis to aid in identifying strengths and weaknesses. A variety of similar types of computer managed instruction techniques may be employed e.g. student record keeping, identification of curriculum deficiency areas, etc.
4. Multi-entrant Selection Criteria - In the system outlined in this paper, only two selection criteria were employed i.e. grade level and objective. It is possible however, to build a hierarchal structure of selection criteria which may be entered at any level. For example, let us assume that a course curriculum is a continuum through four text books. A selection scheme could be established such that a teacher might request a test in certain objectives. Alternately the request might be for a chapter or group of chapters which may contain many objectives or perhaps a unit which contains several chapters, or a book which consists of many units. Finally, a request for a test on the entire course (a final exam) might contain questions on all four books for that course. In this case the hierarchy from lowest level to highest would be objective within chapter within book within course.
5. Item Generation - In the system described above, each item had to be individually developed. That is, if ten items were desired for an objective which stated "the student shall be able to add a pair of two digit numbers", then ten examples of the type 34 + 79 = ? would have to be written and entered into the bank. The reader will no doubt recognize that if the form of the item (x + y = ?) were established, then the computer could randomly supply values for x and y. This would greatly ease the burden of item preparation as well as provide an almost limitless number of items.
6. Other Disciplines - The techniques described herein can be applied to many other subject areas. In fact, many disciplines lend themselves far more easily to CATC than does mathematics; chiefly because special print characters and symbols may be eliminated. Any subject which has quantifiable sub-areas (such as behavorial objectives) is a potential candidate for CATC.

OUTPUT

The primary output from the system is of course, the generated test. This is presented to the requesting teacher in the form of a "ditto" master or rexograph stencil. In one mode of operation, the system also prints the answers to the questions in the right hand margin of the stencil. The teacher may then "run off" one copy of the test with answers, place a strip of tape ofer the answer column, and then reproduce the test for his/her students. Another type of output consists of a "dump" of a section or entire contents of an item bank. This is used by teachers in determining whether or not the system contains the type of questions which he/she needs. In addition it serves as a vehicle for deleting, adding, or changing items in the bank.

While not machine generated, another set of material is helpful. This consists of a booklet of diagrams and illustrations. CREAM is not currently capable of outputing these types of graphics. The solution to this problem is to reference an illustration or diagram in the test item and provide the student with the required pages of the graphics booklet. This is extremely useful in subjects such as map study, art, music, reading comprehension, etc.

Figure 1 shows the coding of a test item for entry into the system and its formated form after output.
Figure 2 is a page of generated test output. Note that the request parameters (number of questions and objectives with the first line being the number of questions for the objective beneath it on the second line) are printed at the top of each test.

FIGURE 1

00002008THE NUMBER 967 WRITTEN IN SCIENTIFIC NOTATION IS ?___ *
3 3*A. 96.7 X 10 B. 9.67 X 10 C. 96.7 X 10 ^{2} D. 9.67 X 10 ^{2} A

THE NUMBER 697 WRITTEN IN SCIENTIFIC NOTATION IS ?____

A. 96.7×10^{2} B. 9.67×10^{2} C. 96.7×10^{3} D. 9.67×10^{3}

FIGURE 2

PAGE 1 10/10/75 5 6 6 3 3
8 10 11 23 28

COMPUTER REFERENCED EVALUATION & ASSESSMENT IN MATHEMATICS

STUDENT NAME MR KLEIN
DATE PINE STREET

8 THE NUMBER 798 WRITTEN IN SCIENTIFIC NOTATION IS ?-----
A. 7.98×10^{2} B. 79.8×10^{2} C. 7.98×10^{3} D. 79.8×10^{3}

8 THE NUMBER 543 WRITTEN IN SCIENTIFIC NOTATION IS ?-----
A. 5.43×10^{3} B. 54.3×10^{3} C. 5.43×10^{1} D. 54.3×10^{2}

8 THE NUMBER 246 WRITTEN IN SCIENTIFIC NOTATION IS ?-----
A. 2.46×10^{3} B. 24.6×10^{2} C. $.246 \times 10^{3}$ D. 2.46×10^{2}

8 THE NUMBER 123 WRITTEN IN SCIENTIFIC NOTATION IS ?-----
A. 1.23×10^{3} B. 12.3×10^{2} C. 1.23×10^{2} D. 1.23×10^{4}

8 THE NUMBER 678 WRITTEN IN SCIENTIFIC NOTATION IS ?-----
A. 67.8×10^{2} B. 67.8×10^{3} C. 6.78×10^{2} D. 6.78×10^{3}

10 THE LEAST COMMON MULTIPLE OF 4 AND 10 IS ?________

10 THE LEAST COMMON MULTIPLE OF 3 AND 6 IS ?________

10 THE LEAST COMMON MULTIPLE OF 4 AND 6 IS ?________

10 WHAT IS THE LEAST COMMON MULTIPLE OF 6 AND 9 ?________

10 WHAT IS THE LEAST COMMON MULTIPLE OF 3 AND 6 ?--------

10 WHAT IS THE LEAST COMMON MULTIPLE OF 8 AND 12 ?________

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A MAN-MACHINE SYSTEM FOR RAPID GRADING OF SHORT QUIZZES

G. A. Deatsman
Assistant Professor, Mathematics
Ohio State University-Mansfield Campus

ABSTRACT. Frequent short quizzes provide valuable feedback for both teacher and students and also encourage students to keep up with homework. In a system devised by the author, students write quizzes on punch cards. The quizzes are graded by a human who inspects the students' work and places each card in an appropriate stack. This allows grading of the students' methods as well as answers and the giving of partial credit. The sorted cards are computer processed.

By taking over all of the paper shuffling, marking, and recording of grades, the computer makes possible human grading of students' complete work at a rate exceeding ten quizzes per minute. This may be a desirable alternative to conventional machine grading.

INTRODUCTION

If one surveys controlled experimentation in education, it soon becomes apparent that the vast majority of studies comparing one instructional procedure with another report no significant difference between them. There is one striking exception. Many experiments have indicated that frequent quizzes are effective in improving student performance.

Dr. B. C. Durkee summarized her exhaustive review of the literature on quizzing by stating, "Most studies appear to support frequent testing at both high school and college level and in a number of subjects including mathematics."[1] Her own study done on college level algebra students revealed that when students were given frequent quizzes their performance was improved by a difference which was significant at the .05 level.

These findings are certainly consistent with both common sense and psychology. We would expect that students who study regularly and keep up with a course will do better. Frequent quizzes should encourage this. They also should provide valuable feedback to the students, allowing them to correct misconceptions, discover weak areas, and focus attention on the most important areas of a subject. Very short quizzes are sufficient to accomplish these objectives if they are frequent enough. If, for example, a student expects a quiz which will be similar to a randomly selected homework problem, he must do all of the homework to prepare for it. Of course it is of no use to copy another students' homework.

Even short quizzes can take a lot of time to grade if one has very large numbers of students. Machine grading, however, has several disadvantages. It is difficult to make up a good quiz of the multiple choice or some other type which can be machine graded. Also, quizzes are valuable feedback for the teacher as well as for the students. It is important that the teacher actually see and analyze students' written work, so that he can see what errors are being made and decide what sort of help his students need. Also, I feel that most of my colleagues would agree that it is very desirable to give partial credit for correct procedures which yield wrong answers due to minor errors. This is (as far as I know) beyond the present capabilities of machine grading.

The remainder of this paper describes a system which allows a teacher to grade short quizzes at a very fast rate by having a computer take over all of the time-consuming paper shuffling, marking, and recording of grades.

ORIGIN AND NATURE OF THE SYSTEM

The system grew out of efforts to increase efficiency in grading quizzes. I was convinced that much of the time required to grade a stack of quizzes was spent in simply moving the papers around. Significant additional time was spent making marks on the papers, computing scores, and writing the scores on the papers.

[1] B.C. Durkee, "A Study of the Effects of Three Homework Procedures on Achievement in College Algebra" (unpublished Doctor's dissertation, Arizona State University, 1972), p. 20.

The first step in improving on the situation was to have the students write their quizzes on 3 by 5 cards. The cards were much easier to handle than papers, and their small size kept me from making the quizzes any longer than necessary. I could grade these quizzes on cards fast enough that I became frustrated by the necessity of pausing to write the grade on each card. To save time in doing this I began simply sorting the cards into stacks according to their score. When finished grading a quiz I would have a stack of A's, a stack of B's, and so forth. By this time it took me as much time to record the grades as it took to grade the quizzes. I soon realized that a computer could do the recording for me and also compute summary statistics.

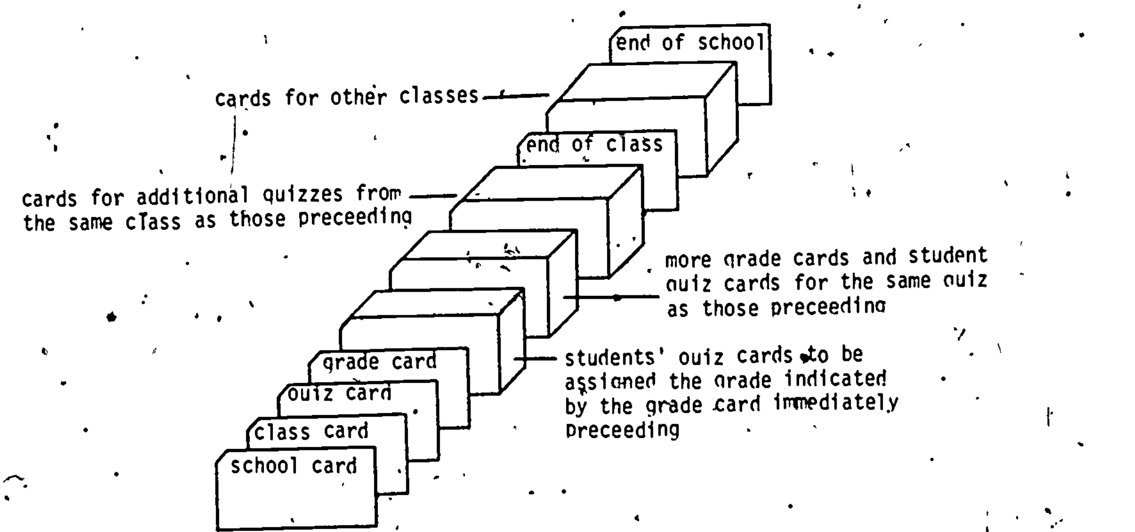
Computer processing has proved invaluable for this type of quiz grading. For the last two years we have been using the grading method at a small campus with no suitable computer facilities conveniently available. After previously having used a computer, the use of human labor for this work was, in comparison, most unsatisfactory. A student helper recorded grades, and she was not always available when it was most convenient for us. Consequently it was difficult to get good turnaround time. The mere recording of the quiz grades for our large sections of freshman algebra students was very tedious, and of course totals and averages had to be computed by hand.

We are now using the computer at a nearby technical school to process grades. Initial costs were no higher than for the student helper, and we expect them to decline with increased use of the system to the point where they are considerably lower than for human clerical help.

DETAILS ON USE OF THE SYSTEM

The student quiz cards are each punched with a student identification number. They are punched in reverse so that the number appears on the blank side of the card. At the beginning of a course each student in a class is assigned a number and given a supply of cards on which his number has been punched. By giving students only a few cards initially and bringing a box of additional cards to class each time a quiz was given we have had no dificulty in getting students to use correct cards in sufficiently good condition for a card reader to process.

Each student writes a quiz on the blank side of a card with his number punched in it. To grade the quizzes one simply inspects each quiz card and decides what grade is to be assigned. Nothing need be marked on the card. Each card is placed in an appropriate stack. This sorting process is very rapid. It is not difficult to grade 100 short quizzes in ten minutes. When the sorting is complete a "grade card" is placed on each stack which tells the computer what grade to assign to the quizzes in that stack. The stacks are then assembled into a deck which is preceeded by a "quiz card" indicating the number of the quiz. One or more of these quiz decks make up a deck which is preceeded by a "class card" which identifies the class. An "end of class" card follows the deck. Finally, one or more of these class decks make up the input for the program. An optional "school card" identifying the school may preceed the rest of the input, and we use and "end of school" card to bring the program to an orderly termination. The following is a graphical illustration of the deck setup for input:



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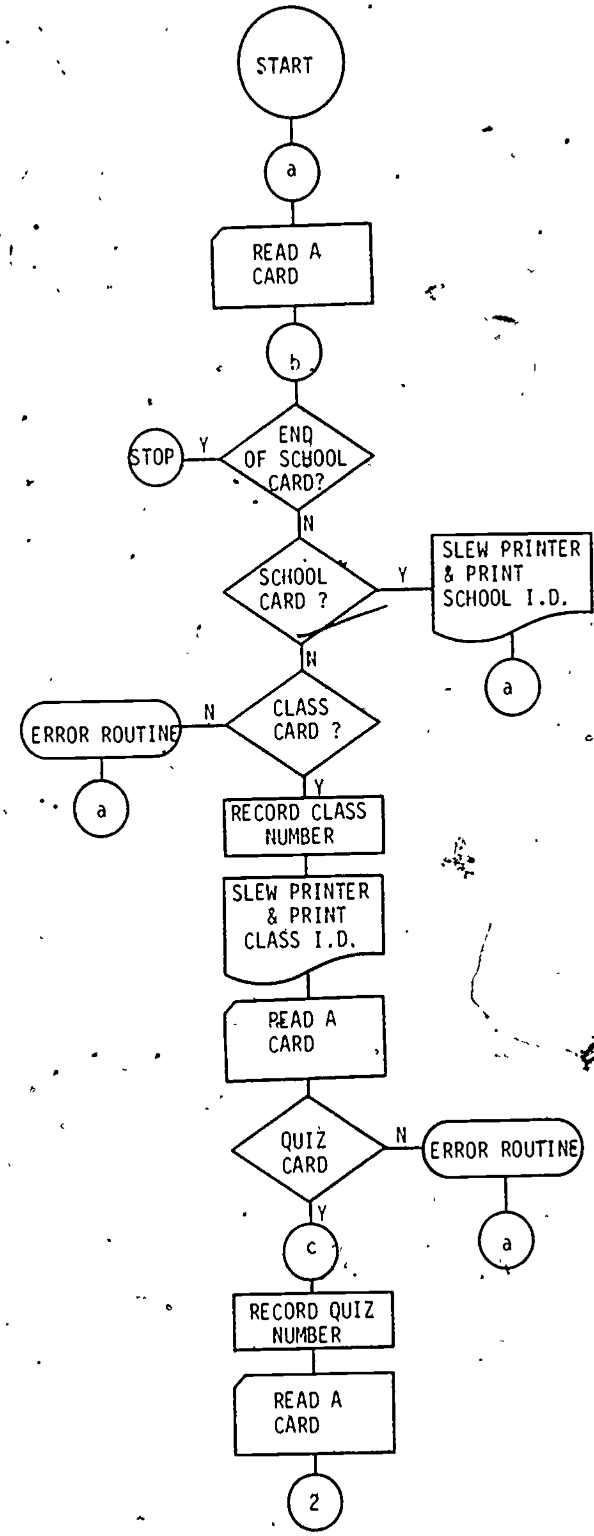
The printout from the computer shows each student's score on each quiz to date. It also shows the total number of points accumulated by each student and his average and percentage. We do not mark on students' quiz cards or return them to the students, but rather go over each quiz as soon as the cards are handed in. The students estimate the grade they expect to receive on the quiz and make a note of it. Every few days we pass around a copy of the latest printout (on which students are identified by number only to preserve confidentiality of grades). If a student does not find his grade to be very close to what he expected he checks out the reason with the instructor. We keep the quiz cards on file until after the course is over. We also keep the grades stored on a disk file in case the cards might be lost and to avoid having to read in the same cards more than once. A sample of output from the program appears below:

WILSON 101

	TOTAL	AVERAGE	PERCENTAGE	SCORES ON ALL QUIZES 1	2	3	4	5	6	7	8	9	10	11	12
STUDENT NUMBER 1	26	2.89	58	4	4	3	4	1	5	1	1	3			
STUDENT NUMBER 2	39	4.33	87	5	5	5	3	5	5	3	3	5			
STUDENT NUMBER 3															
STUDENT NUMBER 4	39	4.33	87	5	5	5	5	5	5	5	4				
STUDENT NUMBER 5															
STUDENT NUMBER 6	30	3.33	67		5	4	5	3	5	3	5				
STUDENT NUMBER 7	23	2.56	51	5	0	1	4	2	5	3	2	1			
STUDENT NUMBER 8	26	2.89	58	3	3	5	3	2	5	2	3				
STUDENT NUMBER 9															
STUDENT NUMBER 10	33	3.67	73	3	4	5	5	5	5	1	3	2			
STUDENT NUMBER 11	37	4.11	82	5	4	5	5	4	5	2	2	5			
STUDENT NUMBER 12	32	3.56	71	4	5	5	3	4	5	3	2	1			
STUDENT NUMBER 13															
STUDENT NUMBER 14															
STUDENT NUMBER 15	39	4.33	87	5	5	5	4	4	5	4	2	5			
STUDENT NUMBER 16															
STUDENT NUMBER 17	35	3.89	78	3	5	5	4	3	5	3	2	5			
STUDENT NUMBER 18															
STUDENT NUMBER 19	32	3.56	71	5			4	3	5	5	5	5			
STUDENT NUMBER 20															
STUDENT NUMBER 21	30	3.33	67	5	5	3	4	5	5		[illegible]	3			
STUDENT NUMBER 22															
STUDENT NUMBER 23	30	3.33	67	5	5		1	3	5	3	3	5			
STUDENT NUMBER 24															
STUDENT NUMBER 25	39	4.33	87	3	5	5	5	4	5	5	4	3			
STUDENT NUMBER 26															
STUDENT NUMBER 27	39	4.33	87	3	4	5	5	5	5	3	5	4			
STUDENT NUMBER 28															
STUDENT NUMBER 29	33	3.67	73	5	4	5	4	5	5	3	2	0			
STUDENT NUMBER 30															
STUDENT NUMBER 31	41	4.56	91	5	4	5	5	3	5	4	5	5			
STUDENT NUMBER 32															
STUDENT NUMBER 33	43	4.78	96	5	5	5	4	5	5	4	5	5			
STUDENT NUMBER 34	27	3.00	60	3	0	1	4	3	5	4	2	5			
STUDENT NUMBER 35	39	4.33	87	5	5	3	4	5	5	4	4	4			
STUDENT NUMBER 36	33	3.67	73	3	2	5	4	5	5	4	5				
STUDENT NUMBER 37	30	3.33	67	3	1	3	4	3	5	4	3	4			
STUDENT NUMBER 38	33	3.67	73	5	5	4	2	3	5	4	2	3			
STUDENT NUMBER 39															
STUDENT NUMBER 40	38	4.22	84	5	5	3	5	5	5	4	2	4			

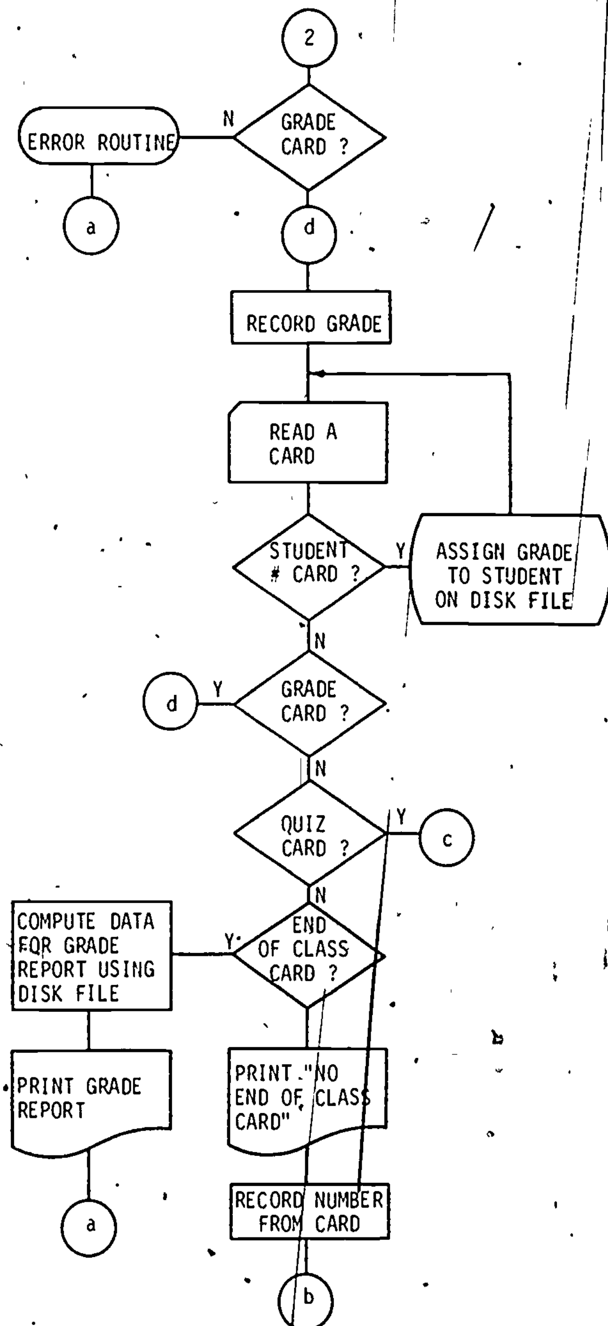
THE PROGRAM

The program for the system is quite simple and straightforward. It allows corrections to be made of grades on the disk file simply by inserting an appropriate quiz card, grade card, and student quiz card in the input for the next run. A flowchart of the program appears on the following pages, and a COBOL listing is available upon request for non-commercial use.



START
a
READ A CARD
b
END OF SCHOOL CARD?
Y
STOP
N
SCHOOL CARD ?
Y
SLEW PRINTER & PRINT SCHOOL I.D.
a
N
CLASS CARD ?
N
ERROR ROUTINE
a
Y
RECORD CLASS NUMBER
SLEW PRINTER & PRINT CLASS I.D.
READ A CARD
QUIZ CARD
N
ERROR ROUTINE
a
Y
c
RECORD QUIZ NUMBER
READ A CARD
2

30


2
GRADE CARD ?
N
ERROR ROUTINE
a
d
RECORD GRADE
READ A CARD
STUDENT # CARD ?
Y
ASSIGN GRADE TO STUDENT ON DISK FILE
N
GRADE CARD ?
Y
d
N
QUIZ CARD ?
Y
c
N
END OF CLASS CARD ?
Y
COMPUTE DATA FOR GRADE REPORT USING DISK FILE
PRINT GRADE REPORT
a
PRINT "NO END OF CLASS CARD"
RECORD NUMBER FROM CARD
b

OVERVIEW

of

COMPUTER-ASSISTED TEST CONSTRUCTION

G. Lippey
Classroom Support Systems
San Jose, CA 95118

Introduction
- Visibility of systems
- Comparison to computer-based scoring
- Recent needs of education

Functions Provided by CATC
- Banking of questions
- Generation of questions
- Selection of questions
  - Item classification
  - Selection decisions
- Printing of tests
- Relations among functions

Existing systems
- Varied environments
- Distribution by institutions
- Functions implemented
- Item banks by discipline
- Size of banks

Advantages of CATC
- Centralization of questions
- Printing tests
- Selecting items
- Test security
- Economic feasibility
- Lack of threat

Other Possibilities
- Test administration
- Relations to scoring
- Evolution of systems
- Cooperation among developers

ALLCOMBS:

A SYSTEM OF COMPUTER-ASSISTED TEST CONSTRUCTION FOR ALL COMBINATIONS OF QUESTION CLASSIFICATIONS

Joe H. Jones

Texas Christian University, Fort Worth, Texas 76129

ABSTRACT: ALLCOMBS is a computer system of test construction for any printer-composable question set retrievable on any Boolean combination of unrestricted question classifications. Free-format entry of variable-length records is utilized in file construction and retrieval for maximum system generality and ease of user access. Question classifications are designated in unlimited character strings without reference to a fixed classification set or hierarchy, and as a consequence, questions can be classified with qualifications permitting multiple applications of any given file. A user option providing for exclusion of questions previously offered an individual student or class allows for unique re-examination as required in competency-based instruction.

I. Introduction to Computer-Assisted Test Construction and ALLCOMBS

This is a description of a system of computer-assisted test construction undergoing implementation at Texas Christian University. As is suggested by the system acronym, ALLCOMBS, this system offers some generality in retrieval and composition of all combinations of question types.

Programs of computer-assisted test construction, CATC, have been under development for the last decade. Successful applications of test construction systems have been described at the Conference on Computers in the Undergraduate Curriculum since the initial meeting of this annual conference in 1970. Special interest conferences on Computer-Assisted Test Construction, meeting in 1974 and 1975, have affirmed an increasing interest in questions of CATC implementation.

Two primary sources in the professional literature offer overviews of the extensive acceptance of CATC in a diversity of testing environments. The first of these sources is the March 1973 issue of the Journal of Educational Technology which is devoted to the topic of test construction. The most recent comprehensive source is the book Computer-Assisted Test Construction edited by Gerald Lippey and published by Educational Technology Publications in 1974.

The summary view offered here is that the efficacy of CATC systems has been established and that further development offers the prospect of increasing applicability and efficiency. The ALLCOMBS system to be presented here has evolved in this context of CATC development as a generalized and flexible system of test construction explicitly designed to facilitate ready access to CATC by the individual user.

Dominant design criteria for ALLCOMBS have been system generality, flexibility, and ease of user access. The system is general in that it will compose all question format types such as multiple choice, true-false, completion, and essay questions retrieved on the basis of any combination of question classifications appropriate to the needs of the individual academic discipline or individual user. The system is flexible in that question format types and classifications may be expanded or contracted selectively on an existing file and record dimensions may be adjusted to the space requirements of a given system installation. Ease of user access is provided for by a free-format style of file entry and retrieval, the expansive use of diagnostic (error) messages, and the acceptance of verbal system parameters in file construction and retrieval.

There are choices made in any system design which amount to trade-offs between desirable attributes which are potential in the system. In the ALLCOMBS system, the election of combinatorial generality in specification of question classifications forfeits certain efficiencies of file organization and retrieval which are desirable for very large files. At the other limit, the compositional generality of ALLCOMBS imposes a system of record tagging, searching, and editing for print composition which is an unnecessary processing burden for simplified, fixed-format printer reproduction of examinations.

The ALLCOMBS system is appropriate and efficient for a large central range of applications of computer-assisted test construction. Within this range, there is sufficient latitude to permit the user to begin file development and retrieval at a simplified level which can extend in sophistication with the increasing needs and experience of the user.

II. ALLCOMBS System Outline

ALLCOMBS is written in FORTRAN IV for batch-mode execution on computer systems utilizing EBCDIC character representation in 32-bit words, the hardward design of the IBM 360/370, the Xerox Sigma 5/7/9, etc. Initial input is punch card to tape or disc files and output is by line printer.

ALLCOMBS is executed in one mode for question editing and file development and in another mode for question retrieval and examination composition. Subprograms are shared by the two modes of execution and are designed to be resident on the computer system disc file, or other intermediate storage, subject to call by the individual user. These resident programs permit users to construct and access exclusive individual or common examination files. It is not anticipated that assistance of professional computer personnel will be required for routine file development or retrieval with the system.

Examination questions are prepared on punch cards by the user for diagnostic editing and subsequent transfer to magnetic tape or disc files. Each block of records constituting a question entry is composed of a permanent file number, a classification record, a question record, an answer record, and a source record. The classification record is any set of verbal, numeric or alphameric fields selected by the user for question classification. The question record is any combination of main paragraphs of verbal text, response paragraphs for multiple-choice questions and any literal character strings utilized for composition of blank response lines, tabular displays or line-printer graphics. The answer record can contain a single character designation of a correct response to a multiple-choice or true-false question and/or a full solution or explanation of the correct response to any question type. The source record carries any appropriate designation of the source of the question in abbreviated or full bibliographic style.

In the diagnostic mode of system execution, a trial composition is made of each question, the completion of essential fields and records is verified, and storage limits for variable-length records are tested against parameters selected for the given system installation. The complete block of records for each question is printed in a hardcopy file to be verified against the original source document.

After diagnostic editing, a given set of questions is added to the existing question file. File references to question classifications are expanded dynamically to include any new classifications introduced, the question and answer records are encrypted for file security, and the file is updated in all respects for subsequent retrieval.

To access these question files, the user prepares an examination request which accesses ALLCOMBS in retrieval and composition mode. In examination retrieval and composition, the user may select options in regard to designation of examinees, examination content, and examination composition or layout.

By appropriate reference to a separate file, examinees may be designated as all students listed on a given class roster. Alternatively, examinations can be prepared for students who are individually named, or multiple examination copies can be prepared for students not designated by name.

Content of the examinations may be selected by a combination of options which specify inclusion or exclusion of particular questions or question classifications. Additionally, the user may specify exclusion of those questions which have appeared previously on examinations given to a class or to individual students.

Individual questions may be designated for inclusion or exclusion by reference to the permanent file number of the question. The user may make this reference explicitly in the examination request by appropriate entry of the question file numbers. The separate file of the class roster carries the record of previous examinations by question file number and selection of an examination containing all new questions for students in the class makes implicit exclusion of the questions which were used previously.

The most general and flexible specification of examination content is by question classification. Examinations can be composed of any number of questions from any number of question classifications in any combination specifiable by the logical or Boolean operators .AND., .OR., .NOT., and .EOR. (exclusive "or"). Within the question sets selected by question classification, questions are selected randomly from those meeting criteria set in regard to these classifications and to the uniqueness of the question set. The selection by question classification can consist of a single classification forming the set from which random selection is to be made, or the logical expression can be as complex as may be permitted by the FORTRAN compiler on the given computer system.

Options for composition or layout include selection of the number of question columns to be printed across a page of variable character length. ALLCOMBS will print any feasible specification of one through six question columns on a line of 22 through 132 characters. Line breaks in the question text are generated automatically on the blank or hyphen nearest to the columnar limit. A system default to full-page layout ensures that questions with lengthy literal strings will be printed.

As implied in the previous description for examination selection, the user may specify a unique examination for each student or a common examination for all students. In examination composition, the user may specify random reordering of questions on a common examination.

An examination key is prepared for each examination which is unique in question content or order. For a common examination in identical order for all students, the user may elect either to print one key for the common examination or individual copies of the key for each examination.

As an additional option of composition, the user may print unique instructions on each exam set.

III. Introduction to Data Preparation for ALLCOMBS

The organization of question files and examination requests for ALLCOMBS is based on the subdivision of data into fields, records, and record blocks. Within the question text, more direct references are made to the composition of these general subdivisions into question main paragraphs, multiple-choice responses or subparagraphs, and literal strings of characters.

Excepting the fixed field designated for the permanent question file number to facilitate card handling, all fields, records, and record blocks are punched in free format with special characters used to denote data divisions. Data divisions may begin in any card position and entries may continue without regard to the physical break between successive cards. Column eighty of a given card and column one of the succeeding card are interpreted as adjacent punch positions and the user may conceive of the input medium as a continuous tape.

Within these data divisions, literal records are utilized for those compositions for which automatic line breaks based on blank or hyphen separation would be inappropriate. Literal records are utilized for such purposes as composition of tabular displays, reproduction of line-printer graphics and statement of mathematical expressions. Additionally, the user instructions for an examination are reproduced from a literal record without program editing.

With the exception of these literal records, leading blanks are accepted within all data divisions and trailing blanks are accepted in all but numeric fields. Given this system of free-format data preparation which accepts leading and trailing blanks, the user can organize data decks for maximum personal convenience and readability. The principal obligation of the user in preparation of question files and examination requests is to observe certain minimum conventions of record designation and ordering.

Excepting some more elaborate tabular and graphic compositions, question files typically can be prepared directly from original written sources. Keypunch forms are neither required nor recommended. The free-format conventions of ALLCOMBS permit the user to concentrate on content rather than form.

Procedures for preparation of question files and examination requests are presented by example in the following two sections. The presentation is expository and explicitly avoids some formalisms of outline and definition more appropriate to a technical reference document.

IV. Preparation of Question Record Blocks

Illustration 1 on the following page shows an examination format which could be obtained by selection of two columns of questions to be printed on a seventy-character line. The questions have been chosen to illustrate the composition of multiple-choice, completion, true-false and essay questions. Questions 1 and 2 also demonstrate the application of literal character strings in question composition.

Illustration 2, shown on the next page following Illustration 1, shows card images of the four blocks of question records which could have originated the question file used for the retrieval in Illustration 1. Beginning with the first line in Illustration 2, reading 75062804 # MULTIPLE CHOICE . . . , which is to be read as the first card in the deck, each print line in Illustration 2 represents successive cards in the original card file for the questions.

The four questions are identified by the four, eight-digit file numbers 75062804, 75123008, 76022703, and 76022756. These file numbers may be any eight-digit set, but as used here represent the date-sequence of the question. The four pairs of digits in the file number denote the year, month, day and sequence during the day of the question origination. Used in this way, the uniqueness of the file number is more nearly assured, and the file number can provide a basis for file aging by origination date.

Each record in the question record block is terminated by a record mark; the record mark selected here is the ampersand, & . The first record in the block is the classification record which may contain one or more verbal or codified classification fields beginning with the field mark, # , the numeric symbol. The first question classification record contains # MULTIPLE CHOICE # FREQUENCY DISTRIBUTIONS # etc., and terminates with # DIFFICULTY EASY # .

The next record is the question text, which includes the responses to multiple-choice questions. The question record of the first question begins with # THE DISTRIBUTION OF . . . and terminates with . . . BUT IS NOT GIVEN ABOVE. & . Main paragraphs of the question text begin with the field mark, # , the numeric symbol.

Multiple-choice responses begin with the "at" symbol, @ , which initiates program assignment of the alphabetic sequence "A.", "B.", etc. The tabular material of the first question is composed in literal character strings marked at each end by the "not" symbol, ¬ .

The criteria for selection of the symbols for data divisions are that the symbols be unique and not be needed within the text to be placed on file. For any given system installation of ALLCOMBS, the user may make any choice of data-division symbols which meet these criteria.

In composition, a line is skipped automatically before each main paragraph, before each subparagraph used as a multiple-choice response, and before each set of literal character strings. Lines are "skipped" between literal character strings by printing an empty string with the symbols: ¬ ¬ .

The composition routine centers the literal strings in any given question column on the basis of the count of the longest string in the question record and left-justifies all other literal character strings to this common origin. If a columnar format has been selected which will not permit printing of the longest string in a question, the composition routine will default to the declared print limit of the system for printing that single question.

Illustration 1

1 THE DISTRIBUTION OF TEST SCORES FOR AN EXAMINATION IS SHOWN AS:

EXAMINATION SCORES

RANGE	NUMBER
90 AND MORE	12
80 THRU 89	17
70 THRU 79	32
60 THRU 69	24
LESS THAN 60	15

THE FIRST DECILE OF THE SCORES IS:

A. A SCORE OF 90.

B. TEN STUDENTS.

C. CANNOT BE DETERMINED FROM THE DATA GIVEN.

D. CAN BE DETERMINED, BUT IS NOT GIVEN ABOVE.

3 ***** REFER TO GRAPHICS FILE ITEM LC74/182. *****

AS SHOWN ON THE SCATTER DIAGRAMS FROM THE GRAPHICS FILE, THE CORRELATION BETWEEN COLLEGE GRADES AND SAT SCORES IS HIGHER THAN THE CORRELATION BETWEEN COLLEGE GRADES AND CLASS STANDING AS A HIGH SCHOOL SENIOR.

TRUE (OR) FALSE

2 A PERSONNEL WORKER IN A CERTAIN PLANT IS COLLECTING DATA ON EMPLOYEE ATTITUDES. SHE GIVES THE FOLLOWING STATEMENT TO EMPLOYEES AND ASKS THEM FOR A RESPONSE FROM THE LIST WHICH FOLLOWS.

"I FEEL THAT I AM PERFORMING A VALUABLE SERVICE FOR SOCIETY WHEN I DO MY JOB WELL."

1 - STRONGLY AGREE
2 - AGREE
3 - NO OPINION
4 - DISAGREE
5 - STRONGLY DISAGREE

COMPLETE THE FOLLOWING:

VARIABLE NAME...............

OBSERVATION UNIT...........

MEASUREMENT SCALE..........

4 IN USING SMALL SAMPLES TO TEST THE DIFFERENCE BETWEEN MEANS OF TWO NORMAL POPULATIONS, THE SAMPLE VARIANCES ARE "POOLED."

EXPLAIN WHY THIS PROCEDURE IS FOLLOWED AND WHAT OTHER TEST OF HYPOTHESIS IS IMPLIED.

(WRITE YOUR ANSWER ON THE BACK OF THIS SHEET AND IDENTIFY IT BY QUESTION NUMBER.)

Illustration 2

75062804 # MULTIPLE CHOICE # FREQUENCY DISTRIBUTIONS # DECILES # JONES P
ERSONAL FILE # DIFFICULTY EASY &
THE DISTRIBUTION OF TEST SCORES FOR AN EXAMINATION IS SHOWN AS:
¬EXAMINATION SCORES¬ ¬ ¬
¬ RANGE NUMBER¬ ¬ ¬
¬90 AND MORE 12¬
¬80 THRU 89 17¬
¬70 THRU 79 32¬
¬60 THRU 69 24¬
¬LESS THAN 60 15¬
THE FIRST DECILE OF THE SCORES IS: @ A SCORE OF 90. @ TEN STUDENTS.
@ CANNOT BE DETERMINED FROM THE DATA GIVEN. @ CAN BE DETERMINED, BUT IS NOT G
IVEN ABOVE. & ANSWER IS D. & JONES PERSONAL FILE &
C
75123008 # MEASUREMENT AND SCALING # SHORT-ANSWER COMPLETION # DIFFICULTY MO
DERATE &
A PERSONNEL WORKER IN A CERTAIN PLANT IS COLLECTING DATA ON EMPLOYEE ATTITUDE
S. SHE GIVES THE FOLLOWING STATEMENT TO EMPLOYEES AND ASKS THEM FOR A RESPONSE
FROM THE LIST WHICH FOLLOWS. # "I FEEL THAT I AM PERFORMING A VALUABLE SERVICE
FOR SOCIETY WHEN I DO MY JOB WELL."
¬1 - STRONGLY AGREE¬ ¬2 - AGREE¬ ¬3 - NO OPINION¬ ¬4 - DISAGREE¬ ¬5 - STRONG
LY DISAGREE¬ # COMPLETE THE FOLLOWING:
¬VARIABLE NAME..............¬ ¬ ¬
¬OBSERVATION UNIT...........¬ ¬ ¬
¬MEASUREMENT SCALE..........¬. &
VARIABLE NAME IS EMPLOYEE ATTITUDE. OBSERVATION UNIT IS INDIVIDUAL EMPLOYEE. M
EASUREMENT SCALE IS ORDINAL. &
SUMMERS AND PETERS CARD FILE, 1973 &
C
76022703 # EXTERNAL GRAPHICS # TRUE-FALSE # CORRELATION # DIFFICULTY EASY &
***** REFER TO GRAPHICS FILE ITEM LC74/182. *****
AS SHOWN ON THE SCATTER DIAGRAMS FROM THE GRAPHICS FILE, THE CORRELATION BETWE
EN COLLEGE GRADES AND SAT SCORES IS HIGHER THAN THE CORRELATION BETWEEN COLLEGE
GRADES AND CLASS STANDING AS A HIGH SCHOOL SENIOR. |
TRUE & TCU ADMISSIONS OFFICE DATA FOR 1973 &
C
76022756 # STUDENT'S T-TEST # DIFFICULTY HARD # THEORETICAL ASSUMPTIONS OF
TEST PROCEDURES # POOLING VARIANCES # ESSAY ANSWER # TESTS OF HYPOTHESES
TESTS OF MEANS # TESTS OF VARIANCES &
IN USING SMALL SAMPLES TO TEST THE DIFFERENCE BETWEEN MEANS OF TWO NORMAL POP
ULATIONS, THE SAMPLE VARIANCES ARE "POOLED."
EXPLAIN WHY THIS PROCEDURE IS FOLLOWED AND WHAT OTHER TEST OF HYPOTHESIS IS I
MPLIED.
(WRITE YOUR ANSWER ON THE BACK OF THIS SHEET AND IDENTIFY IT BY QUESTION NUMB
ER.) &
UNDER THE TEST CONDITIONS SPECIFIED, THE STUDENT T (OR THE F-RATIO) TEST IS USED
, AND INVOLVES THE ASSUMPTION OF EQUAL POPULATION VARIANCES. POOLING OF SAMPLE
VARIANCES IS AN AVERAGING PROCESS FOR THE ESTIMATION OF THE COMMON POPULATION VA
RIANCE. THE TEST FOR DIFFERENCE BETWEEN MEANS UNDER THESE CONDITIONS IMPLIES A
TEST FOR EQUAL POPULATION VARIANCES. &
EXAMINATION FILE FOR GRADUATE QUALIFYING EXAM IN STATISTICS FIELD. &
C

The question record can consist of any combination of main paragraphs and literal character strings. Any number of number of multiple-choice subparagraphs may appear at the end of the record for printing at the bottom of the question, but the number probably will not exceed five or six in practice.

The answer record, printed on the hardcopy question file and on the examination key, can consist of any character set. In the first question in Illustration 2 on the preceding page, the entry ANSWER IS D. & could have been followed by an explanation of why this was an appropriate choice or why the other choices were inappropriate.

The final record is the citation of question source which is printed only on the hardcopy question file. The source citation in the first question in Illustration 2 is duplicated by a question classification which permits retrieval on the basis of the question source. A common application of a source citation in the question classifications would be the composition of examinations based on a given textbook.

Finally, each record block is terminated by the cent symbol, ¢ . Use of an end-block character prevents the cumulation of record sequencing errors from one question to the next in file construction.

Question 2 illustrates the use of literal character strings for the unambiguous reproduction of the scale included in the question and for the creation of response lines of minimum length to be used for answer completion.

Question 3 illustrates a suitable flagging of an external file required for a question. Additionally, the question illustrates the use of the "conditional" symbol, | (EBCDIC hexadecimal 4F), to terminate the question record of a true-false question. This symbol causes automatic generation of the response line TRUE (OR) FALSE . Alternatively, the user could have entered @ TRUE @ FALSE in the question record as a multiple-choice response to facilitate automatic grading.

Question 4 illustrates the fuller use of the answer record for the benefit of the grader or the examinee.

Control of the editing and filing phase through ALLCOMBS is also specified with simplified verbal parameters in free-format style. Creation of magnetic files necessarily involves some peculiarities of the job control language of a given installation and this complete topic of file construction is deferred until a reference system and installation are defined.

V. Preparation of the Examination Request

Where the slash symbol, / , denotes the end of a record and the cent symbol, ¢ , denotes the end of a record block, the examination request is made in the sequence of records shown in Illustration 3 at the bottom of this page.

As a specific example of the construction of an examination request, the four questions presented in Illustrations 1 and 2 in the preceding section could have been retrieved by the examination request shown as card images in Illustration 4 on the following page.

Both the password and the key for file encryption and decryption are unique to each file. The password is time dependent and ALLCOMBS will access the computer system clock to permit only one authorized file entry in any time period specified. The password disclosed on one submission of a batch run cannot be used again for unauthorized file access, nor is it likely that some trial process of password generation will permit unauthorized file entry, particularly if the decay interval of the password is kept short. File decryption is made to a scratch disc or tape only for those questions selected for the examination and the scratch file is cleared automatically after examination composition.

After the password in the examination request, shown in Illustration 4, the next three records contain identification of the instructor, class and examination. To facilitate identification of the output, the first twelve characters in each of these three records are block printed on the title page for the examination request.

In the next record after the examination identification record in Illustration 4, options have been entered for a seventy-character line to be printed in two columns for twenty recipients not named. The user has selected a common examination for all recipients, with one key to be printed. In this record, the user could have entered ROSTER, rather than NOT NAMED = 20, to have obtained an examination for all class members listed on a class roster, or the user could have entered EACH NAMED, to have obtained examinations for students named in the last record block of this request file.

For a common examination, the user could have entered SCRAMBLE, to have the questions reordered randomly on each examination. If the examinees had been selected by ROSTER, or EACH NAMED, the user could have excluded questions previously given the class or individual student by entering CLASS NEW, or STUDENT NEW,.

Illustration 3

Password / instructor identification / class identification / examination identification (by time or other distinction) / options for composition, for designation of the group of examinees, or for exclusion of questions given on previous examinations / literal instruction set for this examination / questions to be included or excluded by file number / questions to be retrieved by question classification specified by Boolean operators / . . . then any number of classification retrieval records terminated by the end-block symbol, ¢ / identification of individual student and questions on prior examinations / . . . then any number of student records terminated by the end-block symbol, ¢ /

Illustration 4

PASSWORD / JOE H JONES - NEELEY SCHOOL OF BUSINESS - XT 507 /
STAT 2153 20 / FEB 2 - DEMONSTRATION EXAMINATION /
PAGE WIDTH = 70, COLUMNS = 2, NOT NAMED = 20, COMMON, ONE KEY, /
THIS EXAMINATION HAS BEEN PREPARED TO DEMONSTRATE THE COMPOSITION
OF EXAMINATIONS TO BE OFFERED IN THIS CLASS THIS SEMESTER. c /
INCLUDE, 76022756, /
3, (# MULTIPLE CHOICE # .OR. # SHORT-ANSWER COMPLETION # . OR .
TRUE-FALSE #) .AND. . NOT . # DIFFICULTY HARD # / c /

Selections of options which would lead to processing contradictions are signalled by diagnostic messages to the user, and in instances in which reasonable resolution seems possible, a system default selection is made.

The record following the options record holds the card image of instructions to be printed on each copy of the examination. In Illustration 4, this record begins with THIS EXAMINATION HAS . . . and ends with the end-block symbol, c. Following this instruction set is a record containing the designation of questions to be included or excluded by file number. The option INCLUDE, followed by any set of file numbers will select those questions without regard to question classification. The option EXCLUDE, will omit the following questions by file number, irrespective of any other selection option exercised.

The record beginning with the numeric field "3," indicates that three questions are to be selected by classifications which meet the truth criteria of the logical expression shown in that record. Each question classification in this record begins and ends with the field mark, # , the numeric symbol, and each logical operator is enclosed in periods, as in the syntax of FORTRAN IV. Parentheses control the ordering of evaluation of the logical expressions.

In retrieving with logical expressions of question classifications, ALLCOMBS passes through the complete question file testing for the truth of the logical expression in each classification set of each question. Where the classifications satisfy the logical conditions specified, the question is copied onto a disc file to form a collection of questions from which final, random selection can be made.

The examination request by classification can consist of an unlimited block of these classification request records, each having a specification of the number of questions to be selected by a unique logical expression. The sample composition in Illustration 1 could have been retrieved by the record block reading: . . . / 1, #MULTIPLE CHOICE# / 1, #SHORT-ANSWER COMPLETION# / 1, #TRUE-FALSE# / c / . . .

VI. Prospects for the ALLCOMBS System

ALLCOMBS has been utilized in reduced form at Texas Christian University for examination composition in a class organized for self-paced instruction. Major features of the design have been verified, but the full system is not yet implemented. It is expected that the complete system will be implemented and documented by September 1976. No data are available on the total computer system space requirements or execution time characteristics of ALLCOMBS. Nonetheless, some characteristics of the system are sufficiently established that it does not seem premature to offer some evaluation of them.

ALLCOMBS will share a principal characteristic of all CATC systems in freeing the instructor from major time demands of examination preparation. The instructor will be freed to consider alternative teaching forms such as self-paced, competency-based instruction.

Designed for the individual instructor, ALLCOMBS will offer some convenience and simplicity of system access which should serve to encourage the use of CATC and the diffusion of its advantages.

A major distinction of ALLCOMBS, which constitutes a major advantage of this system over some applications of CATC, is the generality of the classification and retrieval system. It will accept virtually any system of classification and will accept expansion of the classifications as need and experience dictate.

ALLCOMBS will accept contradictory classification sets for questions, so long as the classifications are unique character sets. For example, one user of a file may classify a question as DIFFICULTY HARD and another user may disagree and classify the question as RESCALE MODERATE. Retrieval can be made by reference to either classification without interference to any other user of the question set. A generalized question file can contain classifications which tailor subsets of the file to specific courses or instructors.

The generality of the format and symbolic designation of data divisions should lead to some efficiencies in exchange of question item banks. It should be possible to translate many item files into ALLCOMBS format with a minimum of editing by placement of symbols for data divisions in the question record block.

And, finally, a note of disclaimer appropriate to all CATC systems. The enjoyment of retrieval and compositional efficiencies comes <u>after</u> a suitable question file has been created and verified: The development and maintenance of a question item file requires a major commitment of resources in order to have a file of sufficient breadth and replication to obtain full advantages of computer file management. Establishment of a question file is not a problem to be minimized. The first question a potential CATC user must answer is whether the game is worth this candle.

CTSS (CLASSROOM TEACHER SUPPORT SYSTEM)

Gerald Lippey
Classroom Support Systems
San Jose, CA 95118

CTSS was developed during 1969 and 1970 as an experimental application under a joint study agreement between IBM and the Los Angeles City Unified School District. It is now in use at several locations, most of them institutions of higher education.

This application grew out of the recognition that a computer can perform an important function by relieving the teacher of clerical chores related to the construction of tests, while leaving him free to make professional instructional decisions. Although it has value in improving pedagogy, it is primarily a cost-effective tool for improving productivity. More information regarding the rationale which underlies applications of this kind may be found in an article by the author (1975).

CTSS uses a centralized data bank of questions on disk storage to aid teachers in constructing tests and exercises. The system also scores students' answer sheets. It operates in batch mode, with teacher requests, tests, and scoring reports transported physically between the teacher and computer center. In this connection, it should be mentioned that the overwhelming majority of educational institutions are not sufficiently affluent to interactively administer tests in quantity or even to provide teachers with terminals which they might use to obtain tests. It would not, for example, be feasible for the Los Angeles schools to provide CTSS service via terminals, and this economic barrier is likely to remain for a long time.

CTSS assists teachers in choosing questions. Banked items may be classified along several dimensions, including subject matter, difficulty, and behavior required. They are retrieved according to classification criteria set by the teacher. Thus, a list of questions may be constructed so that it contains, for example, a number of questions on each of several topics, with the desired mix of difficulty levels. Specific items may also be requested by their identification numbers.

The items selected are listed as an "exercise," which is assigned a number and remembered by the system. The teacher may specify that items be deleted or added, to produce a new "generation" of the exercise. This process may be repeated for subsequent generations until the exercise meets the teacher's needs.

With each exercise, the teacher receives the classification assigned to the items it contains. He also receives references to two sources of published material associated with each question. A summary of the teacher's request and the items retrieved as a consequence accompanies the exercise.

As a teacher option, an exercise may be printed on reproduction masters. Also, upon request, the system will create several "versions" of an exercise, each having the items resequenced at random.

When multiple-choice items are in use, the correct answers to exercises are remembered by the system; so scoring keys need not be submitted. The teacher may add items of his own to be scored and, in fact, may submit answer sheets for tests entirely constructed by him; in these cases, he must of course provide the correct answers to the questions he supplies. Scoring of individual questions can be suppressed. The usual raw data, frequency distributions, summary statistics, and item response breakdown are provided to the teacher. Questions can be assigned to parts of an exercise, each of which will be scored separately. If scrambled versions were obtained, additional reports for each version are available.

For each item collection, there is an item statistics file which contains usage data for every question. This information includes the number of times the question was selected by the system, deleted from an exercise by a teacher, and suppressed from being scored. The file also contains data obtained from scoring, such as the cumulative number of responses to each option and a central tendency of discrimination indices. A program is available to test selected statistics against specified thresholds to obtain a list of those questions likely to need revision. Thresholds can be set for high teacher rejection rate, low average discrimination index, unusually heavy use of a distractor, and very high or low measured difficulty level.

Information on system activity is accumulated in a system statistics file. This file contains data on 25 different kinds of activity, representing the use of various CTSS functions. The information is accumulated simultaneously over two time periods (long and short). It is classified by item collection used and by up to twelve groups to which teachers may be assigned. System activity reports may be obtained at any time.

An assortment of additional programs is available for printing and updating item banks and other files. Also, several dozen specialized programs were written to aid those who oversee system operation. Over a dozen collections of machine-readable questions have been prepared for use with CTSS, and others are under development.

Various aspects of CTSS have been described elsewhere. These include the role it plays in the Los Angeles City Schools (Lippey et al, 1971) and the approach to its implementation (Lippey, 1972). Since these were prepared, several improvements were made to the system. Inquiries regarding its present state and its availability should be directed to the author.

Although CTSS appears to be the most comprehensive item retrieval and test printing system, there are a large number of computer programs which assist with test construction. The author has briefly reviewed over 100 approaches, and there must be at least two to three times this number. Most of them make use of test items in machine-readable form to print questions on demand. Many include, as does CTSS, computer assistance in selecting questions. Some "generate" similar questions using random techniques, and a few assist only in the item selection process, leaving the items and tests to be formatted and printed by conventional means. A fairly detailed discussion of computer-assisted test construction can be found in the book by this title (Lippey, 1974).

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