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ABSTRACT

This is an introductory presentation of economic evaluation methods for assessing computer-assisted instruction (CAI). Six different costing techniques, including cost effectiveness, are reviewed. Cost effectiveness is then examined in terms of its usefulness for evaluating CAI. A simplified system for cost/effectiveness evaluation is presented which involves determination of objectives, alternatives, and costs, as well as interpretation of results. (CH)

ECONOMIC EVALUATION OF CAI IN SPECIAL EDUCATION

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INTRODUCTION

We have been invited here today to discuss several aspects of the cost and effectiveness of employing computer-assisted instruction (CAI) in the area of special education. This is an important area for discussion. Few would deny that the expenditure of large amounts of resources needs to be based on economic as well as pedagological arguments--that schools must be productive and accountable to the agents fo society that fund them. However, a number of individuals who have worked with the development of CAI have indicated a doubt that it will ever be "cost-effective" but that we should go ahead, at least in some instances, with CAI development for non-economic reasons (Torr, 1976; Oettinger, 1969). Others have argued that cost-effectiveness analysis strategies can not be applied until after the systems to be studies are operational (Seidel, 1969). Part of the problem that is encountered in the application of economic evaluation strategies to innovative instructional techniques such as CAI is a confusion over terminology. A number of questions need to be answered before there can be any agreement on the appropriateness or usefulness of cost evaluation strategies in any particular application:

(1) What are cost-effectiveness and cost-benefit analysis and how do they differ from other cost evaluation strategies?

(2) Exactly what are the alternatives to be compared? Are they equally viable?

(3) Is cost-effectiveness an appropriate decision tool when the desired objective is non-quantifiable (such as an affective outcome)?

(4) At what point in time during the development of an innovative instructional approach is it appropriate to employ cost-effectiveness and/or cost-benefit evaluation strategies?

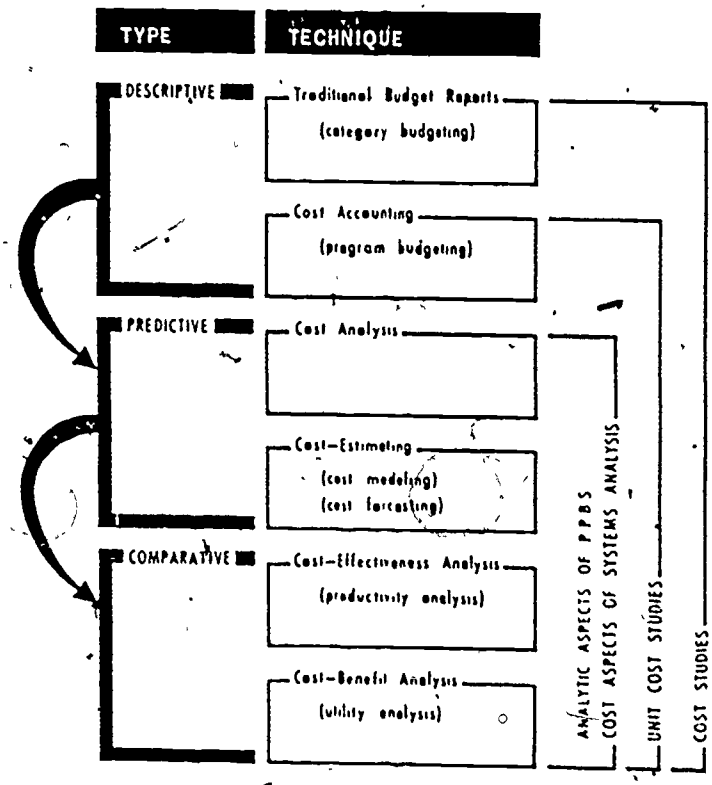
In this paper, in order to address these and other questions which need to be considered in the application of cost evaluation strategies, I will (A) define--and distinguish between--a number of different costing techniques, (B) present a simplified system for cost-effectiveness evaluation, and (C) apply cost-effectiveness evaluation strategies to the problem of using computer-assisted instruction in the area of special education.

DEFINITION OF COSTING TERMINOLOGY

There is a large number of different costing techniques and procedures which have been used interchangeably in the past. This lack of discrimination has produced a high degree of confusion. In order to reduce the confusion a classification system for costing terminology has been proposed by the author (Wilkinson, 1971, 1972). The basic elements of this system are outlined in Figure 1 (on following page).

The techniques are first classified into one of three groups on the basis of purpose of the study: Descriptive, Predictive, or Comparative. They are then further divided within these three categories on the basis of the type of activities conducted under the technique.

FIGURE ONE:



Descriptive

Descriptive studies seek to describe actual, existing, on-going programs. The constitute the essential data base upon which all other costing studies are are built. Within this category, a distintion is made between traditional (fiduciary) budgeting and those techniques which seek to relate costs to program objectives and outputs:

Traditional Budgeting--involves the establishment of expense categories (such as personnel, supplies, equipment, etc.), the appropriation of resources to organizational units, and the authorization of expenditures by organizational units in order to aid management in the control and reporting of the resource inputs of programs.

Cost Accounting--involves the accurate measurement of output quality (stu-

dent achievement) and/or quantity (number of graduates) at each stage of the educational process and the assignment of costs incurred to achieve that output to each stage in order to aid in managerial decisions pertaining to the allocation of resources to maintain established production criteria.

Predictive

The predictive group includes studies which seek to establish costs for proposed systems. They involve the accurate definition of objectives, the definition of strategies to obtain objectives, the determination of resources required to mount the strategies, and the conversion of determined resources to dollar amounts in order to aid management in the establishment of budgets and information systems. The major sub-categories are:

Cost Analysis--involves the analytical determination of the resources require to mount a predefined strategy at a set level of effectiveness.

Cost-Estimating--involves the application of statistical techniques to descriptive data to predict a range of costs and effectiveness for a given strategy.

Comparative

The comparative studies are based upon predictive studies whicn in turn are based upon descriptive studies. The major distinctions are between those studies which seek to compare the relative costs and effectiveness of different strategies for obtaining a particular objective or set of objectives and those which seek to compare the "good" derived from the achievement of an objective with the "cost" to society of seeking to achieve the objective. These are:

Cost-Effectiveness Analysis--involves the comparison of the resources re-

quired (predicted costs) for, and the output of, feasible alternative strategies for the achievement of program objectives in order to aid management in the selection of the better strategy for either the achievement of the most production at a set cost or the achievement of a set level of production for the least cost under differing conditions.

Cost-Benefit Analysis--involves the comparison of all the relevant resources (such as dollar value of personnel, equipment, etc.) required to achieve an objective with the likely benefits (dollar value of results) to be obtained from achievement of the objective in order to aid in managerial decisions as to the desirability of initiating or continuing a program in light of long-range time and social considerations.

The types of studies which need to be made of various applications of instructional technology, including CAI, are those on the cost-effectiveness and cost-benefit end of the scale. However, these are based upon predictive and descriptive studies and herein lies the problem that causes a number of experts to say that the time is not ripe for cost-effectiveness studies of CAI. There is no adaquate descriptive data base from which to make predictions or comparisons (Schramm, 1973; Jamison, 1974). There has been a proliferation of literature on the cost-effectiveness of technology. Caffarella (1975) was able to identify 429 references on the cost-effectiveness of instructional technology. However, of the 300 that he was able to locate, only 32 were supported by emperical or quantitative data. This is the sort of problem that the study reported on by Dr. Segal seeks to solve.

Even without an adequate data base, we intuitively use cost evaluation strategies to make instructional decisions. We feel that, as expensive as

CAI is, it is better to develop such an approach than to do nothing to attempt to improve school retention or to enhance individual student achievment. When we do this, we are making a cost-benefit evaluation. There is a large literature on the economic return to investment in education which helps to justify this sort of decision (Woodhall, 1967; Scanlon, 1973; Rodrigues, 1974). Based on 1973 figures, the difference in median yearly income for those who have completed high school and those who have only completed the first 8 years is $3,089. Spread over 47 years of productive life (18-65) this represents an increase of taxable income of $145,283. Even a small reduction of the over-all drop-out rate as a result of implementing CAI might go a long way toward justifying the expense, even without a concurrent reduction or redeployment of current educational resources. When we consider the target population that we are concerned with in this session, the gain is even more striking. Those students who fall within special education programs are, unless the educational system is able to assist them in overcoming their handicaps, much more likely to be a drain on society's resources than a productive member of society. If just one person were removed from the welfare role and placed on the tax role as a result of CAI, there would be a significant gain to society.

The sort of analysis that I have been discussing needs to be done with considerable more rigor to be valid. Such concepts as discounting investment cost over time need to be included. But, even if it is done with all the economic rigor possible, it will primarily be able to tell us if something should be done for a problem area and give us the broad financial limits within which we may operate. It will not tell us if CAI is the "best" solu-

tion or what form of CAI should be used. For this sort of decision, cost-effectiveness analysis must be employed. And, it is to this form of decision-making that I now turn.

COST-EFFECTIVENESS ANALYSIS

The central purpose of cost-effectiveness analysis is the evaluation of, and choice between, alternative means to achieve a given objective. The analysis can proceed from either of two orientations--the achievement of the most output for a set dollar cost or the achievement of the least dollar cost for a set level of output. No matter which of these approaches is employed, there are certain fundamental operations which need to be carried out:

(1) Determination of Objectives

(2) Determination of Viable Alternatives

(3) Determination of Relevant Costs

(4) Presentation and Interpretation of Results

It will not be possible for me to go into detail on the techniques and procedures which are appropriate at each of these stages of the cost-effectiveness evaluation process in this presentation. I would, however, like to hit a few of the high points and examine some of the questions which are of primary concern to the topic under consideration.

Determination of Objectives

The statement of objectives should include the following: (1) the outputs to be obtained from the system, (2) the inputs available to the system, and (3) the units by which output and input are to be measured. The statement of objectives would not include information about presentation require-

ments and strategies (such as, CAI will be evaluated). Such aspects are not objectives to be met. They are constraints which limit the options which are available and help to establish the viable alternatives to be evaluated.

A number of different measures have been proposed, and used, in cost-effectiveness evaluations. One common measure has been performance on standardized achievement tests. The problem there is that such tests are designed to eliminate, or at least minimize, the effects of different teaching strategies. A better form of measurement might be criterion referenced testing. Other studies have used such economic indicators as student-contact-hours, graduates, or student-credit-hours.

Two of the papers presented earlier in this session serve as good examples of the two basic types of output measures. Dr. Cartwright presents a basically economic approach--dollar cost per student credit hour--while Dr. Segal is concerned with marginal annual costs per achievement gain per child. Other examples of CAI cost-effectiveness output measures can be located by consulting some of the supplementary references which have been attached to this paper.

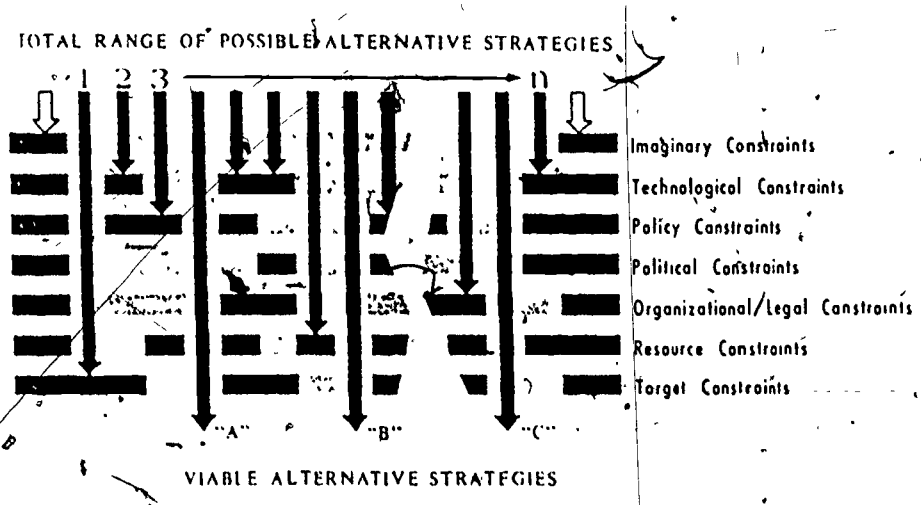
One problem with objectives, which was alluded to in the questions at the start of this paper, is that of using cost-effectiveness to evaluate non-quantifiable objectives. I think that the answer would have to be yes and no. If you were able to identify a number of different strategies which were equally good at achieving the desired objective--a fixed effectiveness approach--you could use this evaluation technique to chose between them. However, if, as is more often the case, the achievement might vary as a result of changing

the resource mix, it would not be an appropriate tool. For this reason cost-effectiveness is often referred to as a decision-assisting tool rather than a decision-making tool. Often such non-quantifiable out-comes will cause the decision maker to chose the less economical alternative. However, the reasons for such a choice need to be clearly spelled out, and the time to do this is during the statement of the objectives.

Determination of Viable Alternatives

The second step of a cost-effectiveness analysis is to determine the alternative instructional procedures, media, etc., to be compared. Initially you would want to start with the total universe of possible strategies--limited only by your imagination. In practical situations, this universe of possibilities is very rapidly filtered down by a consideration of those practical constraints which serve to limit our options when we are dealing with real-world problems. The following figure illustrates how such a consideration of constraints can reduce the total population of alternatives to just three viable alternates.

FIGURE TWO:



In many cases, one of the constraints under which we operate is the prior choice of one of the media alternatives to be evaluated--for example, CAI. However, to say that CAI is to be one of the alternatives is not enough. CAI is a fairly broad term which can mean a large number of things--both in terms of the software that is to be displayed and the hardware configurations upon which the software is to be displayed. Braby, et al, (1975) have identified 10 major variations of computer based delivery systems--ranging from a basic definition of CAI as a form of individualized instruction that employs digital computer technology to manage and display information to a student, accept student responses, provide knowledge of results, and select subsequent learning events, through variations of the PLATO IV and TICCIT systems, Computer Managed Instruction, and variations of computer simulation and gaming configurations. If CAI is to be one of the alternatives, the form and format of the configuration must be clearly specified.

The need for a clearly defined CAI configuration is even more important when it comes to determining the alternatives against which it is to be compared. The comparison is to be with "viable" alternatives. What are viable alternatives to CAI? This would be determined by both the objectives and the constraints under which the project is operating. If the program is primarily one of rote drill and practice, an alternative could be a linear programmed text or a simple workbook. And, given the almost constant research results of no significant difference, CAI would probably be a poor choice from a cost-effectiveness point of view. However, if the constraints called for taking advantage of the flexibility, memory capacity, and fast response capabilities of the computer in order to provide individually shaped, corrected/reinforced programs which take into consideration the needs, knowledge, prejudices, etc., of each learner, clearly alternatives

other than workbooks need to be considered. Traditional instruction--the self-contained classroom of one teacher, 20-35 students, and various textbooks, aids, etc.--does not provide this sort of flexibility and, therefore, should not be one of the alternatives considered (in spite of the fact that this is the most commonly evaluated alternative to CAI in existing studies). Possibly a tutor, working on a one-to-one basis (provided that this tutor has the same grasp of the subject field and the various ways in which it can be misunderstood and mastered as the team of design and subject field specialists who developed the CAI program) would be able to provide such an alternative. Another possible alternative would be a paper and pencil (or other media), test, teach, and retest approach such as in Individually Prescribed Instruction programs.

Other than to point out that there was no apparent attempt to identify and evaluate viable alternatives in a conscious and rigorous manner, there is no need to comment on the example studies which have been presented here today.

Determination of Relevant Costs

Once the strategies to be considered have been identified, the next step is to establish the relative cost and productivity of each strategy. Basically, two techniques can be employed to determine these values. One applies cost analysis while the other establishes cost-estimating-relationships.

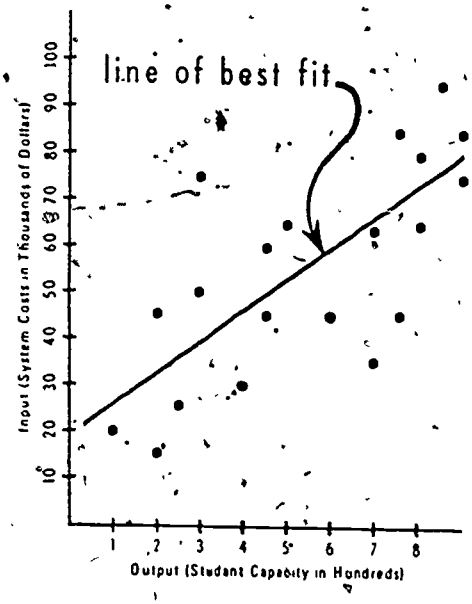
Cost analysis can proceed from one of two approaches: fixed-effectiveness or fixed-cost. For the fixed-effectiveness approach, a target level of effectiveness is established. Then, systems are defined which would employ one of the alternatives under consideration and produce at the set level of effectiveness. The resources (such as personnel, equipment, etc.) which would be needed to develop and maintain the systems are then determined and these resources converted to dollar

costs at the market price level, producing a total dollar cost for each alternative. The problem of choice then becomes one of selecting the least expensive alternative. The other cost analysis approach starts from a fixed-cost basis. This approach requires the analyst to determine the productivity of different systems, each of which employes one of the strategies being considered, which could be developed for a set level of funding. The problem of choice under this approach is to select the most productive alternative.

The determination of the cost estimate through cost analysis can become a highly complex cost accounting task, particularly if such concepts as sunk cost, inheritable assests, and discounting are applicable in the situation. Also, there is the difficulty of predicting the cost and the effectiveness of non-existant systems. The major problem with cost analysis, however, is that the estimate produced is a single-point figure rather than a continuous function over variations in output and therefore requires a new estimate to be made if the projected funding level is not sufficiently productive to be economical.

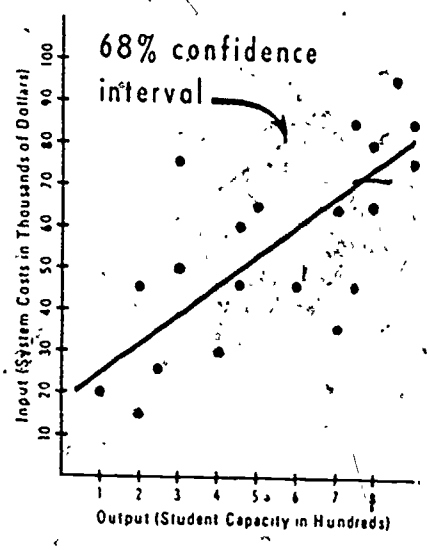
Cost-estimating relationships (CER) seek to avoid the major problem of cost analysis by establishing a continuous prediction function over a range of output levels. This is done by means of standard procedures of regression analysis applied to historical data from systems similar to the alternative under consideration. As illustrated in the following figure, existing data on the cost and productivity of similar systems are plotted on a scattergram and the line of best fit is determined. Assuming that the assumptions necessary to employ regression analysis have been met, the line of best fit produces a continuous predicted value of input or system cost over the range of possible system output.

FIGURE THREE:



There are a number of problems associated with the use of cost-estimating relationships. Often, for example, the line of best fit which can be derived from historical data is curved rather than straight. And in a strategy, such as CAI, which has a large capital investment for implementation (central memories, terminals, processors, etc.) each segment of which has an ultimate capacity, the CER is more likely to take the form of stair steps with sloping platforms. Other difficulties arise from the data base from which the estimates are derived. The information may be in the wrong format (requiring examination of the detailed cost figures as well as total system cost) and very likely the data were generated at different times (requiring at least adjustment for inflation or other changes in the market value of resources). Such problems greatly increase the difficulties encountered by the analyst and affect the reliability of the values generated through the use of CERs. This can be seen in Figure Four (on the following page) where confidence intervals have been plotted on the CER generated from the un-adjusted data shown above.

FIGURE FOUR:



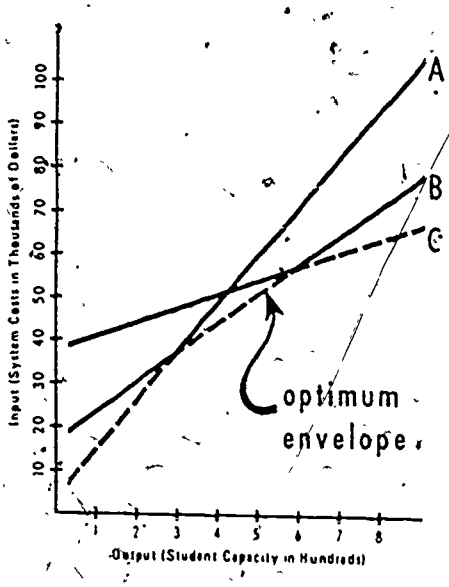
Such high levels of uncertainty can make the decision makers job one of acting on intuition rather than acting on some rational economic basis.

Presentation and Interpretation of Results

With the establishment of the estimated costs for the various alternatives under consideration, the final task is to present the data in a format that will aid the decision maker in arriving at his conclusions. If the cost analysis prediction technique has been employed, the task is relatively simple--a one page summary of the results would be more than adequate. Detailed projections are not necessary at this point although they should be kept ready for budget preparation. A balance sheet approach, however, is not feasible if CERs were employed, because the continuous nature of the projection cannot be readily conveyed by raw figures. With projections derived from cost-esstimating relationships a graphic decision model should be employed, such as the one shown in Figure Five on the following page.

By plotting the CERs of each of the strategies to be considered on a single matrix, it is possible to determine an envelope of optimum choice (shown as

FIGURE FIVE:



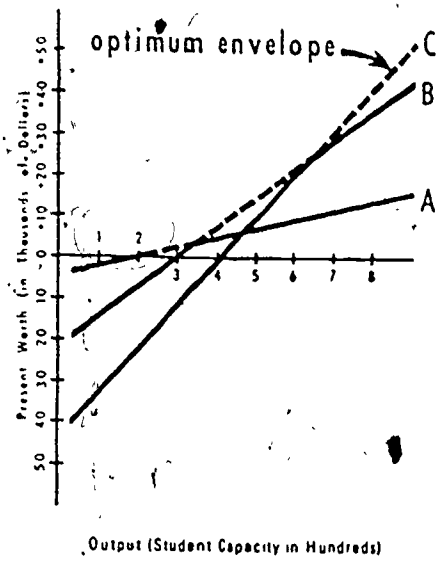
a dotted line) which identifies the "best" choice of strategies for any level of desired output or at any level of available funding.

Although the cost-effectiveness approach to decision making seems to limit the freedom of the decision maker, such is not necessarily the case. Using the example above, a system may be planned to start with a capacity of 250 students but eventually to expand to 500 students. In such a situation, the decision maker might well choose the more expensive alternative B over alternative A for the initial system so that in the long run he would be benefiting from the more economical alternative. Also, since there is a certain degree of uncertainty associated with the derived estimates due to unreliability of the data base, the decision maker's personal preferences may still enter into the decision process. The only requirement would be that he justify on some valid basis the choice of a less obviously economical alternative.

The distinction between cost-effectiveness and cost-benefit analysis can be illustrated by converting the cost-effectiveness decision model presented above to a cost-benefit decision model. The converstion is produced by esti-

mating the value of benefits to be obtained from the institution of any one of the alternatives at any level of output. Once this value has been determined, the cost of producing the output is subtracted from the value to be obtained from employing the strategy at that level of production and the decision matrix is redrawn as in the following figure. The base line of stu-

FIGURE SIX:



dent capacity is now at the midpoint of the model, with positive worth of the systems above the line and negative worth below the line. It is now possible to see that for each of the alternatives there is a negative worth to society for some level of productivity or output. At some point of output, the best choice is to do nothing.

ANSLYSIS OF RRESENTATIONS

With a context provided, it now possible to look at and analyze the other papers presented in this session. On the surface none of them are cost-effectiveness studies in the way that I have defined such studies. The closest is

the ETS project reported on by Dr. Segal. However, it more closely represents a case of cost accounting. The purpose of the study is to produce the data base for generating a CER for CAI, and therefore is essential to the generation of cost-effectiveness studies in the future. There is a great need for such an emperically established data base for CAI--and for other forms of mediated instruction--so that such studies can be conducted. The other papers are both concerned with cost and with effectiveness but they do not show the analitical comparison of alternatives that is called for in the term "cost-effectiveness".

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