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ABSTRACT

This paper examined in a critical fashion the existing applications of cost-effectiveness analysis in education, particularly the study of instructional effectiveness in the community college. Various schemes for measuring costs of instruction such as cost benefit analysis, cost-effectiveness analysis and planning programming budgeting systems were examined and the difficulties inherent in using them outlined. Measures of effectiveness of instruction were also explored with particular attention to measures appropriate for a quantitative analysis. Criteria for a useful measure of effectiveness were specified and use of measurement of population saturation, achievement, and social benefits were examined. Finally, these concepts were applied to a variety of real instructional situations, including a comparison of the cost-effectiveness of the several methods of teaching remedial mathematics employed at Santa Barbara City College (California) between September 1961 and September 1971. (Author/AL)

COST-EFFECTIVENESS ANALYSIS OF VARIOUS METHODS OF INSTRUCTION IN DEVELOPMENTAL MATHEMATICS

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I. Introduction

Administrators and teachers are constantly faced with the task of making important, often irreversible, decisions under conditions of uncertainty and incomplete knowledge. There is an increasing trend in these situations toward the use of rational, quantifiable, highly visible, decision-making processes. Systems analysis is

> ...the comparison of alternative means of carrying out some function, when those means are rather complicated and comprise a number of interrelated elements. Such analysis could often be called "economic analysis", since the aim is to find the best use of one's resources but the word "systems" is useful in calling attention to the complex nature of the alternatives being compared. (25)

Systems analysis thus provides a framework for decision-making and its power is that it forces the analyst to make explicit those elements of the situation he is taking into consideration.

The single most important requirement for a systems analysis of any system is that there exist a meaningful, unambiguous, and quantitative measure of the system output. In large scale educational systems the output may be specified in units of students graduated, standardized test scores, increase in lifetime income, or student credit hours completed. The major problem in evaluating educational systems is the vagueness of specification of objectives and goals designed to reflect their output. In addition to more or less specific skills (language skills, mathematics, science, etc.) there are subjective statements of cultural values, patriotism, aesthetic appreciation, and so on. Despite this difficulty it is important that those aspects of administrative and instructional planning decisions that are amenable to a quantitative approach be explored and appropriate systems analysis techniques developed.

It is the function of this paper to examine critically existing applications of cost effectiveness analysis in education, particularly the study of instructional effectiveness in the community college. Various schemes for measuring costs of instruction will be examined and the difficulties inherent in this task will be outlined. Measures of effectiveness of instruction will be explored with particular attention to measures appropriate for a quantitative analysis. Criteria for a useful measure of effectiveness will be specified and several possibilities examined. Finally, these concepts will be applied to a variety of real instructional situations, including a comparison of the cost-effectiveness of the several methods of teaching remedial mathematics employed at Santa Barbara City College between September 1961 and September 1971.

II. Cost Effectiveness Analysis in Education

A. Overview

Cost effectiveness implies that we identify costs and attendant benefits in some educational system, and that we use a combination of the two to evaluate the system. The analysis will be used in making decisions concerning resource allocation and the selection of alternative strategies in the operation of the system.(17) While most teachers are willing, though not eager, to talk about instructional effectiveness, they are quite unwilling to consider costs. Cost is indelicate, even crass, word in the hallowed ivy halls. Nevertheless, we operate today in a climate of scarcity of resouces: time, equipment, money, personnel. We do not now have and are unlikely to get unlimited resources. Education and individual instructional programs are competing with alternative programs for the same limited resources.

The phrases "Cost-Effectiveness Analysis" and "Cost-Benefit Analysis" are often taken as synonymous. They are not. Alkin (3) and others (16, 21, 47, 48) have pointed out that one of the main requirements of cost-benefit (CB) analysis is that both input and output measures be specified in the same units, namely dollars. CB analysis is an economic tool used in the examination of both public and private sectors of the economy: government, defense, business, education. Its chief use is in the examination of historical data in an effort to provide prescriptive decision statements.(47) Typically CB analysis is the second stage of a systems analysis and is most often performed at the level of large scale educational systems: state, national, district, or total college level. Bowles study of educational planning on the national level (5), Levin's analysis of public education systems (30), Abt's considerations of the voucher system (1,2) and the Hirsch and Marcus study of Junior College education (21), are all large-scale CB studies. Many such studies seek to determine the social gains, income, and other economic benefits resulting from formal education. Planning Program Budgeting Systems (PPBS) represents cost-benefit analysis on a big scale, a kind of fiscal systems analysis. (6,33)

In contrast, cost-effectiveness (CE) analysis may be made at all levels, and are less concerned with large-scale economic consequences of educational structures as with the evaluation of system performance with respect to established objectives and in the light of cost factors. CE is primarily a tool for comparison of the outcomes of alternative educational decisions.

A major requirement for the successful use of cost-effectiveness analysis is that either the cost or the effectiveness variables be limited. According to the common mathematical principles underlying maximization, both factors may not vary simultaneously. One must be held constant while the other is varied if we are to locate optimal values. We may specify the level of instructional efficiency in terms of achievement of specified objectives and examine the cost of alternative means to reach that level or we may specify an instructional budget and compare the effectiveness of alternative instructional strategies. (3,24) The equal cost alternative study of Carpenter and Haggard (13) is a classic example of the latter option. The most serious error made by educational planners applying these systems analysis tools is the attempt to locate optimal alternatives by allowing both cost and effectiveness to vary simultaneously. Cost-Effectiveness means that we look at both system performance and system cost when one of these are fixed. (25)

The typical sequence of actions in a CE analysis is:

1) Define objectives

2) Find a quantifiable output measure for each objective

3) Set up a cost accounting for the system, hopefully for each objective

4) Construct alternatives. (In a CE analysis of instruction we might look at large vs small classes, traditional versus non-traditional use of teachers, programmed instruction, tutors, educational television, Computer Assisted Instruction, Audio-Tutorial systems, etc.)

5) Test each alternative, either under conditions of fixed cost or fixed objectives

6) Compare relative effectiveness of each alternative (output) with cost (input)

A typical danger in 4) is to assume that a major purpose is to produce "schooling."

Cost-Effectiveness measures of instructional programs usually ignore student inputs, those inputs they bring into the program from outside (3) - skills, values, intelligence, personality traits, family background, etc. The true effectiveness of instructional systems is given by measures of change in student achievement of objectives. Typically this change is measured by course outcomes, test outcomes, grades, etc. but should ideally include attitude changes, value changes, impact on the community, the teacher, and the school. Long-term effectiveness is often implied in system objectives but seldom measured. There are very few CE studies of specific instructional programs, classroom level programs where the alternatives are ways of instructing, changes in the obviously manipulable variables of class size, instructional materials and media, course organization or sequence, use of paraprofessional help, and so on.

B. Cost Measures

Almost every school budget has a category labeled instruction, but the numbers it contains do not represent the cost of instruction. Costs of administrative support, library and AV staff, clerks and secretarial help, maintenance, classroom construction, teacher fringe benefits and many other real costs are not included. Valid cost data is not easily obtained. The costs needed are usually combined with other costs, short and long term costs are not spelled out, capital and operating costs may be combined or hidden.

Further, although the usual measure of cost is money, many other costs are expressed in terms of information, time, human effort, or lost opportunity, and these may be more important than the dollar cost differences in alternatives. Johnson and Dietrich (23) list the following cost problems in CE analysis:

1) Costs are seldom linear. Some costs are fixed, others are proportional to the number of students enrolled, and still others have a more complex relationship to enrollment.
2) Cost records are inadequate. Records may not include sufficient detail or may not include historical data.
3) Not all costs appear in dollar accounts. Opportunity costs do not appear. The time of students is considered a free resource.

Alternative uses of classrooms or other resources are not considered.

4) Teacher load data is not reliable. Many uses of teacher time do not appear on formal records.

Despite these problems, the determination of costs for instructional programs is far simpler than the determination of effectiveness.

C. Effectiveness Measures

It is no surprise, given the diversity, complexity, and subtlety of educational endeavors, that effectiveness is difficult to measure with validity and reliability. Because education is an open system, effectiveness (achievement of objectives) is a more valid measure of its optimal functioning than efficiency (relative effort required to achieve objectives). (30) However, typical educational programs are designed in terms of courses, semesters, quarters, fixed time intervals, group achievement rates, and other artificial devices that reward efficiency rather than effectiveness. This unfortunate fact makes CE analysis and effectiveness measurement very difficult.

There is a need, for CE, to specify objectives concretely, to "think through programs and their alternatives in output terms." (33) PPBS is simply a way of assuring that educational planners focus on measurable objectives. (13,18) The usefulness of effectiveness measures is, at best proportional to the specificity of the objectives of the system.

Satisfactory measures of effectiveness listed by Miller and

Rath (42) include:

1) Measures of Population Saturation Pre-test/Post-test gains in ability to perform a given objective may be measured for a population. If 10% of the students in a course have a certain level of achievement on the first day of the course, and 80% have reached that level on the last day, we may use these figures to measure effectiveness in terms of the relative increase in population saturation.

2) Measures of Achievement Standardized tests may be used to compare individual or group achievement with that of a normative population. If no pretest is used, achievement scores ignore student input to the situation. Achievement tests are best used as before and after measures. Most useful are measures of attainment of specific objectives or sets of objectives. These may include both affective and cognitive measures.

3) Measures of Social Benefits The social benefits of educational programs may be estimated or inferred from real-life situations or by the use of appropriate projective tests.

In addition we may consider long term versus short term retention of effectiveness under differing instructional strategies. (49)

D. Use of Cost-Effectiveness Indices The purpose of a CE analysis is usually to effect the most effective allocation of resources. Shubik (45) lists eight ways in which goods and services are usually allocated in our society:

1) Open market competition with a price system

2) Voting

3) Bidding

4) Bargaining

5) Allocation by higher authority or fiat

6) Allocation by fraud or deceit

7) Allocation by custom or tradition

8) Allocation by chance

Educational systems use 7) almost exclusively and 8) very often. Random allocation is a major means of distribution of diseconomies. In almost all of these allocation procedures, the effects of persuasion and other political activities are an important factor. CE analysis provides a basis around which to base political discussions.(44) There is a need to wed objective decision-making inputs more effectively to the political realities of the institution in which the decisions are made.

Traditionally, cost-effectiveness analysis may be summarized in terms of a single ratio or index. Miller and Rath (42) define the CE index or CE ratio as

$$E = \sum_{I=1}^{N} \frac{P(I)\,U(I)}{C(I)}$$

where P(I) is the probability of occurence of the Ith outcome, U(I) is the utility of the Ith outcome, C(I) is the cost of that outcome, and N is the number of outcomes considered.

The purpose of the CE analysis is not, however, to arrive at a CE index number, but to acquire the ability to rank alternatives in order to obtain a basis for choosing among them. The purpose is formative rather than summative evaluation, in Scriven's terminology. (51) Cost-effectiveness analysis is an orderly method of helping decision makers to identify a preferred course of action from a set of alternatives. The purposes are:

1) to discover new alternatives
2) to improve on the existing obvious alternatives (44)
3) to make more visible non-quantifiable considerations
4) to provide a means of considering incremental costs (how should an additional or reduced amount of money be spent?)
5) to provide a rational alternative to the use of pure intuition, expert opinion, or committee decision in chosing instructional strategies.

Of necessity, any cost-effectiveness analysis is incomplete because of intangibles that cannot be included, limitations imposed by lack of time, money, information, or uncontrollable changes in the system itself. Because of this it is especially important that modern operations research techniques - mathematical programming, Leontief I/O analysis, Markov process models, linear programming, Monte Carlo Simulation, Net-Shift Analysis, and other powerful tools - be used with the cost-effectiveness study to extend its usefulness.

III. Cost Effectiveness of Various Methods of Instruction: Applications

The purpose of this portion of the study is to

1) examine and compare several measures of effectiveness of instruction for several courses, and to compare conventional measures based on

grades with measures based on behavioral objectives.

2) determine the relative effectiveness of various methods of instruction in a junior college course in remedial arithmetic. In particular it will compare a system of individualized instruction using programmed materials and peer tutors with small traditional classes, large classes and independent study.

3) calculate cost-effectiveness ratios for these methods of instruction

4) compare four methods of individualized instruction using a programmed text and varying numbers of peer tutors.

5) Examine some of the hidden costs that are important in such a cost-effectiveness study, but which are usually ignored.

6) Consider further possibilities for research into the cost-effectiveness of classroom instructional methods.

A. Remedial Mathematics

A distinguishing feature of the community college is its open door admission policy and the necessity of offering remedial or developmental courses in order to assure that marginal students have a rasonable chance of success. Basic arithmetic represents a major portion of the teaching responsibility of most junior college mathematics departments. The level of success in these courses is depressingly low (10), less than 70% in most cases. At Santa Barbara City College where the present study was conducted, Math 1, remedial arithmetic serves a number of functions:

1) It enables students scoring low on the SCAT pretest to meet the math entrance requirements in a variety of courses: elementary algebra, physics and other physical science courses, life science courses, statistics, economics, psychology, pre-nursing, vocational-technical courses, business, and so on.

2) It fulfills the mathematics requirement for the A. A. degree.

3) It enables students, who elect to do so, to review their arithmetic skills.

The course content is basically the arithmetic of whole numbers, decimals, fractions, and percentage.(10)

Students enrolling exhibit a wide range of age, educational, social, and economic background, occupational and personal interests. (11) The assumptions we traditionally make about college students are not valid for this group.(38)

1) They are not motivated to participate in traditional academic activities, to succeed academically or to try again after failing.

2) They are grossly deficient in the conceptual and intellectual skills needed for successful academic work in traditional settings.

3) They lack the attitudes and values needed for success in traditional academic situations.

4) Their out-of-class environment cannot be depended upon to reinforce and extend any learning stimulated in the classroom.

5) The range of interests and abilities is extremely large.

Traditional methods of instruction have become associated with failure for these students. Many develop an expectation of failure and exhibit a pattern of repeated failure. (11) The same failure-oriented student is to be found in developmental English, Introductory Psychology, Introductory Political Science, and similar courses. Instructors usually identify them as not profiting from instruction. Their chief characteristic to the admissions officer or other administrator is their high dropout rate. Because their every encounter with education is colored with the expectation and the humiliation of failure, no amount of juggling of AV equipment or other hardware and no level of lecturer eloquence will entirely offset the pattern of failure. For this reason, remedial mathematics at Santa Barbara City College (10) is taught on an individualized basis using peer tutors and geared toward the achievement of clearly identified behavioral objectives. The system is open with respect to course, semester and other time requirements. All work is achievement-oriented; F and D grades are not used, students continue to work with their tutors until they have achieved a satisfactory level of completion of the course objectives.

Remedial mathematics at Santa Barbara City College has, by both accident and design, undergone a series of changes in the past ten years. Foresighted planners in the Mathematics Division and the administration have allowed the course to become essentially a a research tool for developmental math instruction. The following phases may be identified:

<u>Phase 1</u> From Spring 1961 to Spring 1966 Math 1 was taught in the conventional manner using small classes, average size 26. Unfortunately, grading in these lecture classes was not based on specific performance objectives or standardized tests.

<u>Phase 2</u> From Fall 1966 to Spring 1967 Math 1 was taught with the traditional lecture approach and with programmed instruction using classes of average size 42. Again, grading was not based on specific performance objectives or standardized tests. Students were required to attend class.

<u>Phase 3</u> From Fall 1967 to Spring 1969 Math 1 was taught using a single large class (average 225 during the spring semester and 508 during the fall semester). Students were not required to attend and used self-instructional programmed materials. Grades were determined by a single final examination.

<u>Phase 4</u> From Fall 1969 to the present Math 1 has been taught as individualized instruction using programmed self-teaching materials and tutors. Grading is based on performance objectives and standardized testing. The instructor acts as manager of the instructional system, works with tutors, develops materials, etc. rather than in lecture or other classroom situations. Attendance at tutoring session is required.

Table 1 shows the grade distribution records for this course in remedial math over the interval from 1961-1971. Table 2 shows the corresponding grade distribution for Math 7, Elementary Algebra, a similar developmental course, and for the Mathematics Division as a whole. Graph 1 shows the changes in P(S) and P(W), the probabilities of success and withdrawal for Math 1, remedial arithmetic, during the interval 1961 to 1971. P(S) is defined as

$$P(S) = \frac{\text{Total number of A,B, and C grades}}{\text{Total number of students receiving a grade}}$$

P(W) is defined as

$$P(W) = \frac{\text{Total number of withdrawn, W, grades}}{\text{Total number of students receiving a grade}}$$

Notice that in Phase 1, where small class sections were used, the drop probabilities are relatively low and success probabilities are high. P(S) is approximately equal to the value for the Mathematics Division as a whole: $P(S) = 0.72$, approximately. P(W) is also approximately equal to the value found for the Mathematics Division as a whole: $P(W) = 0.25$.

In Phase 2, where larger class sections were held, P(S) values dropped both for remedial math and for the mathematics division. The success rate for elementary algebra, Math7, similarly dropped. Withdrawal rates for both courses increased during this phase. The changes in P(S) and P(W) for Math 1 cannot be entirely attributed to instructional methodology changes because of the corresponding changes in Math 7, an independent course not undergoing obvious changes in procedures.

In phase 3, where credit by examination and optional attendance were adopted, success probabilities dropped still lower and withdrawal rates climbed. Division-wide values of these indices remained relatively stable.

In Phase 4 under individualized instruction and increased resource expenditures, success rates climbed and withdrawal rates decreased. Both withdrawal and success rates approached those for Elementary Algebra, Math 7, and for the Mathematics Division as a whole.

In summary:

	Average P(S)			Average P(W)		
	Math 1	Math 7	Math Div	Math 1	Math 7	Math Div
Phase 1 (small lecture classes)	.72	.35	.72	.25	.20	.25
Phase 2 (large classes, lecture+ PI)	.45	.36	.60	.46	.40	.36
Phase 3 (very large classes, credit by exam)	.30	.46	.43	.60	.35	.40
Phase 4 (individualized inst., behavioral objectives, PI, tutors)	.55	.65	.50	.48	.28	.38

Because neither cost nor effectiveness were fixed in early versions of the course, any useful cost-effectiveness analysis to decide among alternatives is not possible. In Phase 4, however, the instructional strategy has changed each semester while a constant effectiveness level was maintained. That is, performance requirements were held constant in terms of behavioral objectives and standardized tests. Course changes involved modification of the tutor/ student ratio and attendance reuirements.

Fall 1969 1 tutor, attendance not required

Spring 1970 4 tutors, attendance not required

Fall 1970 7 tutors, attendance required in math labs where the student/ tutor ratio was 15/1.

Spring 1971 10 tutors, attendance required in math labs where the student/tutor ratio was 6/1.

Both pre- and post-testing of performance in terms of course objectives was carried out. A cost-effectiveness analysis can thus be made for the instructional alternatives in Phase 4 but this phase cannot be compared with the earlier phases of the course.

B. COSTS

All costs were calculated on the basis of 1971 dollars and 1971 salary scales. Only direct instructional costs were included: instructor salaries, paraprofessional salaries, costs of specialized equipment amortized over its useful life expectancy. This procedure ignores the cost of instructional facilities such as large lecture halls versus small classrooms, administrative costs, maintenance costs, and so on. In calculating the cost per student only those students who received a grade for the course were counted. Students dropping during the first five weeks of the semester were ignored for the purposes of the study. More than 90% of these were "no-shows."

Table 3 gives these costs for Math 1, remedial arithmetic, and Math 7, elementary algebra.

Phase 4 was designed specifically to treat student time as a cost to be taken into account rather than as a free resource. In every instructional system one of the very large, but generally intangible, costs is the student time spent. This cost is rarely included in instructional cost analysis. In Phase 4 of this study, students scheduled their own time, took required examinations ad lib, and completed the course as early as they wished. The cost savings associated with this procedure could be determined by an analysis of student judgements of utility.

During the fall 1969 and spring 1970 semesters a considerable cost savings was effected by scheduling tutor sessions in unused rooms during the week before classes began after all other courses had been assigned rooms. Normally, the course would be scheduled into specified rooms, thus effectively withholding these rooms from alternative uses, a positive cost. By scheduling into unused rooms a more effective all-college use was made of available space. The cost savings to the college was significant. If the course, initial enrollment 650 by 1971, was rescheduled into small classes using traditional instruction methods, the increase in cost for teacher salaries and new classroom facilities required would exceed $40,000.

C. EFFECTIVENESS

Measures of effectiveness are difficult to assign in an open course such as we have in Phase 4. Students may return to complete the course at any time and some initially enrolled in 1970 are now completing course requirements. The 1970 probability of success, P(S), is still changing. Thus a withdrawn grade may mean that, in fact, a student has completed 75% of the course objectives and needs only to pass successfully the fourth of the four examinations to receive a passing grade.

Most cost-effectiveness studies performed at the classroom level examine only cost per student enrolled or per student credit hour. Such studies are useful in costing instructional materials (20,22,23,41,46) such as Computer-Assisted Instruction (27) or Educational Television(26,39,40). These costing studies are easy to perform, do not really use a measure of effectiveness, and are not cost-effectiveness analyses. They may be used to make trade-offs on the use of some audio-visual materials rather than others, but cost-effectiveness trade-offs cannot be made.

A variety of effectiveness measures have been calculated for this study. Most are a form of the CE Index (42) defined on page 9 of this paper.

1) Probability of Success, $P(S)$ is the fraction of students receiving A, B, or C grades. In terms of the CE Index, the variable I may take on three values corresponding to the grades A, B, and C. $P(A)$ is the probability of receiving an A grade. $P(B)$ is the probability of receiving a B grade. $P(C)$ is the probability of receiving a C grade. We assume that $U(A) = U(B) = U(C) = 1$, all success grades have equal utility. Non-success grades have zero utility.

2) The weighted probability of success, $P_w(S)$ is defined as $P_w(S) = 4\ P(A) + 3\ P(B) = 2\ P(C)$. This effectiveness measure assignes a greater utility to $P(A)$, $U(A) = 4$, than to $P(B)$, $U(B) = 3$, or to $P(C)$, $U(C) = 2$. The weighting corresponds to the usual weights used in calculating grade point averages, except that grades below C are given zero utility, $U(D) = U(F) = U(W) = 0$

Graph 3 shows $P_w(S)$ changes for Math 1, Math 7, and the Mathematics division during the period 1961-1971.

3) The success G.P.A., $P_g(S)$, is defined as $P_g(S) = 4\ P(A) + 3\ P(B) + 2\ P(C) - P(D) - P(F) - P(W)$. This effectiveness measure assigns a negative utility to non-success grades: $U(A) = 4$, $U(B) = 3$, $U(C) = 2$, $U(D) = UF) = U(W) = -1$.

The success G.P.A. is an attempt to take into account the withdrawal rate as a measure of effectiveness. The difficulty is that not all students receiving a W grade would assign it the same utility. Many have received the arithmetic review they needed and are quite satisfied. They might assign a utility of $U(W) = 1$ or even higher. Others enroll but interact with the system not at all and should not be included in an evaluation of the instructional methodology. Unfortunately, they are not easily identified. Other students may assign a withdrawal grade a utility of -2 or even less.

Graph 4 shows changes in $P_g(S)$ for remedial arithmetic, elementary algebra, and the mathematics division. Graphs 3 and 4 show $P_w(S)$ and $P_g(S)$ for the period 1961- 1971 and may be used to compare the effects on grade measures of small classes, large classes, credit by examination, and tutoring.

4) G Statistic, G, developed by McGuigan (33, 34), is defined as

$$G = \frac{\text{actual gain}}{\text{possible gain}} = \frac{\text{post test} - \text{pre test}}{\text{Maximum} - \text{pre test}}$$

It is a measure of behavioral change. The G Statistic assumes the existence of equivalent forms of pre- and post-tests with equal total possible score for each. McGuigan presents data for 37 programmed and 15 non-programmed courses, indicating the following percentile equivalents for G:

G	Percentile Programmed course	Percentile Non-programmed Course
50	49	79
60	73	80
70	89	99

During Phase 4 of the present study, a random sample of approximately 100 students were pre-tested each semester on the objectives of the course. These data may be used to calculate values of G for the four instructional alternatives of Phase 4. These values are shown in Table 4 and graph .

5) The fraction of Objectives achieved, %BO, is the most straightforward measure of effectiveness that can be used. It is simply the fraction of course objectives achieved when those objectives are specified in unambiguous performance terms. Unfortunately, few courses of instruction are organized around specified behavioral objectives. In this study, only phase 4 made use of behavioral objectives.

No attempt has been made to quantify attitude changes for use as a measure of effectiveness, although informal inquiry indicates that student norale is much higher under the individualized instruction method of teaching than under conventional methods.

Table 3 summarizes the cost-effectivenes indices calculated according to Miller and Rath(42), for the effectiveness measures listed above. This index is useful in that it enables us to rank alternative methods of instruction used in Phase 4. Not surprisingly, CE indices are higher for the Phase 4 program than in most earlier phases. The highest CE ratio occurred for fall 1969 when no tutors were employed. Withdrawal rates were highest, but costs were lowest. In spring 1970 tutors were introduced and the CE ratio decreased. In succeeding semesters the CE ratio increased as methods of using tutors effectively were developed.

A great many questions remain unanswered in this analysis. In particular, the search for an ideal CE index has not been completed.

An ideal CE ratio should (a) increase as effectiveness increases, (b) decrease as cost increases, (c) decrease as withdrawal rates increase, (d) be sensitive to a weighting of A grades with respect to B or C grades, and (e) remain relatively insensitive to number of students enrolled. The measures used seem to vary strongly with enrollment. Notice that from fall 1966 to spring 1969 low spring enrollments produced low CE ratios while high fall enrollments produced high CE ratios.

IV. SUMMARY AND CONCLUSIONS

Cost-effectiveness analysis can be applied to classroom level instruction as a decision making aid in the selection among alternative modes of instruction. Its use as an analytical tool is possible only where either cost or effectiveness is held constant across the alternatives being considered. Analysis is possible where effectiveness is measured in terms of performance objectives or other clear-cut unambiguous measures.

Studies with remedial mathematics courses indicate that, although costs are lowest when a credit by examination option, with use of programmed instruction and no required attendance, is used, effectiveness is correspondingly low and the cost-effectiveness ratio is comparable to individualized instruction with programmed text and tutors. Intangible cost factors such as room use, student time spent, and instructor preparation time make the second alternative much more attractive. If the tutors used are peers, students in the same college, an effectiveness measure giving the increase in tutor benefits should be included.

Examination of the CE history of an individualized instruction approach to a remedial mathematics course indicates that when a major cost increase takes place, such as extensive use of tutors, there is an initial drop in cost-effectiveness Index followed by a possible return to higher levels as instructional planners learn to use the new resource more effectively.

This preliminary study suggests the following possibilities for future research:

1) Net shift analysis(8,12,32) may be used to develop a measure of effectiveness. Net shift or Interval shift analysis is a procedure, based on linear programming techniques, which is useful in evaluating the degree to which a given set of final course achievement scores meets some final goal score distribution. The application of net shift analysis to cost-effectiveness analysis might profitably be studied.

2) The objective of any course of instruction is to increase the probability of success in the course. The probability of success can be measured as the course progresses and the sequence of changes or probability transitions may be treated as states in a Markov process. The probabilities in a Markov transition matrix might be used as measures of effectiveness in a cost-effectiveness analysis.

3) Hopefully, the instructional outcomes represented by examination scores and behavioral objectives achieved while the student is actively engaged in the course, reflect long-term gains in performance. Studies should be performed to test this assumption in the case of instructional programs employing tutors. It is entirely conceivable that reliance on tutors during the course may result in a decrease in long-term retention.

4) There is a need to estimate more accurately the utility of certain intangible costs usually overlooked in educational cost-effectiveness studies: student time, lessened stress of grades under certain instructional methods, value of discretionary time, subjective effect of using behavioral objectives, and so on. The utility factors U(I) may be estimated from student judgements using multiple linear regression techniques.

5) There is a need to study fixed-cost alternatives using performance objectives. This might best be done in Math 7, elementary algebra, where historical data is available at Santa Barbara City College. Large class versus small class effectiveness should be studied in an attempt to determine optimal class size. Modifications of the traditional approach may also be studied: inclusion of study of programmed materials in place of a portion of lecture, use of tutors in or out of class, use of individual audio cassettes for explaining difficult topics, substitute media for a portion of classtime, and so on. Cost-effectiveness analysis may be applied to the evaluation of coordinated instructional systems (4).

6) Experience with peer tutor programs indicates that a great deal of learning and positive attitude change takes place in the tutor.(36,37) This is a positive benefit to the tutor and represents a variety of course effectiveness that has not been studied from the cost-effectiveness point of view.

BIBLIOGRAPHY

1. Abt, Clark C. "Design for an Education System Cost-Effectiveness Model," Socio-Economic Planning Sciences, 2, 1969, 399-416

2. ___, "Reforming Urban Education with Cost-Effectiveness Analysis," Educational Technology, September 1970, 36-38

3. Alkin, Marvin C. "Evaluating the Cost Effectiveness of Instructional Programs," Center for the Study of Evaluation, U.C.L.A., Los Angeles, Calif., No. 25, May, 1969

4. Bennett, Robert L. "Increasing the Effectiveness of Community College Educational Programs through the Use of Coordinated Instruction Systems," California Junior College Association, San Mateo, Calif., Feb., 1971

5. Bowles, Samuel Planning Educational Systems for Economic Growth, Harvard University Press, Cambridge, Mass., 1969

6. Bradley, B. D. "Program Budgeting," The RAND Corporation, Santa Monica, Calif., P-3859, May 1968

7. Brightman, Richard W. "Strategies for Change, Part IV: Comparing Instructional Effectiveness," Coast Community College District, Costa Mesa, Calif., Research Report, June, 1971

8. Bruno, James E. "Design of Performance Contracts Which Maximize Net School District Utility," mimeographed, U.C.L.A., Los Angeles, Calif., 1970

9. Cage, Bob N. and H. R. Fowler "Cost Analysis: First Step Toward Differential Funding," ERIC #ED 048 863, ERIC Document Reproduction Service, Jan., 1971

10. Carman, Robert A. "A Systems Approach to the Development of a Junior College Course in Remedial Mathematics," Santa Barbara, Calif., August, 1969, Available as ERIC Document ED 034 536

11. ______, "Systems Analysis of a Learning Resources Center," Santa Barbara, Calif., Dec., 1970, Available as ERIC Document ED 047

12. ______, "Linear Programming with Applications to Educational Planning," Santa Barbara, Calif., Oct. 1971, Available as ERIC Document ED 051 563

13. Carpenter, M. B. and S. A. Haggart "Analysis of Educational Programs within a Program Budgeting System," The RAND Corporation, Santa Monica, Calif., P-4195, Sept., 1969

14. Cohen, Arthur M. and F. B. Brower "Measuring Faculty Performance," American Association of Junior Colleges, Washington, D. C., 1969

15. Dyer, James S. "Cost Effectiveness for a Public System of Higher Education," Unpublished Doctoral Dissertation, College of Business Administration, University of Texas, Austin, 1969

16. Franklin, John "Cost-Effectiveness and Cost-Benefit Analysis of Educational Programs," Socio-Economic Planning Sciences, 2, 1969, 381-388

17. Goldman, Thomas A. (Ed.) Cost Effectiveness Analysis: New Approaches in Decision-Making, Frederick A. Praeger, Inc., New York, 1967

18. Haggart, S. A. and M. B. Carpenter "Program Budgeting as an Analytical Tool for School District Planning," The RAND Corporation, Santa Monica, Calif., P-4031, Feb., 1969

19. Helmer, O. and Nicholas Rescher "On the Epistemology of the Inexact Sciences," Management Sciences, 6, No. 1, Oct. 1959, 25-52

20. Hinton, John R. "Audio-Tutorial Practices in California Community Colleges," Research Office Report, Diablo Valley College, Pleasant Hill, Calif., May, 1969

21. Hirsch, W. Z. and J. J. Marcus "Some Benefit-Cost Considerations of Universal Junior College Education," National Tax Journal, 19, #1, June 1966, 48-57

22. Howey, Mary Lou "Producation Cost Analysis," Educational Television, Nov., 1970

23. Johnson, R. Craig and John E. Dietrich, Cost Analysis of Instructional Technology in Tickton, Sidney G., To Improve Learning: An Evaluation of Instructional Technology, Vol. II, R. R. Bowker Co., New York, 1971, 965-976

24. Judy, R. W. "Systems Analysis for Efficient Resource Allocation in Higher Education," Institute for the Quantitative Analysis of Social and Economic Policy, University of Toronto, Toronto, Canada, Nov., 1968

25. Kershaw, J. A. and R. N. McKean Systems Analysis and Education, The RAND Corporation, Santa Monica, Calif., RM-2473-FF, 1959

26. Kiesling, Herbert "On the Economic Analysis of Educational Technology," in Tickton, Sidney G. To Improve Learning: An Evaluation of Instructional Technology, Vol. II, R. R. Bowker Co., New York, 1971, 977-998

27. Kopstein, F. F. and F. J. Seidel "Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics," A V Communications Review, 16, No. 2, Summer 1968, 155-158

28. Lave, R. E. and D. W. Kyle "The Application of Systems Analysis to Educational Planning," Comparative Education Review, 12, #1, 1968, 39-56

29. Levin, Henry M. "Cost Effectiveness Evaluation of Instructional Technology: The Problems," in Tickton, Sidney G., To Improve Learning: An Evolution of Instructional Technology, Vol. II, R. R. Bowker Co., New York, 1971, 999-1005

30. Levin, Melvin Educational Investment in an Urban Society, Teacher's College Press, New York, 1970

31. Levin, R. and C. A. Kirkpatrick Quantitative Approaches to Management, McGraw-Hill Book Co., New York, 1965

32. Lindman, Erick Net-Shift Analysis for Comparing Raw Score Distributions, Working Paper #8, Center for the Study of Evaluation, U.C.L.A., Los Angeles, March 1970

33. McGivney, Joseph H. "The New 'Systems' Approaches to Resource Allocation Decisions: A Second Look," Educational Technology, Dec. 1969, 31-34

34. McGuigan, F. J. "The G Statistic: An Index of Amount Learned," Journal of Programmed Instruction, 3, 1965, 14-16

35. ________, F. J. and R. J. Peters, Jr. "Assessing the Effectiveness of Programmed Texts - Methodology and Some Findings," Journal of Programmed Instruction, 3, 1965, 23-34

36. MacMillan, Thomas F. "An Analysis of the Effectiveness of Tutorial Assistance in English 42: Performance and Persistence Among Low Achieving Students," Santa Barbara City College Research Report, Santa Barbara, Calif. Available as ERIC Document ED 042 442

37. ________, "An Evaluation of Extended Opportunity Services at Santa Barbara City College," Research Report, Santa Barbara City College, Santa Barbara, Calif., April 1971

38. ________, "Academic Performance, Aptitude and Persistence of Special Assistance Students," Research Report, Santa Barbara City College, Santa Barbara, Calif., August 1971

39. Molnar, Andrew R. "Media and Cost-Effectiveness," West Long Branch, N. J., Aces-Analog/Hybrid Computor Educational Society, October, 1970, 8 pp. Paper presented at DAVI Detroit Convention, April 30, 1970

40. ________, "The Cost of Audio-Visual Instruction," School Management, June 1964, June 1966, Oct. 1968, Jan 1968, Jan 1969, Jan 1970, Jan 1971

41. Miller, James G. "Deciding Whether and How to Use Educational Technology in the Light of Cost-Effectiveness Evaluation, in Tickton, Sidney G., To Improve Learning: An Evaluation of Instructional Technology, Vol. II, R. R. Bowker Co., New York, 1971, 1007-1028

42. ______, and G. J. Rath "Planning-Programming-Budgeting and Cost Effectiveness Analysis in Educational Systems," in Tickton, Sidney G., To Improve Learning: An Evaluation of Instructional Technology, Vol. II, R. R. Bowker Co., New York, 1971, 1029-1059

43. Quade, E. S. "Cost-Effectiveness Analysis: An Appreciation," The RAND Corporation, Santa Monica, Calif., P-3248, Oct. 1965

44. ______, "Systems Analysis Techniques for Planning-Programming-Budgeting," The RAND Corporation, Santa Monica, Calif., P-3322, March 1966

45. Shubik, Martin "On Different Methods for Allocating Resources," The RAND Corporation, Santa Monica, Calif., p-4161, July, 1969

46. Speagle, Richard E. "The Cost of Instructional Technology," in Tickton, Sidney G. To Improve Learning: An Evaluation of Instructional Technology, Vol. II, R. R. Bowker Co., New York, 1971, 1061-1074

47. ______, "Cost-Benefits: A Buyer's Guide for Instructional Technology", in Ticton, Sidney G., To Improve Learning: An Evaluation of Instructional Technology, Vol II, R. R. Bowker Co., New York, 1971, 1075-1088

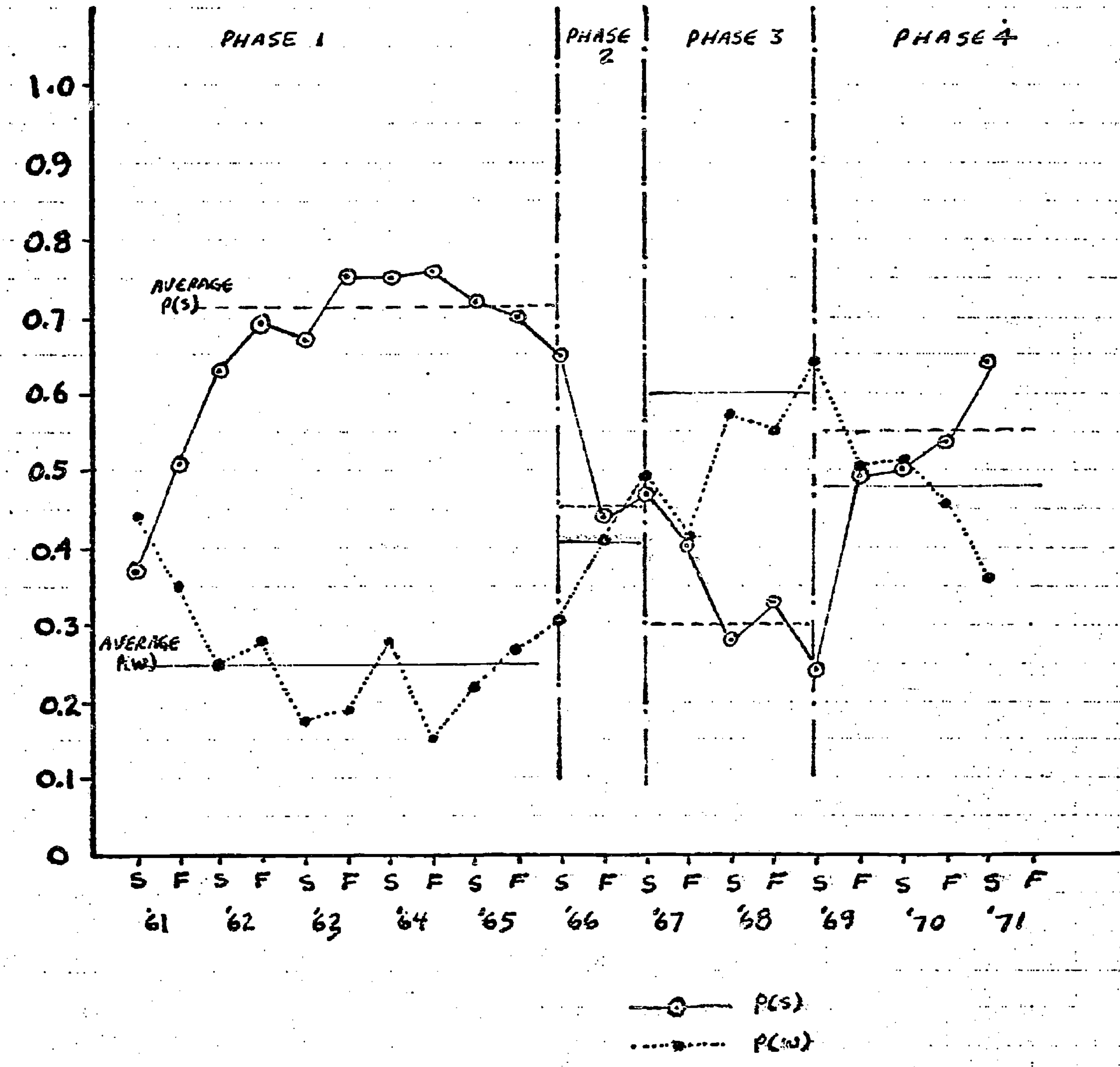
48. Spiegelman, R. G. "A Benefit-Cost Model to Evaluate Educational Programs," Socio-Economic Planning Sciences, 1, 1968, 443-460

49. Taylor, Gary R. "The Lone Learner," Audiovisual Instruction, 16, April, 1971, 54-55

50. Tickton, Sidney G. To Improve Learning: An Evaluation of Instructional Technology, Vol. I, R. R. Bowker Co., New York, 1971, 83-89

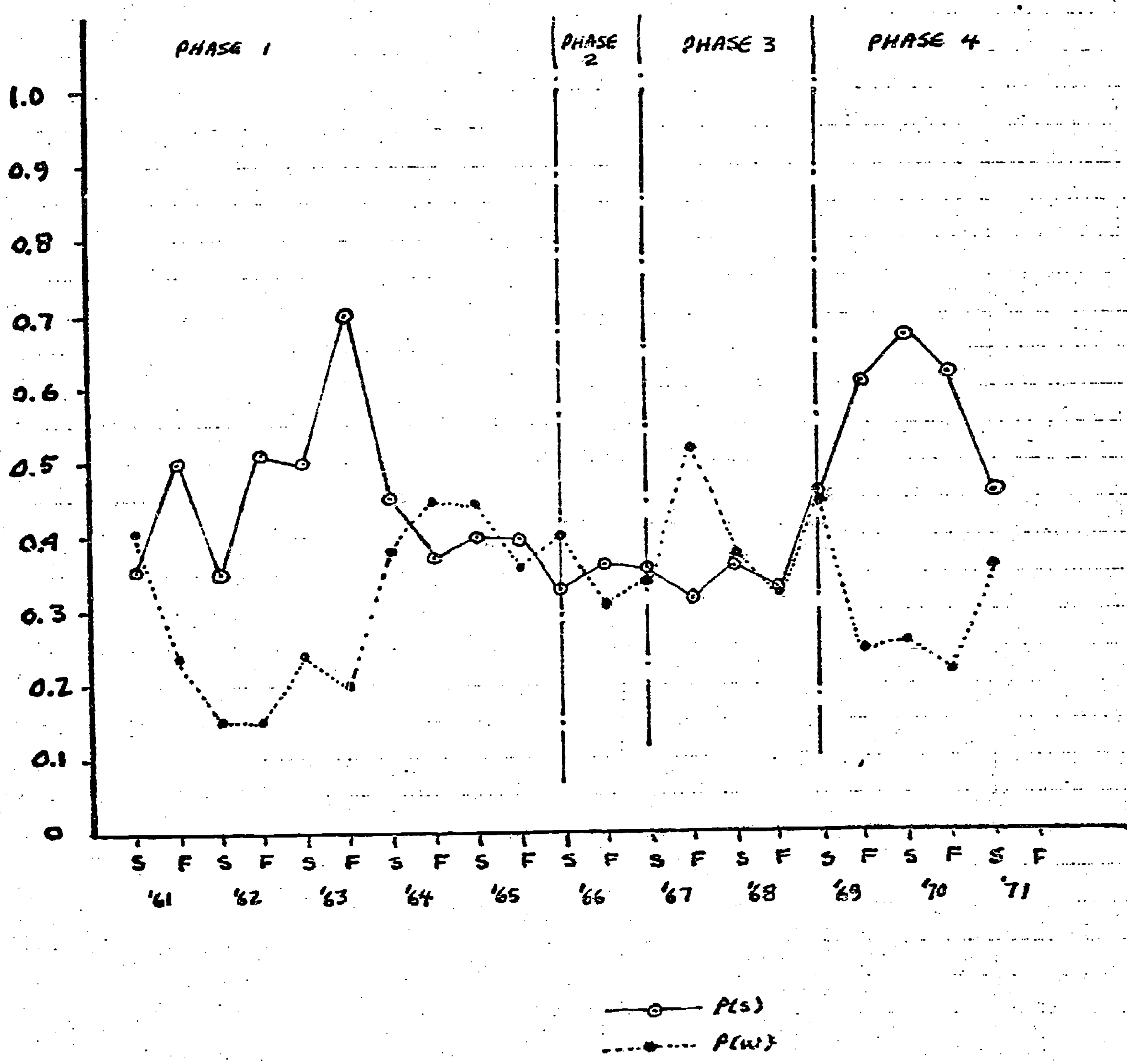
51. Tyler, R. W., Michael Sonnen, and R. M. Gagne Perspectives of Curriculum Evaluation, Rand McNally, Chicago, 1967

MATH 1, REMEDIAL ARITHMETIC

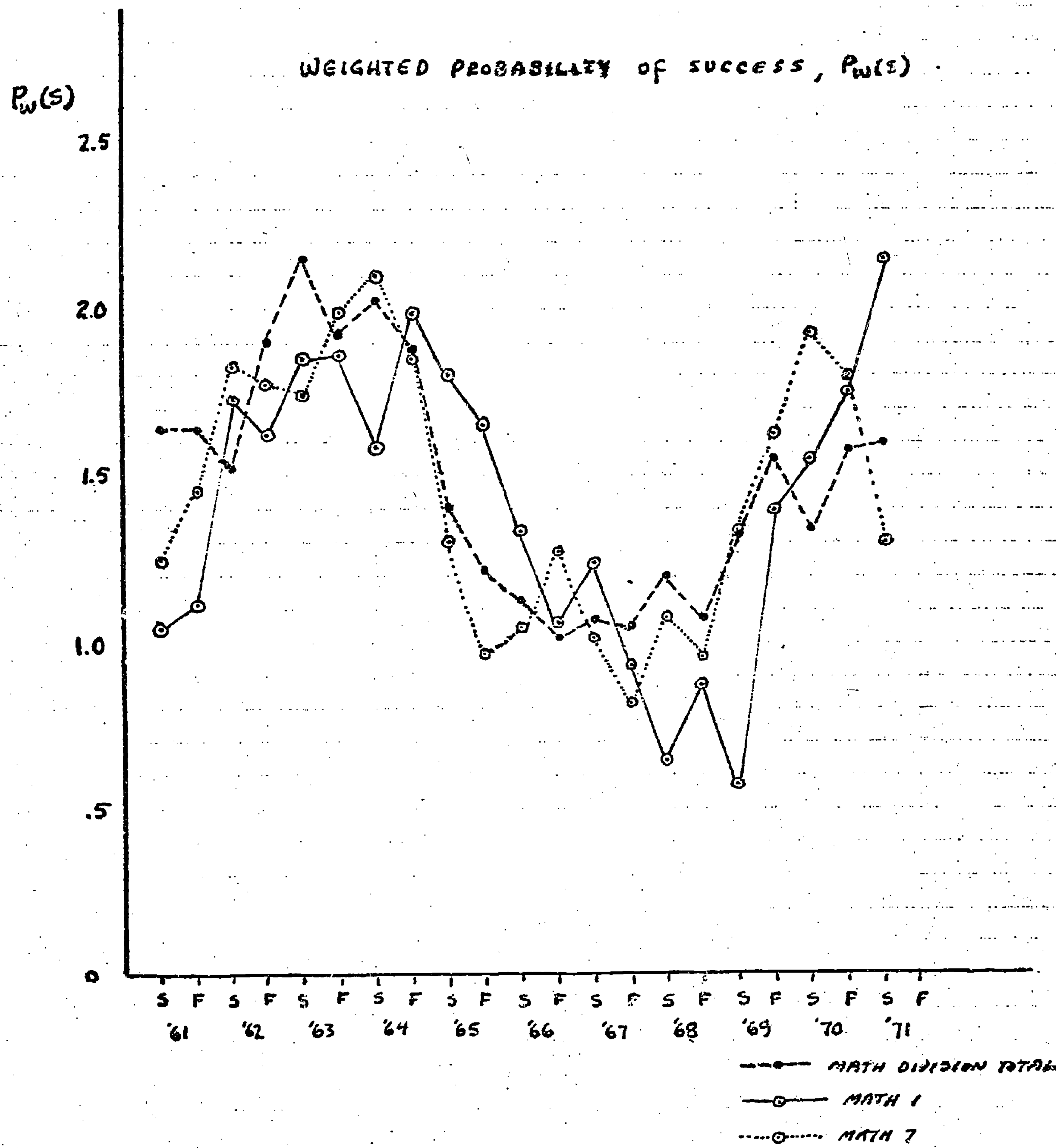


GRAPH 1

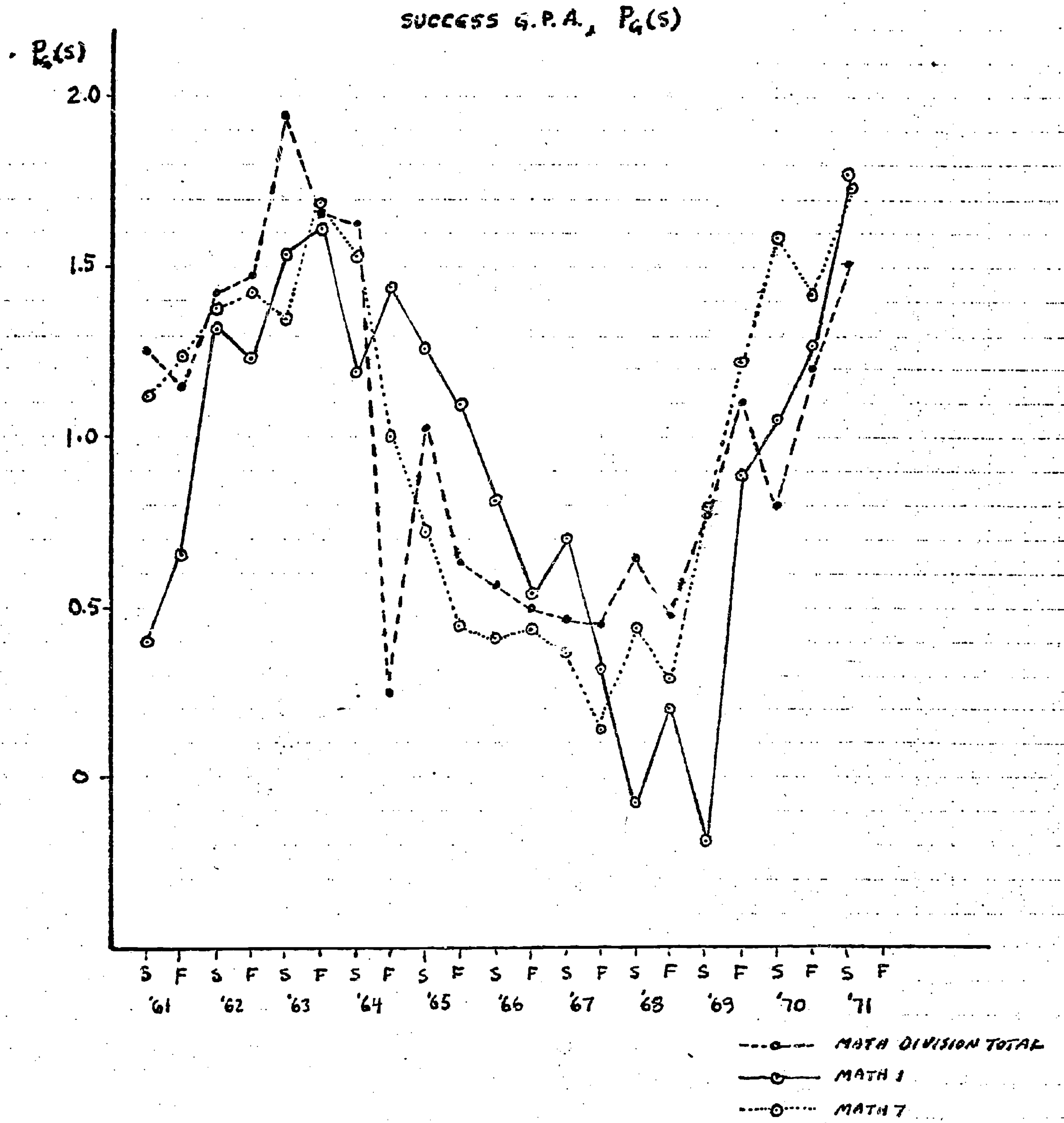
MATH 7, ELEMENTARY ALGEBRA



GRAPH 2

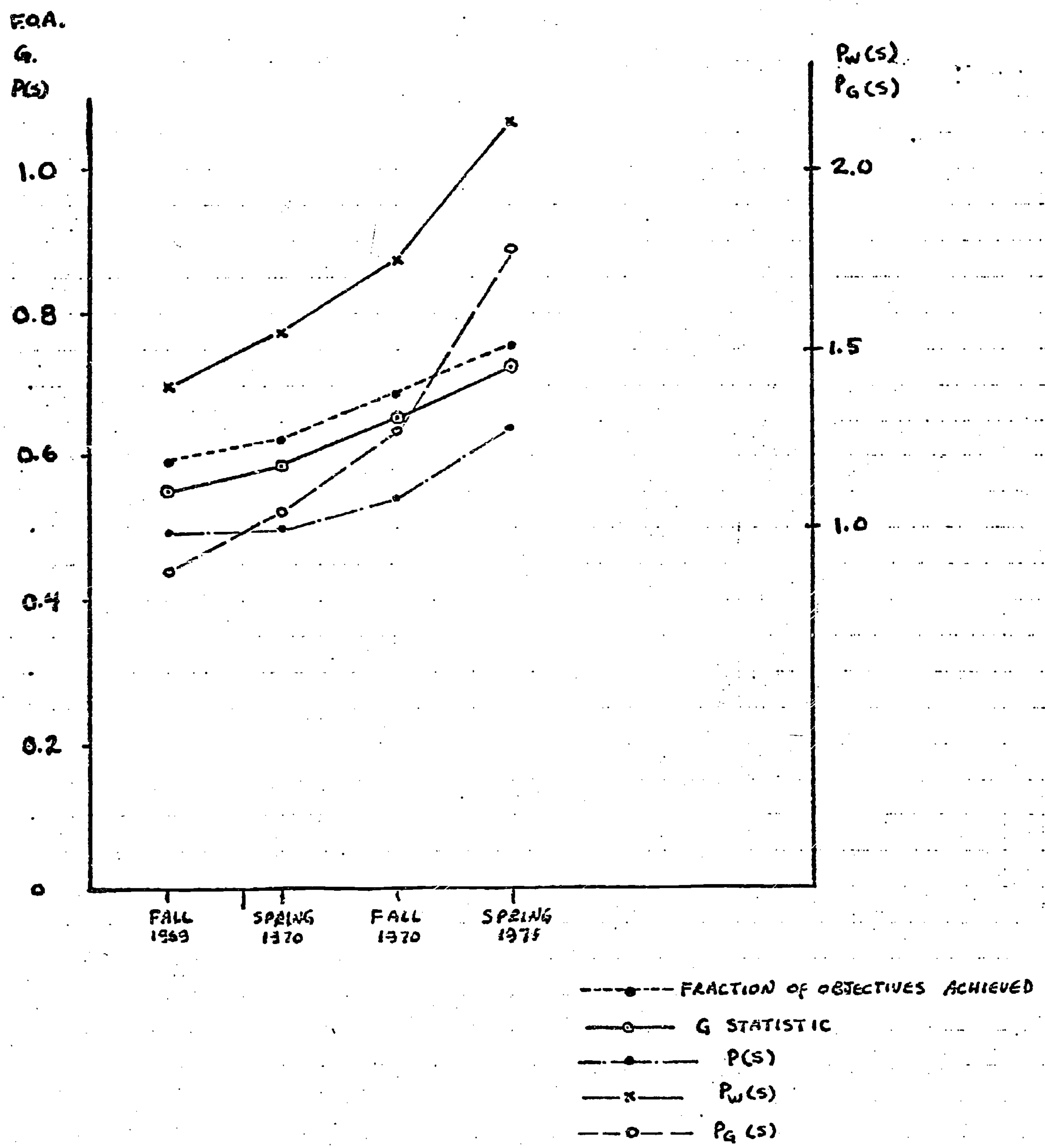

WEIGHTED PROBABILITY OF SUCCESS, $P_W(S)$
$P_W(S)$
2.5
2.0
1.5
1.0
.5
0
S F S F S F S F S F S F S F S F S F S F S F
'61 '62 '63 '64 '65 '66 '67 '68 '69 '70 '71
MATH DIVISION TOTAL
MATH 1
MATH 7

GRAPH 3



SUCCESS G.P.A., $P_G(S)$
$P_G(S)$
2.0
1.5
1.0
0.5
0
S F S F S F S F S F S F S F S F S F S F S F
'61 '62 '63 '64 '65 '66 '67 '68 '69 '70 '71
MATH DIVISION TOTAL
MATH 1
MATH 7

GRAPH 4



F.O.A.
G.
P(S)
1.0
0.8
0.6
0.4
0.2
0
$P_W(S)$
$P_G(S)$
2.0
1.5
1.0
FALL 1969
SPRING 1970
FALL 1970
SPRING 1971
FRACTION OF OBJECTIVES ACHIEVED
G STATISTIC
P(S)
$P_W(S)$
$P_G(S)$

GRAPH 5

TABLE 1

MATH 1 GRADE DISTRIBUTION

	A(%)	B(%)	C(%)	W(%)	Total
Spring 71	124(27)	150(32)	25(5)	165(36)	459
Fall 70	81(16)	175(34)	20(4)	236(46)	512
Spring 70	22(10)	78(34)	14(6)	114(50)	228
Fall 69	15(5)	97(32)	36(12)	155(51)	303
Spring 69	5(2)	13(5)	45(17)	170(64)	266
Fall 68	36(7)	36(7)	98(19)	283(55)	514
Spring 68	3(2)	8(4)	44(22)	113(57)	197
Fall 67	10(1)	51(10)	147(29)	208(41)	506
Spring 67	17(8)	28(13)	55(26)	104(49)	212
Fall66	25(6)	71(17)	88(21)	171(41)	417
Spring 66	9(7)	25(20)	47(38)	38(31)	123
Fall 65	24(9)	82(31)	82(30)	72(27)	265
Spring 65	10(11)	19(21)	37(40)	20(22)	92
Fall 64	19(8)	72(30)	91(38)	36(15)	239
Spring 64	5(8)	15(23)	19(29)	18(28)	65
Fall 63	8(4)	58(28)	90(43)	40(19)	207
Spring 63	8(13)	16(25)	18(29)	11(17)	64
Fall 62	4(10)	10(28)	12(31)	10(28)	37
Spring 62	5(14)	7(20)	7(20)	9(25)	36
Fall 61	2(8)	5(17)	4(26)	10(35)	29
Spring 61	2(7)	4(15)	4(15)	12(44)	27

TABLE 2

Math 7 P(S) and P(W)

Spring 71	P(S) =	.64	P(W) =	.36
Fall 70		.62		.38
Spring 70		.67		.33
Fall 69		.25		.75
Spring 69		.46		.46
Fall 68		.33		.33
Spring 68		.36		.37
Fall 67		.32		.52
Spring 67		.36		.34
Fall 66		.31		.36
Spring 66		.40		.31
Fall 65		.36		.40
Spring 65		.44		.40
Fall 64		.45		.37
Spring 64		.38		.45
Fall 63		.70		.20
Spring 63		.29		.50
Fall 62		.15		.51
Spring 62		.15		.35
Fall 61		.24		.56
Spring 61		.41		.36

TABLE 3

Math 1 Cost Calculations

	Number Students	Fraction of Instructor Load	Instructor Cost (1)	Tutor Cost (2)	Equip. Cost	Total Instructional Costs	Cost per Student	Cost per Successful Student	CE Index	G?Cost
Spring 71	459	4/15	$1600	2862.50	0	4462.50	$9.72	$15.18	.07	.07
Fall 70	512	4/15	1600	2003.75	0	3603.75	7.04	13.04	.08	.09
Spring 70	228	4/15	1600	1145.00	0	2745.00	12.04	24.08	.04	.05
Fall 69	303	4/15	1600	286.25	0	1886.25	6.22	12.69	.08	.09
Spring 69	266	4/15	1600	0	0	1600.00	6.02	25.09	.04	-
Fall 68	514	4/15	1600	0	0	1600.00	3.11	9.42	.11	-
Spring 68	197	4/15	1600	0	0	1600.00	8.12	24.61	.04	-
Fall 67	506	4/15	1600	0	0	1600.00	3.16	7.90	.12	-
Spring 67	212	1 1/3	8000	0	0	8000.00	37.73	80.27	.01	-
Fall 66	417	2 2/3	16,000	0	0	16000.00	38.37	123.78	.008	-
Spring 66	123	1 1/3	8000	0	0	8000.00	65.04	167.60	.006	-
Fall 65	265	2 2/5	14,400	0	0	14400.00	54.34	150.60	.007	-
Spring 65	92	4/5	4800	0	0	4800.00	52.17	118.57	.009	-
Fall 64	239	2 2/5	14,400	0	0	14400.00	60.25	79.27	.01	-
Spring 64	65	4/5	4800	0	0	4800.00	73.85	98.46	.01	-
Fall 63	207	1 13/15	11,200	0	0	11200.00	54.11	72.14	.01	-
Spring 63	64	4/5	4800	0	0	4800.00	75.00	111.94	.01	-
Fall 62	37	4/15	1600	0	0	1600.00	43.24	288.27	.003	-
Spring 62	36	4/15	1600	0	0	1600.00	44.44	296.27	.003	-
Fall 61	29	4/15	1600	0	0	1600.00	55.17	229.67	.002	-
Spring 61	27	4/15	1600	0	0	1600.00	59.29	160.16	.006	-

(1) at $12,00 per year average

(2) at $2.25 per hour, 15 hours per week, 15 weeks per semester

TABLE 4

Effectiveness Measures for Math 1

	P(S)	P(W)	$P_w(S)$	$P_g(S)$	G	% Objectives Achieved
Spring 1971	.64	.36	2.14	1.78	.721	76.8
Fall 1970	.54	.46	1.74	1.28	.656	68.9
Spring 1970	.50	.50	1.54	1.04	.583	62.6
Fall 1969	.49	.51	1.40	.89	.552	59.1