ED 142 393 SE 022 551

AUTHOR Roecks, Alan L.; Chapin, John
TITLE Mathematics Achievement in Schools Having and Not Having CMI: An Assessment of MICA. E.S.E.A. Title III Computer Managed Instruction Program, MICA Management of Instruction with Computer Assistance.
PUB DATE Apr 77
NOTE 24p.; Paper presented at the annual meeting of the American Educational Research Association (New York, New York, April 4-8, 1977); Not available in hard copy due to marginal legibility of original document

EDRS PRICE MF-$0.83 Plus Postage. HC Not Available from EDRS.
DESCRIPTORS *Computer Assisted Instruction; Computers; *Educational Research; Elementary Education; *Elementary School Mathematics; Evaluation; *Individualized Instruction; Instruction; *Management by Objectives; Mathematics Education

ABSTRACT

After presenting a brief discussion of the history and use of Computer Managed Instruction (CMI), the author describes the development and evaluation of a CMI system in the Madison Metropolitan School District (Wisconsin). Variables considered in the evaluation included efficiency of the software components, quality of instruction, and changes and problems in schools implementing the program in addition to student achievement. When achievement of fifth-grade students using CMI was compared with that of a control group, no significant difference was found. However, CMI was effective in relieving teachers of clerical burdens and the quality of instruction in CMI schools was found to be quite satisfactory. (SD)

28.17

E.S.E.A. TITLE III

COMPUTER MANAGED INSTRUCTION PROGRAM

MICA

MANAGEMENT OF INSTRUCTION WITH COMPUTER ASSISTANCE

Mathematics Achievement in Schools Having and Not Having CMI: An Assessment of MICA

by

Alan L. Roecks

John Chapin

Paper presented at the annual meeting of the American Educational Research Association held in New York City, New York

April, 1977

MATHEMATICS ACHIEVEMENT IN SCHOOLS HAVING AND NOT HAVING CMI: AN ASSESSMENT OF MICA

by

Alan L. Roecks

John Chapin

Madison Metropolitan School District

This paper focuses on the development of Computer Managed Instruction (CMI) in the Madison Metropolitan School District in Madison, Wisconsin. The CMI effort involved about 900 fourth and fifth grade students in nine elementary schools, all having the same mathematics curriculum. During the 1975-76 academic year six of the schools used CMI and three of the schools did not have CMI and used manual systems. Application of Students' t-test on gain scores for fifth grade students in CMI and manual schools reveal no significant difference ($p <$ .01) between groups.

The remaining program evaluation results for the CMI effort were considerably more encouraging, however. These results revealed that the CMI system was effective in relieving teachers of clerical burdens and providing them with useful information - thus, facilitating the process of individualization of instruction. The findings, furthermore, indicated that quality of instruction provided the nine schools was apparently quite satisfactory. A final finding was that schools underwent few changes in order to implement CMI.

> The real argument for more educational computing goes beyond merely using the computer as an efficient means of instruction. It is much more. The computer in the schoolhouse is the first essential step towards computer literacy, the most meaningful, direct link that today's students have with the outside world. (p. 46)
>
> Harold J. Peters, Computer Decisions, July 1976

BACKGROUND

Wiley (1975) points out the declining rate of productivity in the economic sector of the United States has been receiving considerable attention during the past decade. However, concern about educational productivity has been expressed only recently, despite the fact that 8 percent of the American gross national product has been earmarked for education. Rochart and Morton (1975) have stated the use of computers in education has increased at an annual rate of about 20 percent since 1971. Lippey (1973) suggests three classifications of computer applications in education, indicating computers are used as research tools, for student programs, and for operational support. Among those applications of the computer in support of instruction, he contends, there appears to be an increasing interest in using the computer to assist in managing instructional activities rather than administering instruction.

Nearly all such Computer Managed Instruction (C.M.I.) activities support some aspect of individualization of instruction. A CMI system should have as its primary objectives collecting and processing information on students (Spuck, Hunter, Owen and Belt, 1975). This information is then disseminated to educational decision-makers so that it will have direct and forceful impact on the process of instructional decision making. Cooley and Glaser (1968) in describing the role of the computer stated: "The function of the computer in a CMI system focuses upon allowing better information flow to the complicated decision process on a continual basis." (p. 1). At the operational level, Bolton and Clark (1973) maintain a dual function exists for a CMI system: to utilize the computer to optimize the learning environment for each child and to maximize the efficient use of human and material resources. Chapin and Roecks (1975) discuss some of the issues involved in implementing a CMI system at the classroom level:

> Teachers in individualized programs face diversified student populations whose needs are only truly met with an instructional system that can cope with students who have highly varying basic abilities, educational experiences, and basic skills. These students, whose rates of learning might vary by as much as a factor of six, require individualized goals. Unique pathways through the curriculum, different learning styles, individually selected assignments, and alternative assessment

strategies are required to meet the potential of individualization. In terms of curriculum materials, the primary problems is one of abundance. The last ten years have seen an explosion in the amount and variety of commercial curriculum materials that can be used across the subject spectrum. Just keeping track of what is available, much less what is used within a large school system, has become a major administrative task. How is a teacher to manage the use of multi-texts, supplemental materials, learning packets, modular units of instruction, multiple tests...? All of these materials must be integrated into the instructional system so that at the proper moment the classroom teacher can use the correct instructional material to meet an individual's unique problem. (p. 7).

In 1968, the first major CMI system, IMS, became operational through the efforts of the System Development Corporation of Los Angeles (Silberman, 1968). Since this time, several CMI efforts similar to IMS have been developed. In reviewing these early CMI efforts, Baker (1971) has listed four common functions that were being performed by the computer in each of the CMI systems: test scoring, diagnosing, prescribing, and reporting. The major difference between these CMI systems, he noted, lay in the relative amount of emphasis actually given to each of the four functions. Wiley (1975) reports one of the most successful CMI efforts has been Kelley's individualized economics course which was piloted at the University of Wisconsin in 1971-72 and is presently being used at Duke University. Cooley and Glaser (1968) describe a management information system, IPI/MIS, designed by the Pittsburgh Learning Research and Development Center to operate a program of Individually Prescribed Instruction. Lekan (1971) indicated the AIMS system provides considerable information about students and uses this information in the optimization of instruction. WIS-SIM, which was developed by the Wisconsin Research and Development Center for Cognitive Learning, supports a program of Individually Guided Instruction for about 1000 elementary students (Spuck, Hunter, Owen and Belt, 1975). Two of the more recent CMI efforts for which evaluation information is available are Project PLAN and MICA. These systems are described in more detail in the following pages.

Project PLAN (Program for Learning in Accordance with Needs) which is distributed by Westinghouse Learning Corporation is a computer managed individualized learning program that allows each student to learn at his or her own rate in several content areas. The computer assists the teacher by planning student instruction, keeping track of student progress and scoring and analyzing tests. In assessing Project PLAN, Patterson and Johnson (1974) found that eight out of twelve classrooms showed a teaching pattern of relatively high individual interaction, low group interaction and high classroom management activities. Their research also indicated PLAN teachers spend more time in individual and small group instruction than regular classroom situations. With regard to student achievement, Patterson (1974) found student mathematics results from standardized tests at grades 4 and 5 to be slightly better for PLAN schools. In response to attitude surveys, students in 12 out of 13 PLAN classrooms indicated higher satisfaction than did students in control classrooms. Teachers in PLAN classrooms indicated higher relative satisfaction than did control teachers.

MICA (Management of Instruction with Computer Assistance) is a CMI software system which has been primarily funded by Title III, E.S.E.A. Located in Madison, Wisconsin, this effort has supported an individualized mathematics curriculum for the fourth and fifth grade. In developing MICA, a group of Madison teachers at Sherman Elementary School began a cooperative effort with the University of Wisconsin Laboratory of Experimental Design to develop a CMI system whose purpose was to provide a feasible means of implementing individualization of instruction. This effort began in 1972 and after a year of systems work MICA was piloted at Sherman School using the teacher-designed math curriculum.

The development of the MICA software system paralleled further development of the Sherman math curriculum. Operationally, this meant that schools wishing to have CMI subsequently adopted the individualized math curriculum in their schools and actively participated in CMI developmental efforts. As of Fall, 1975, nine elementary schools were supporting the Madison CMI effort and were using the same curriculum, Sherman math. The fourth and fifth grade population involved in this effort consisted of about 900 students.

Due to limited financial resources, only six of the nine schools were able to receive the full impact of CMI; i.e., only six schools had computer terminals in the schools and used the MICA software computer package during the 1975-76 academic year. The remaining three schools who did not have computer terminals and thus, the support of MICA, taught mathematics in the same way as the schools having CMI; recordkeeping and other clerical tasks in these schools were performed by school staff rather than the computer. These schools were then identified as "manual" or "non-CMI" schools. It should be noted that the actual choice of which schools received CMI support--with the possible exception of Sherman School whose staff provided initial leadership--was essentially arbitrary. Those schools not receiving CMI were assured of CMI support whenever additional funding became available.

PROGRAM EVALUATION FOR MADISON'S CMI EFFORT

A rather thorough program evaluation of the Madison CMI effort was begun in 1975 and completed over a year later in the Summer of 1976. This evaluation examined the effectiveness of the MICA software system, the quality of instruction provided for the nine schools associated with the CMI effort, and the nature of change due to implementing a technologically innovative product (CMI).

Efficiency of MICA Software

Successful implementation of CMI is dependent on an efficient software system which can meet the needs of the individualized instructional setting (Baker, 1977). The philosophy involved in the development of such a software system has been articulated in an earlier article by Chapin and Roecks (1975):

> Underlying this effort was the development of an acceptable philosophy of instruction that such a CMI system was to support. The central principle was that teachers should be 100% free of all clerical or non-instructional tasks and that all data processing should be done by machines or aides. Teachers should devote their time entirely to teaching and they should have all information required for instructional decisions readily at hand. These general feelings were captured in a Madison Public Schools Research and Development Department study of the Sherman effort which concluded that the real needs of individualization could only be met with a utilitarian system that could handle multiple schools, multiple curriculums, and a wide variety of instructional settings and philosophies. Such a system must completely remove the clerical burden from the teachers without imposing upon them arbitrary and unwanted decisions or information. The system must be interactive and fast enough to process information at a rate equal to the speed at which students come to decision points in the curriculum. Neither students nor teachers can afford to wait for proper information. (p. 10).

With these guidelines in mind, several time and motion studies were done to ascertain how much teacher time was spent in individualized settings with MICA and in settings without MICA support, or manual settings. These studies revealed that teachers using the MICA system were freed of nearly all clerical burdens previously associated with individualization; furthermore, these teachers were able to provide more instructional time for students during math hour (Chapin, Heggland and Kurtz, 1976; Roecks, Kurtz and Heggland, 1976). In comparison to manual settings not having MICA, it was found that the individualized settings with MICA could handle information recording and retrieval tasks faster with less labor required and that less student time was spent in waiting activity (Chapin, 1976; Chapin, Heggland and Kurtz, 1976; Roecks, Kurtz and Heggland, 1976). In summary, these results strongly suggested that the MICA system had been able to facilitate the process of individualization of mathematics instruction. A survey of teacher and student attitudes towards the MICA system also support this contention (Roecks, 1976 [b]; Roecks, 1976 [c]).

Quality of Instruction in CMI Schools

A second emphasis of the program evaluation involved researching the quality of instruction provided--a factor which can profoundly influence student performance. The quality of instruction provided to students is dictated in large part by two considerations: the effectiveness of the instructional agents (teachers) and the overall worth of the instructional program (curriculum). The MICA evaluation staff addressed these two issues describing the quality of instruction for the nine schools having Sherman math including the six CMI schools. It was found that teachers participating in the MICA program not only believed and actually had more time available for direct interaction with students--making them more effective instructional agents (Roecks, 1976 [b]). Students in schools having the instructional program supporting the MICA system, Sherman math, recorded scores at least as high as students in schools having a more traditional curriculum.

(Roecks, 1976 [a]). Thus, one factor which strongly influenced student performance--the quantity of instruction provided, was shown by studies of teacher effectiveness and curriculum worth to be quite adequate in the six schools supported by MICA and the three manual schools.

Changes Resulting from Implementing CMI

The third emphasis of the program evaluation involved researching the nature of change accompanying the implementation of CMI. The nature of this problem made this research approach primarily descriptive. Three factors were identified as impacting the change. The factors included the time at which each school began to use the MICA software system, each school's commitment to CMI and the degree of developmental problems experienced by each school. Interaction among and between factors was likely present, making the factors somewhat interdependent. The effect of each of these factors on the nine schools involved in implementing CMI is summarized in Table 1 below.

Sherman School housed the pilot activities for the Madison CMI effort, receiving in the Fall of 1973 the support of a limited version of the MICA software package. Sandburg became the seond pilot school in 1974, using an abridged version of MICA. The "official" version of CMI was launched in the Fall of 1975 using a completed version of the MICA software package. Four elementary schools--Glendale, Muir, Schenk and Thoreau--in addition to Sandburg and Sherman participated in this effort. The remaining three schools using manual systems were Emerson, Lapham and Spring Harbor.

Table 1
Factors Involved in Implementing
CMI in Nine Schools with Sherman Math

Elementary School Having Sherman Math	CMI Implementation Factors: Used MICA Software in School	Commitment to CMI during 1975-76 Academic Year	Degree of Developmental Problems
Glendale	Began 1975	high	low
Muir	Began 1975	very high	low-medium
Sandburg	Began 1974	med-high	low-medium
Schenk	Began 1975	high	low
Sherman	Began 1973	high	low
Thoreau	Began 1975	medium	medium
Emerson	manual system	medium	very low
Lapham	manual system	very high	low-medium
Spring Harbor	manual system	med-high	very low

Evaluating the cost of the MICA program was straightforward and it was demonstrated that the adoption of the MICA program into the school system would result in a significant cost/student reduction over a ten-year period (Chapin, 1976). Attempting to assess the effect of CMI (in the form of MICA) on student achievement, however, posed a considerably more complex problem.

The principle problem we faced was a conceptual one; namely many factors influence student performance to a greater extent than CMI--in fact CMI affects student performance in only an indirect manner. CMI directly affects the teacher by providing him or her with useful instructional information and relieving the teacher of clerical burdens. The instructional milieu is then enriched by a system of CMI. The classroom environment, however, is only one of many factors affecting student achievement (Harnischfeger and Wiley, 1976). Other potential factors which could have influenced performance of students in schools participating in the CMI effort included the quantity of instruction in instructional setting, home/community environment, the quality of instruction[1] and social background of teachers and students.

These conceptual considerations were presented to the Board of Education in June of 1976. The arguments were apparently not persuasive and an evaluation of the patterns of achievement for the schools involved in the CMI effort was therefore begun in July, 1976. Of particular interest was research comparing achievement results for the six schools having MICA with results for the three manual schools. The remainder of this paper will chronicle the methodology employed in this research, the subsequent findings, research limitations and a discussion of results.

---

[1]As discussed earlier in the paper, research involving the quality of education revealed that the quality of instruction was quite adequate for the nine schools participating in the CMI effort. Hence, student performance is apparently more profoundly influenced by other factors than quantity of instruction.

METHODOLOGY

During the Summer of 1976 a study was begun to do research achievement outcomes of students in schools participating in the CMI effort.

The population for this study consisted of all students in the nine elementary schools exposed to the Sherman math curriculum during their fifth grade year of 1975-76, 483 in number. The sample consisted of all fifth grade students in the nine elementary schools using Sherman math who had remained at the same elementary school for the past three years, 342 in number. Thus, 70% of the students were present from Grade 3 through Grade 5. The motivation for selecting the sample in this manner was to control for the possible effects due to student mobility.[2] An additional benefit afforded by this selection procedure was that we could then focus on all students who had been exposed to the Sherman Math curriculum for the previous two years, since Sherman math (and CMI) is offered during the fourth and fifth grade years.

The achievement measures used in this study were student mathematics results from the Sequential Tests of Educational Progress (STEP). These tests were administered to students during the 1975-76 academic year at the beginning and end of their fifth grade experience. Using these tests as criteria, we could then examine students performance in mathematics during their fifth grade year. The Basic Concepts test was administered at both the beginning (September, 1975) and end (May, 1976) of the 1975-76 academic year. The Computation test was administered only once--at the end of the fifth grade year. Thus, a period of eight months spanned the testing of students entering and leaving Grade 5.

Research Question I

Two research questions were addressed by this study. The second question is discussed in detail in the next section. The first question asked if there were differences between the achievement outcomes for students in the six schools having MICA and the three manual schools. Stated formally, this question asked:

QUESTION I: IS THERE ANY DIFFERENCE BETWEEN ACHIEVEMENT OUTCOMES FOR STUDENTS IN SCHOOLS HAVING MICA COMPARED TO MANUAL SCHOOLS?

Two comparison groups were defined by this question: the 267 students in the six schools with MICA and the 75 students in the three manual schools. For further information on specific composition by school, the reader is referred to Table 1 presented earlier in the paper.

[2]Student mobility affects some school's achievement scores positively, others negatively. In other words, better students move into those communities served by some schools, poorer students move into communities served by other schools.

Descriptive information for answering this question was obtained by computing mean and standard deviation values for both groups. These measures were determined for the two Spring assessments (Basic Concepts and Computation tests) as well as the Fall assessment (Basic Concept test).

A meaningful statistical analysis for student performance must take into account both entry (pre) and ending (post) levels of performance. For this study, a student's "entry" score was his or her Grade 5 Fall assessment result; his or her "ending" score was the corresponding Grade 5 Spring assessment result. As the Computation test was administered only once in the Spring, results from the Basic Concepts test, which was given twice, were used.

A difference score for each student was computed by subtracting his or her Fall Basic Concepts test score from the corresponding Spring score. As expected for nearly every student this score was positive, reflecting a gain in mathematics achievement.

A statistical comparison of the difference scores for both groups was made using Students t-statistic (see Hays, 1973). A statistical difference ($p < .01$) between group means indicates achievement differences between groups exist. The nature of such differences could then be explored by examining the magnitude of differences.

Research Question II

The first research question compared achievement results for students in schools with MICA with results from students in manual schools. This question then was very specific in nature; it was posed in response to inquiry from the local Board of Education.

The second research question, on the other hand, was concerned with possible differences in achievement results among all nine schools participating in the CMI effort. This question then was general in scope; it was posed by members of the MICA evaluation staff who wished to research the issue of how much an effect (if any at all) that implementing a CMI program had on student achievement for participating elementary schools.

The motivation behind carrying out this research was to establish whether or not factors previously identfied as impacting implementation of a CMI system actually influenced student performance. (For more information on the specific factors, the reader is referred to Table 1.) As stated earlier, we had good reason to believe that the implementation of a CMI program was accomplished without major problems in nearly all schools and thus would have little influence on student performance. This question then provided a means for empirically validating this claim.

Stated formally, Research Question II is as follows:

QUESTION II: IS THERE ANY DIFFERENCE AMONG SPRING ACHIEVEMENT PATTERNS FOR SCHOOLS INVOLVED IN IMPLEMENTING CMI AFTER ADJUSTMENT HAS BEEN MADE FOR STARTING ACHIEVEMENT LEVELS?

In order to address the issues contained in this question properly, it was necessary to adjust "ending" or Spring assessment values according to the "starting" values in the Fall. The same issue was resolved in Question I by computing difference scores for the two groups under consideration. For this question, however, nine groups (each of the schools) were being considered.

Two techniques that are often considered appropariate in such situations are covariance analysis and blocking (Elashoff, 1969). For this study, covariance analysis appeared to be preferable due to the difficulty of establishing meaningful blocking levels across all nine schools. A further discussion of this issue is given by footnote 3, presented in the Appendix.

Critical Assumptions for ANCOVA:

Before covariate analyses or analysis of covariance (ANCOVA) can be applied as a valid statistical technique, certain critical assumptions must be met. Assumptions critical to the underlying rationale for the use of covariance analysis are that assignment to treatments has been at random, that the covariate is independent of treatments and that there is no treatment - slope interaction (Elashoff, 1969). A discussion of how the design of this study met these assumptions is given in the Appendix.

For now, it is sufficient to say that two of the three crucial assumptions are definitely met for this study. The assumptions of randomization of students to treatment groups was apparently violated. Kirk (1969) points out that ANCOVA can be useful in situations such as addressed by this question provided caution is taken in interpreting results. In particular, in such cases, we can be sure that the covariate adjustment has removed all bias.

ANCOVA Hypotheses

ANCOVA was applied to the fifth grade mathematics achievement results for two different situations. In each case, the dependent measure was the student's Spring test score; i.e., for Case 1, the dependent measure was the student's results on the Basic Concepts test and for Case 2 the student's results on the Computation test. The same covariate was used in both cases: namely, the student's score on the Fall Assessment of the Basic Concepts test. The independent variable under study was the impact of implementing CMI as it effected each school.

More formally we were interested in testing the following hypotheses presented here in null form:

H_0: CASE 1: There is no significant difference among adjusted means scores for the nine schools ($p < .01$) participating in the CMI effort. The dependent measure of interest is the student's score on the Spring Math Basic Concepts Test and the covariate is the student's score on the Fall test of Math Basic Concepts.

H_0: CASE 2: There is no significant difference among adjusted mean scores for the nine schools ($p < .01$) participating in the CMI effort. The dependent measure of interest is the student's score on the Spring Computation test and the covariate is the student's score on the Fall Math Basic Concepts test.

Should the results reveal significant differences among mean scores, implementing CMI apparently had an effect on student achievement. The nature of this effect could be further explained by employing post hoc comparisons in order to ascertain just where differences lie.

RESULTS

QUESTION I: IS THERE ANY DIFFERENCE BETWEEN ACHIEVEMENT OUTCOMES FOR SCHOOLS HAVING MICA COMPARED TO MANUAL SCHOOLS?

This question was addressed by considering the achievement outcomes for two groups: the 267 students in the six MICA schools and for the 75 students in the three manual schools. Mean and standard deviation values computed for both groups on the one Fall measure (Basic Concepts test) and two Spring measures (Basic Concepts and Computation test) are presented in Table 2 below. These results suggest very little difference existed between the two groups.

The results on the Spring assessment of the Computation test revealed a mean score of 41.0 for the MICA student group and a slightly lower mean score of 40.1 for the manual group. The standard deviation values were very similar and were 10.8 and 10.9 for the MICA and manual group respectively.

TABLE 2
Descriptive Statistics for Students in Elementary Schools Having MICA or Manual Schools
(Grade 5, 1975-76 Academic Year)

Standardized test / Nine Schools Having Sherman Math		STEP test of Basic Concepts				STEP test of Mathematics Computation	
		Fall		Spring		Spring	
	N	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Schools Having MICA (six schools)	267	27.3	8.6	32.4	9.2	41.0	16.8
Manual Schools (three schools)	75	27.1	7.8	32.4	8.8	40.1	10.9

The results for the Basic Concepts test indicated essentially no difference between Fall (or starting) mean values and Spring (or ending) values. Students in schools having MICA began Grade 5 with a slightly higher mean score (27.3) than students in manual schools whose mean score was 27.1. Mean scores for both groups were identical for the Spring testing with a value of 32.4 being recorded.

A t-test based on the difference scores on the Basic Concepts test for students in each group revealed no significant differences ($p < .01$) between groups.

Thus the results strongly suggest there was no significant difference between achievement outcomes for students in schools having MICA and for students in manual schools.

QUESTION II: IS THERE ANY DIFFERENCE AMONG SPRING ACHIEVEMENT PATTERNS FOR SCHOOLS INVOLVED IN IMPLEMENTING CMI AFTER ADJUSTMENT HAS BEEN MADE FOR STARTING ACHIEVEMENT LEVELS?

This question was addressed by application of analysis of covariance, where the student's Fall assessment score served as covariate and the student's Spring assessment scores were used as dependent variables. Two cases were considered, one for each dependent variable. For Case 1 the dependent variable was the student's Spring Basic Concepts test score; for Case 2, the dependent variable was the student's Spring Computation test score.

The disappointing results revealed F-statistics whose value was less than 1. The F-statistics reflecting the degree of difference among mean scores for Case 1 was .86 and .97 for Case 2. The ANCOVA tables for Cases 1 and 2 are presented in Tables 3 and 4 as shown below. Mean and standard deviation values for each school on all three tests are given in the Appendix.

F-ratios less than 1 generally indicate that the statistical analysis is suspect. Hays (1973) suggests that such a condition results when randomization has not been successful. Thus, it appears that Question II cannot be addressed employing the technique of analysis of covariance.

Table 3: ANCOVA Table for Case 1

Dependent measure: STEP Test of Mathematics Basic Concepts, Spring Assessment
Covariate: STEP Test of Mathematics Basic Concepts, Fall Assessment

ANCOVA Table

Source	Degrees of Freedom	S.S.	M.S.	F
Among Schools	8	139.71	17.46	.86
Error	332	6704.52	20.19	
Equality of Slopes	8	115.8	19.49	.96
Error	324	6548.63	20.21	

Table 4: ANCOVA Table for Case 2

Dependent measure: STEP Test of Mathematics Computation, Spring Assessment
Covariate: STEP Test of Mathematics Basic Concepts, Fall Assessment

ANCOVA Table

Source	Degrees of Freedom	S.S.	M.S.	F
Among Schools	8	372.16	46.5	.97
Error	332	15991.24	48.17	
Equality of Slopes	8	279.27	34.91	.72
Error	324	15711.98	48.49	

LIMITATIONS AND IMPLICATIONS

Listed below are some of the limitations of this study which the reader should keep in mind while reviewing the findings presented. The first set of limitations are specific to Research Question I, which examined differences between achievement results for students in schools with MICA and for students in manual schools.

1. The purpose of Computer Managed Instruction (CMI) is to facilitate individualization of instruction in a continuous progress setting by relieving the teachers' clerical burden and freeing up more of their time to directly interact with students. The computer, when used in this manner, can then be seen as directly affecting the teacher, but only indirectly affecting the student. This study examined the possible effect of a CMI project (MICA) on student achievement. It is unclear just how conclusive the results of such a study can be.

2. Educational innovations such as CMI often take several years to be assimilated into or rejected by the educational community. It might very well be that the full impact of a CMI project such as MICA has yet to be realized.

3. The Sherman Math curriculum (and CMI) was used for students in both the fourth and fifth grades. This study dealt with only the impact of the curriculum (and CMI) for students during their fifth grade experience. Future studies should research performance at the fourth grade level.

4. There were possible differences among schools. [illegible] differences would include the attitude and ability of the teaching staff, the overall climate of the school, and the environment of the neighborhood in which the school is located.

5. Difference scores, which are notably unreliable (Lord and Novick, 1969), were used to compare achievement results between students in MICA schools and manual schools using a t-statistic. This procedure, however, appeared to be the best procedure available for answering the question posed.

6. The results of this study are only generalizable to students who have received their education in the Madison schools while remaining in the same elementary school. Mobility patterns vary considerably among schools, depending primarily on the characteristics of the community in which the school is located.

The following limitations and implications are relevant to Research Question II. This question was not properly answered because the results of the covariance analysis indicated the procedure was not appropriate for the data under consideration. A forewarning of this severe limitation was given when the critical assumptions underlying ANCOVA were examined.

The use of intact groups creates interpretation difficulties that are not present when the random assignment is used in forming the experimental groups. This was the case for the results of Question II, where the recorded F-ratios from ANCOVA results were all less than 1. Hays (1973) suggests that F-ratios whose values are less than 1 often result when randomization has not been successfully accomplished. Further discussing this limitation Kirk (1969) states:

> Even when analysis of covariance is skillfully used, we can never be certain that some variable that has been overlooked will not bias the evaluation of the experiment. This problem is absent in properly randomized experiments because the effects of all uncontrolled variables are distributed among groups in such a way they can be taken into account in the test of significance. The use of intact groups removes this safeguard. p. 456.

Alternative Approaches

Given that ANCOVA is not appropriate for addressing this question, one may ask if there is another statistical technique that is appropriate. In response, several other techniques were considered including blocking and the analysis of variance (ANOVA) of difference scores. These techniques, like ANCOVA, appear to have inherent weaknesses however.

Establishing meaningful blocking levels proved to be administratively impossible due to the differing ranges in test score values recorded for each of the nine schools.

A limitation stated for Question I was that difference scores tend to be unreliable (Lord and Novick, 1968). This limitation is much more profound and far-reaching for Research Question II--making confidence in the accuracy of results very doubtful if subsequent analyses were performed using difference scores.

An alternative and less sophisticated approach involves applying a one-way ANCOVA to each of the three achievement measures recorded for each. This analysis would then provide information specific to each assessment of each test. Subsequent application of ANCOVA to Spring assessment results revealed significant differences ($p < .01$) existed among schools on both the Basic Concepts and Computation tests. Statistical signficance was not attained, however, when ANCOVA was applied to Fall testing scores on the Basic Concepts test.

Some readers may question our rationale for including the research involved with Question II--especially in light of the fact that the question was never really answered. It is our contention as researchers, however, that we learn from our failures as well as our successes. Other researchers, for example, could have encountered similar circumstances and resolved them in an alternative manner. Our approach could then stimulate an alternative direction to be followed. Or perhaps our conceptual approach to the problem will provide insight to researchers who study similar problems in the future. We hope that in sharing our failures as well as our successes we can contribute to the accumulating body of knowledge in educational research.

SUMMARY

This paper presented a brief history of the development of Computer Managed Instruction (CMI). The focus of this paper has been on the development and subsequent evaluation of the CMI effort located in the Madison Metropolitan School District in Madison, Wisconsin. This CMI effort included about 900 fourth and fifth grade students in nine elementary schools all having the same individualized curriculum, Sherman math. Six of the schools used the computer program supporting the CMI effort, Management of Instruction with Computer Assistance (MICA), during the 1975-76 academic year. The remaining three schools used a manual system.

A summary of program evaluation results for this CMI effort was presented. These results revealed that the MICA system was effective in relieving the teachers of clerical burdens and providing them with useful information--thus facilitating the process of individualization of instruction. The findings furthermore indicated that the quality of instruction provided in the nine schools was apparently quite satisfactory. A final finding was that schools underwent few changes in order to implement CMI.

In June of 1976 these encouraging results were presented to the Madison Board of Education in hopes of receiving future funding for the CMI effort. Before making any commitment, the Board requested that the issues of program cost and program effect on student mathematics achievement be researched.

As cost evaluation of the MICA program revealed that adoption of the program into the school system would result in significant cost/student reductions over a ten year period.

Attempting to assess the effect of CMI on student achievement posed a problem of considerable conceptual difficulty. Many factors influence student achievement to a greater extent than CMI, in fact, CMI affects student performance only in an indirect manner. An efficient CMI system directly affects the teacher by relieving clerical burdens and providing useful information, therefore enriching the instructional milieu. The classroom environment, however, is only one of many factors influencing student performance.

Despite this conceptual limitation, it was necessary to research the relationship of student achievement and CMI and a study was begun in the Summer of 1976. Only fifth grade students were included in this study. This study focused on two questions. The first question asked if there were differences in achievement patterns for students in schools with the MICA software in contrast to students in manual schools. As expected, the results revealed no significant differences between groups.

The purpose of the second question was to find out if implementing a CMI program affected a school's student performance. The fact that students were not randomly assigned to schools severely limited application of commonly used inferential statistical techniques, resulting in the question not being properly addressed.

FUTURE DIRECTIONS

The results for the studies of cost effectiveness and achievement outcomes as well as the results for the program evaluation previously completed were presented to the Board of Education in August of 1976. The purpose of this presentation was to request funding for the second semester of the 1976-77 academic year.

One month later the Board gave their decision which was not to become involved in supporting the CMI effort. The primary reason given for this decision was that no appreciable gains in student achievement were observed.

The Madison CMI effort was discontinued January, 1977.

It is beyond the scope of this paper to discuss the many factors influencing this decision or to pose strategies which would have been employed to change it.

The distressing fact is that educational computing in the form of CMI is not present in Madison, Wisconsin, public schools due to lack of local funding. Unfortunately, such decisions are becoming alarmingly common-place in school districts across the United States. In discussing this national trend in a recent article of Computer Decisions, Harold Peters laments that, "Despite a rise in performance and a drop in prices, computers are being kept out of the classroom by inadequate funding." (p. 42).

If we want our educational system to meet the needs of future generations--generations which will very likely be very dependent on computer technology--it is necessary to begin employing educational computing in today's classrooms. As pointed out by Peters (1976) educators of today must realize:

> The short-term benefits of increased investment is what is now a marginal market will be hard to measure. The long-range implications, however, are clear. Investment in educational computing today is quite literally, an investment in our future. (Emphasis supplied) (p. 46).

BIBLIOGRAPHY

Baker, F. B. "Computer Based Instruction Management Systems: A first look." Review of Educational Research, February, 1971, 51-70.

Baker, F. B. "CMI: Theory and Practice. Educational Technology Press, In Press, 1977.

Bolton, F., and J. Clark. "Computer Managed Instruction." Journal of Educational Data Processing, 1973, 10 (4), 5-9.

Chapin, J. D. The Cost Effectiveness of Computer Managed Instruction A Summary. Computer Managed Instruction Project funded through Title III, E.S.E.A. Madison Metropolitan School District, Report #6, June, 1976.

Chapin, J. D., Heggland, T., and C. Kurtz. Computer Managed Instruction Impact on Classroom Efficiency, Computer Managed Instruction Project funded through Title III, E.S.E.A. Madison Metropolitan School District, Report #9, August, 1976.

Chapin, J. D., and A. L. Roecks. An Evaluation of the Development of Computer Managed Instruction at the Madison Public Schools. Paper presented at the annual meeting of the Wisconsin Educational Research Association held in Madison, Wisconsin, December, 1975.

Cooley, W. W. and R. Glaser. An Information and Management System for Individually prescribed instruction. Working paper No. 44. Pittsburgh: University of Pittsburgh Research and Development Center, 1968.

Cox, D. R. "The Use of a Concomitant Variable in Selecting an Experimental Design." Biometrika 44:150-158, June, 1957.

Elashoff, J. D. "Analyses of Covariance: A Delicate Instrument." AERJ, 1969, 6, 383-401.

Glaser, R. "Adapting the Elementary School Curriculum to Individual Performance." In, Proceedings of the 1967 Invitational Conference on Testing Problems. Princeton, N. J.: Educational Testing Service, 1968.

Hays, W. L. Statistics for the Social Sciences. New York: Holt Rinehart, and Winston, Inc. 1973.

Harnischfeger, A. and D. Wiley. "Achievement Test Scores Drop. So What?" Educational Researcher, March 1976, 5-13.

Lekan, H. A. 1971 Index to Computer Assisted Instruction. Milwaukee: University of Wisconsin, Instructional Media Laboratory, 1971.

Lippey, G. Computer Managed Instruction: Some Strategies Considerations. IBM 160293, IBM San Jose, 1973, 1-9.

Lord, F. M. and M. Novick. Statistical Theories of Mental Test Scores. Reading, Mass: Addison-Wesley Publishing Co., 1968.

Patterson, E. An Evaluation of Project Plan. Computer Managed Individualized Learning Project funded through Title III, E.S.E.A. St. Louis Public Schools, August 1974.

Patterson, E. and G. Johnson. Don't Program the World - Plan It. A paper presented at the 12th Annual DSPI Conference, Miami Beach, April, 1974, 1-17.

Peters, H. W. "The Electronic Aristotle." Computer Decisions, July, 1976, 42-46.

Rockhart, I. and M. S. Morton. Computers and the Learning Process In Higher Education, McGraw Hill, 1975.

Roecks, A. L. A Brief Look at the Effects of Sherman Math on Mathematics Achievement. Computer Managed Instruction Project funded through Title III, E.S.E.A. Madison Metropolitan School District, Report #3, April, 1976 (a).

Roecks, A. L. An Assessment of the Attitudinal Impact of Computer Managed Instruction on Students and Teachers. Computer Managed Instruction Project funded through Title III, E.S.E.A. Madison Metropolitan School District, Report #5, May, 1976 (b).

Roecks, A. L. Parents Perceptions of Sherman Math, Individualization, and Computer Managed Instruction. Computer Managed Instruction Project funded through Title III, E.S.E.A. Madison Metropolitan School District, Report #7, June, 1976 (c).

Roecks, A. L., Kurtz, D. and T. Heggland. How Students of Differing Achievement Levels Use Their Classroom Time. Computer Managed Instruction Project funded through Title III, E.S.E.A. Madison Metropolitan School District, Report #10, December, 1976.

Spuck, D. W., Hunter, S. N., Owen, S. P. and S. L. Belt. Computer Management of Individualized Instruction. Theoretical Paper No. 55. Madison: Wisconsin Research and Development Center for Cognitive Learning, 1975, 1-38.

Silberman, H. F. Design Objective of the Instructional Management System. SP 3038/001/00, Santa Monica, California. System Development Corporation, 1968.

Wiley, L. W., Jr. Computers and Instructional Productivity: A Professional Report, Bethesda: IBM, May, 1975, 1-30.

Winer, B. J. Statistical Principles in Experimental Design. McGraw-Hill, New York, 1971.

APPENDIX

1. Crucial assumptions for ANCOVA
2. Tables of descriptive statistics

CRITICAL ASSUMPTIONS FOR ANCOVA

Several assumptions must be met for the analysis of covariance to be a valid statistical technique. Assumptions crucial to the underlying rationale for the use of covariance analysis are that assignment to treatments has been at random, that the covariate is independent of treatments and that there is no treatment slope interaction (Elashoff, 1969). A discussion of how well the design of this study for Research Question II met these assumptions is contained in the remainder of this Appendix.

Randomization:

The analysis of covariance is based on the assumption that individuals were assigned randomly and that all groups were treated exactly the same except for treatments. Covariance adjustment procedures, however, are often recommended for reducing bias due to the covariate in studies where the experimenter must work with intact groups. Winer (1971) indicates that covariance analysis can indeed be useful where assignment to groups is not random but must be used with caution--particularly if initial biases on the covariate can be controlled directly by use of blocking.[3]

In this study, intact groups were considered as students were not randomly assigned to schools. Treatments in the form of each school's involvement with CMI appeared to be assigned at random. With the exception of the Sherman Elementary School whose staff provided the initial developmental leadership, the exposure of the remaining eight schools to CMI was dictated by chance occurrence. Elashoff (1969) states that covariate analyses in such cases should be approached with caution, however.

---

[3]Blocking was not used for this study for both practical and methodological reasons. Practically, it would have been difficult to construct homogeneous blocks given the wide range of test score distributions of the nine schools. Methodologically, covariance analyses appeared to be preferable in terms of the overall precision provided. In comparing the precision of blocking versus covariance, Cox, (1957) concluded that if the correlation coefficient ρ (between the covariate and dependent measure) is less than 0.4 blocking is preferable, if ρ is greater than 0.6 covariance is somewhat better and if $\rho > 0.8$ covariance analysis is appreciably better. In the two cases identified for this study the correlation coefficients were 0.84 and 0.76 respectively; thus, covariance appeared to be preferable to blocking.

Thus, it appears that the assumption of randomization has been violated in terms of random assignment of students to schools, resulting in intact groups (schools) being considered. ANCOVA however, can be useful in such situations but the results must be interpreted with caution. In particular, we can never be sure that the covariance adjustment has removed all bias; in fact, some bias may still be present from a disturbing variable which was overlooked.

Covariate is Independent of Treatment:

A basic postulate underlying ANCOVA is that the covariate is statistically independent of the treatment effect. To achieve statistical independence, the covariate should be measured prior to the administration of treatments (which it was) and treatments should be assigned to groups at random (as discussed in the preceding section). Elashoff (1969) suggests that in analysis of variance of the covariate (Fall Basic Concepts test) may be useful as an indication of whether or not treatments are affecting the covariate. An analysis of variance revealed that there was no significant differences ($p < .01$) among mean scores for the nine schools on the Fall Basic Concepts test.

No Treatment - Slope Interaction:

The standard covariance analysis procedure rests on the assumption that the regression of the dependent measure on the covariate was linear and that the slope is the same for all treatment groups. Application of a general regression program revealed that less than a one per cent increase unexplained sum of squares resulted with the addition of a quadratic and/or cubic term. Hence, the assumption of linearity was apparently met.

The test of no-treatment-slope interaction is performed during ANCOVA. The results of this test have been formally presented in the results section of the paper in Tables 3 and 4. For purposes of explanation, it is noted here that this assumption was not violated for either Case 1 or Case 2.

In summary, it appears that two crucial assumptions were met: namely, that the covariate is independent of the treatment and that there was no treatment slope interaction. The third crucial assumption involving randomization of students to treatment groups was violated; ANCOVA, however, can be useful in such instances provided caution is taken in interpreting results. In particular, in such cases, we can never be sure that the covariate adjustment has removed all bias.

Table 5

Mean and Standard Deviation Values on Achievement Tests for Nine Schools Participating in the CMI Effort (1975-76 Academic Year, Grade 5)

Elementary School (Achievement Test →)		STEP Test of Mathematics Basic Concepts				STEP Test of Mathematics Computation	
		Fall Assessment		Spring Assessment		Spring Assessment	
	N	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Glendale	50	25.6	9.4	32.3	8.2	38.4	11.3
Muir	48	30.6	8.6	34.9	7.4	45.0	9.1
Sandburg	26	24.4	7.0	29.7	6.6	36.0	10.3
Schenk	50	25.5	7.9	30.8	8.2	39.9	10.4
Sherman	42	24.9	7.6	29.5	8.2	38.3	11.4
Thoreau	51	31.3	8.1	35.7	7.1	45.6	8.9
Emerson	14	27.0	7.1	31.9	8.3	40.9	8.7
Lapham	36	23.9	8.2	30.7	8.6	36.1	12.0
Spring Harbor	25	29.0	9.6	34.0	8.2	41.2	11.0

Table 6

Pearson Product Moment Correlation Coefficients For Students Remaining in Madison Public Schools From Grade 3 through Grade 5

(N = 342)

	Grade 5 Assessment (1975-76 Academic Year)	
	Spring Basic Concepts	Spring Computation
Fall Basic Concepts	.84	.76
Spring Basic Concepts		.80