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DOCUMENT RESUME

ED 309 611		EC 220 756

AUTHOR	McDermott, Paul A.; Stegemann, Jane Hessemer
TITLE	The Comparative Effects of Computer-Assisted Instruction of Motivation and Achievement of Learning Disabled and Nonlearning Disabled Students.
INSTITUTION	Pennsylvania Univ., Philadelphia.
SPONS AGENCY	Department of Education, Washington, DC.
PUB DATE	87
GRANT	G008530237
NOTE	99p.
PUB TYPE	Reports - Research/Technical (143)
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	*Computer Assisted Instruction; Drills (Practice); *Instructional Effectiveness; Intermediate Grades; *Learning Disabilities; *Mathematics Achievement; *Multiplication; Rewards; *Student Motivation; Teaching Methods; Underachievement

ABSTRACT

This study investigated the processes by which variation in format for presenting multiplication problems influenced children's motivation and achievement. The three multiplication drill and practice instructional methods were: (1) computer-assisted instruction (CAI) with a reward game, (2) computer-assisted instruction without a reward game, and (3) paper-and-pencil. A sample of 69 fourth-grade students was classified into one of two groups, labelled achiever or underachiever, and the students were randomly assigned to one of the three instructional methods. Results indicated that both achievement and motivation were related to instructional method. When motivation was defined as amount of time the student participated in the study, the two CAI groups were more motivated than the paper-and-pencil students. When achievement was defined as the number of multiplication problems completed correctly, the group of students using CAI without a reward game achieved more than the group using CAI with a reward game. When achievement was measured by pre- and post-achievement test comparison, there were no significant effects. There were no significant interactions between method of instruction and type of achiever. (JDD)

THE COMPARATIVE EFFECTS OF COMPUTER-ASSISTED INSTRUCTION ON MOTIVATION AND ACHIEVEMENT OF LEARNING DISABLED AND NONLEARNING DISABLED STUDENTS

Principal Investigator: Paul A. McDermott, Ph.D.

Student Investigator: Jane Hessemer Stegemann, Ph.D.

University of Pennsylvania

Presented to the U.S. Department of Education

in

1987

PERFORMANCE REPORT FOR GRANT NUMBER: G008530237
CODE OF FEDERAL DOMESTIC ASSISTANCE CATALOG NUMBER: 84.023B

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Statement of Problem

Computer usage in schools is becoming widespread, and it is considered to be an influential learning tool. However, there is controversy over effective usage. A paucity of empirical research exists concerning how computer-assisted instruction (CAI) drill and practice affects motivation and achievement of school children.

Procedures and Methods

This study investigated the processes by which variation in format for presenting multiplication problems (CAI versus paper-and-pencil) may influence children's motivation and achievement. A sample of 69 fourth-grade children was classified into one of two groups, labelled "achiever" or "underachiever." Group assignment was based on a comparison of each student's standard score on the mathematics subtest of the Comprehensive Tests of Basic Skills with that on the Test of

Cognitive Skills. For the purposes of this study, students were labelled "underachievers" because they were not classified by the school as learning disabled, although they met the definition as stated in this report (i.e., a significant discrepancy between predicted achievement and actual achievement). The students were randomly assigned to one of three instructional methods: (1) CAI multiplication drill and practice with a reward game (CAIm), (2) CAI multiplication drill and practice without a reward game (CAI), and (3) an equivalent multiplication paper-and-pencil drill and practice without a reward (Pap&pen). Motivation was defined as the number of problems attempted. Achievement was defined as the number of problems completed correctly. The instruction lasted for one month. Repeated measures analyses of covariance were performed on the achievement and motivation dependent variables. Achievement was measured also by a pretest and posttest comparison, using the pretest as a covariate.

Results

Results indicated that both achievement and motivation were related to instructional method. When motivation was defined as amount of time the student participated in the study, the CAI and CAIm students were more motivated than the Pap&pen students. When achievement was defined as the number of multiplication problems completed correctly, the CAI students achieved more than the CAIm students, followed by the Pap&pen students. When achievement was measured by pre- and post- achievement test comparison, there were no significant effects. There were no significant interactions between method of instruction and type of achiever.

Conclusions

This research suggests various approaches to further study the effect of CAI on motivation and achievement. In addition, computer technology needs to be integrated with sound curriculum theory of instruction in mathematics.

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CHAPTER I

Introduction

While the computer is a powerful tool, much controversy exists over its appropriate use with school-aged children. The purpose of the present study was to explore the comparative effectiveness of mathematics computer-assisted instruction (CAI) drill and practice versus paper-and-pencil drill and practice.

The effect of variation in instructional format on motivation and achievement in mathematics was investigated. Specifically, CAI with or without a game reward was compared with paper-and-pencil mathematics drill and practice. The interaction of ability level with instructional method was also measured.

In Lepper's (1985) discussion of CAI drill and practice versus embedded instruction in the context of an educational game, he speculates on the effects of such a strategy on motivation. This question, however, remains an empirical issue, one to which the "obvious" answer may be incorrect (Lepper, 1985). While researchers have speculated that motivational enrichment strategies, such as games, are expected to have positive effects (Lepper & Gilovich, 1982), there are no reports of an empirical test of this assumption.

The present study examined the following questions: Does CAI mathematics drill and practice increase motivation and achievement for school-aged children? Are students' motivation and achievement enhanced by employing special effects (a game to be played following a certain number of correct responses)? Is there a significant difference between the responses of achievers and underachievers to the various CAI formats? Is there an aptitude-treatment interaction (Cronbach & Snow, 1977)?

Computer-Assisted Instruction Defined

CAI is a teaching process that uses the computer to present instructional materials tailored for each student (Williamson & McCullough, 1983). Six types or modes of CAI have been described in the literature:

(1) Drill and Practice, which integrate and consolidate previously learned material via computer practice and are supplemental to regular instruction;

(2) Tutorial Programs, which assume the role of teacher and present the material in a programmed format;

(3) Games, which are designed to develop general problem-solving methods and strategies;

(4) Simulations, which attempt to model the underlying characteristics of a real phenomenon so that its properties can be studied;

(5) Problem-solving, which uses the computer to solve real-world problems; and

(6) Computer-Managed Instruction, which allows the teacher to use the computer as a tool in

diagnostic, prescriptive and evaluative tasks.
(Watkins & Webb, 1981).

What advantages might CAI provide for the education of children achieving below expectation? McDermott and Watkins (1983) have recounted the following relevant attributes of CAI: (a) frequent and immediate feedback; (b) individualized pacing and programming; (c) modularized and hierarchical curriculum; (d) mastery learning paradigm; (e) clarity of presentation; (f) motivation; (g) multi-sensory learning format; and (h) personalized instruction. Within the context of these attributes, in the following section the relationship between CAI and motivation is discussed.

Motivation

Children's motivation to learn is often taken for granted. The desire to learn is an intrinsic motive, one that finds both source and reward in its own exercise. But the will to learn can become a "problem" under specialized circumstances such as those of a school, where a curriculum is set, students confined, and a path fixed. "The problem exists not so much in learning itself, but in the fact that what the school imposes often fails to engage the natural energies that sustain spontaneous learning..." (Bruner, 1961, p. 127). Competence motivation implies a desire to achieve mastery of a task simply for its own sake (White, 1959; Stott & Albin, 1975). However, after repeated failure in school, the child may lose the desire to achieve due to a lack of a sense of effectiveness and mastery

(White, 1959).

In addition, it is well documented that American public schools value the analytical learning style, which emphasizes spoken and written language and content reflective of the lifestyle of white Protestants (Lee, 1986). On the other hand, Lee states that black children usually are proficient in the relational learning style, which emphasizes visual and audio stimuli. Relational learners fail in school far more often than analytical learners. Some children, especially those who have experienced repeated failure in school-related tasks, no longer expect that their efforts will lead to reward or success. They become no longer motivated to learn.

Motivation may be encouraged by instilling an expectancy of reward. This may involve the use of rather concrete reinforcements (e.g., more time at recess or a computer game) until some nominal learning has been accomplished (Malone, 1980, 1981; Malone & Lepper, 1986). Intrinsic reinforcements, such as personal satisfaction with a job well done, are also likely to motivate the child to perform better in school if a child believes the work is important (Ross, 1976). CAI can provide external reinforcement (via games), which may "hook" a child into learning again. When a child receives consistent positive feedback following successes with CAI drill and practice, a desire for mastery may be regained.

Some learning theorists argue that motivation for learning will evolve naturally in the context of a good relationship between the student and the teacher. However, Maehr (1978) noted that teachers often slot children into categories, much as adults are placed in positions or levels within social groups. With these categories come a set of expectations for the group's performance and actions. Often the group will work only toward insuring the realization of these minimal expectations. Effective teachers often facilitate learning by structuring the environment to make the child feel motivated to learn. This action is based on the assumption that the child's incentive is either to please the teacher or to win the teacher's praise and approval. However, children who have had negative experiences with teachers during the past may not care about pleasing that adult or about the teacher's approval. Approval from the teacher may serve as social reinforcement only after a positive relationship with a student has evolved. While an individual tutor may be able to accomplish this, it can take a great deal of time.

Psychologists frequently talk to teachers about children who are not achieving and make observations describing the relationship between a child's negative self-image and social and/or economic conditions. These children may be unwilling to take risks in academic and social situations. They may doubt their ability to succeed, and therefore they may not expect to succeed (Ross, 1976; Griswold, 1984). Children with this type of negative feeling usually do not work up to capacity.

Likewise, their affective state is seldom discussed within the context of traditional curriculum theory and microcomputers and education. Hofmann (1983) proposes that judicious use of well-written microcomputer software, designed to create an exciting educational environment, may be motivating for children who have been "turned off" to learning.

The use of CAI can be beneficial for several reasons. First, the microcomputer is "user-friendly". It allows students to learn in a nonthreatening environment, where mistakes may be made without the embarrassment of having to face the reactions of teachers and students. Additionally, CAI can provide colorful graphic displays to catch a student's attention, encourage participation, and sustain interest (Gagne, 1974).

Second, the computer gives a student undivided attention; it waits while the child works, and there is no pressure to complete a task in a prescribed time period. Unlike a teacher or tutor, the computer does not respond in an emotional fashion, nor does it mind repeating itself several times (Schiffman, Tobin & Buchanan, 1982). The computer is unbiased and nonjudgmental.

Third, reinforcements are immediate rather than delayed until the teacher can grade the work. Drill and practice can become exciting through the use of animation, sound effects, and game-playing situations. Some CAI drill and practice also eliminates the debilitating effect of making repeated errors without knowing it. CAI software, such as the "Math Machine", provides feedback in three modalities: a printed personalized comment, colorful graphic display, and a unique but nondistracting sound. When added to the CAI situation, positive feedback increases the likelihood of the frequency and correctness with which a student will respond in the future (Watkins & Webb, 1981; Malone 1980, 1981). Positive feedback may also enhance the self-esteem of children who have experienced repeated failure in school. According to Ross (1976), raising a student's general confidence level can be a tremendous contribution to the ability to learn.

In summary, research studies reviewed suggest that CAI can be effective with low achieving students. However, such studies generally do not consider the more fundamental question of how CAI improves instruction and therefore motivation and achievement. To investigate these questions, this study explored how variation in instructional method affects achievers' and underachievers' motivation and achievement.

Chapter II

Review of Literature

Many researchers have studied the effects of CAI on the achievement of special education and regular education students (Burns & Bozeman, 1981; Hartley, 1978; Kulik, Kulik & Bangert-Drowns, 1985; Martin, 1973; Suppes, 1972). There are, however, relatively few studies of the effect of CAI on motivation of these two groups of students (Kleiman, Humphrey & Lindsay, 1981; Schiffman, Tobin & Buchanan, 1982; White, 1983; MacArthur, 1986).

All of the research discussed below involves a review of achievement or motivational changes as a function of CAI implementation. The studies of the effect of CAI on achievement are divided into two major categories: (a) qualitative or observational and (b) quantitative. The motivation studies are all qualitative/observational; there are no quantitative studies to date. The studies reviewed can be categorized into one or more of the following: (a) comparison of regular education and special education children with CAI, (b) comparison of CAI to regular instruction with special education children, (c) use as a dependent variable of either achievement or motivation, and (d) use of drill and practice CAI or tutorial CAI. Many studies in this review have limitations which render comparisons of studies and interpretations difficult.

Limitations of Prior Research

While some researchers have investigated the effects of CAI on motivation and achievement, many of the research designs lack empirical controls and information about the extent to which CAI is responsible for the results obtained.

Definition and descriptive problems. In several of the studies reviewed, the criteria used are not clearly defined (Garfield, 1978). For example, several studies lacked criteria for the definition of low ability (Forman, 1972; Suppes, 1972; Martin, 1973; Niemac & Walberg, 1985). In addition, adequate descriptions of the samples were missing, involving variables such as gender, race, age, and prior mathematics and/or reading skill development. Inconsistent definitions across studies make cross-comparison and interpretation difficult (Hartley, 1978).

Sampling problems. Many problems in the research arise from sampling difficulties. Inadequate sample sizes are common, most being quite small. Small sample size is often unavoidable because there are fewer children with handicaps at any one academic or social skill level than there are in regular samples (Schiffman, et al., 1982). As a consequence, certain types of control groups may not have been used. For example, the teacher may be reluctant to withhold CAI from a student who needs a great deal of remedial work.

Regression toward the mean. Using a special education population results in another more difficult problem. A statistical phenomenon, regression toward the mean, can be a rival hypothesis. It suggests that the experimental condition was what created the change. This is a common problem when measuring achievement (Suppes, 1972; Chiang, 1978). For example, a group of regular education students are chosen for a special experimental treatment because they do poorly on an achievement test (the pretest). Following treatment, a test using a parallel form of the test (posttest) is administered. The posttest scores will almost surely average higher than the pretest scores. "This dependable result is not due to any genuine effect of x, and test-retest practice effect. It is rather a tautological aspect of the imperfect correlation between the pretest and posttest" (Stanley & Campbell, 1963, p. 10). Regression effects are inevitable accompaniments of imperfect test-retest correlation of low achieving groups such as the students used in many studies. Consequently, the use of gain scores is dubious. A feasible remedy for the problem is to use a posttest analysis, which uses the pretest as the covariate.

Time variation problems. While researchers have adequately explained the modes of CAI used in their studies, (i.e., drill and practice) most have not indicated the amount of time that the children spent on CAI (Forman, 1982; Thorkildsen, Allard & Reid, 1983). This varies greatly and could, in part, account for discrepancies among the results. For example, one public school may have two computers for the entire school. Due to demand from other students, low achieving students may use drill and practice CAI only 15 minutes per month. However, in another situation, each student may be able to spend 15 minutes per day on drill and practice. These situations must be defined, to allow accurate results and interpretations. Time with CAI should be known and used as a covariate.

Equivalent materials problems. The researcher must consider whether materials used for different groups are equivalent. Some studies compare CAI and traditional instruction, but most of them do not indicate whether the materials used for the groups were similar (Visonhaler & Bass, 1972; Lysiak & Evans, 1976). Therefore, large differences in instructional materials between groups could contribute to the identified group differences, thereby confounding the results. Thus, within a study it is important to have equivalent materials.

Novelty effect problems. Another difficulty in comparing traditional instruction with CAI is the novelty effect (White, 1983; Lysiak & Evans, 1976). If the student has not had experience with computers, a student may feel "special," which may influence his or her performance (Clark, 1985). This problem exists particularly with low-achieving children who generally do not receive CAI, for it is stressed that individualized traditional instruction is best for children needing special help. Future research designs must more accurately represent the true situation in the schools.

McDermott and Watkins (1983) note that combinations of computerized and conventional remedial instruction may work with problem learners and that success will vary as a function of the severity of the learning disorders and differential styles of learning. They report that "future research is best directed to test the efficacy of various combinations of computerized and conventional remedial instruction with learning-impaired children" (p.86). In addition, the results must be related to the severity and duration of impairment, motivation levels, and learning styles. In summary, limitations of prior research may have contributed to the contradictory results found in both the qualitative and quantitative studies reviewed.

CAI and Achievement: Qualitative Approach

In qualitative studies, the data were collected by informal means (i.e., anecdotal records, general reviews of studies). For example, Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975) reviewed literature including studies of computer-based drills and practice, tutorials, and simulations carried out in elementary schools, high schools, and colleges. Ten of 27 studies reported findings from elementary schools with CAI having positive effects.

Hallworth and Brebner (1980) recommended that students who have failed to learn in the regular environment and those who feel inadequate and inferior will benefit most from the "patience" and repetitiveness of the computer.

Forman (1982) drew the following conclusions from her review of many studies of regular education and special education students:

(1) The use of CAI either improved learning or showed no difference when compared to traditional classroom approaches.

(2) When CAI and traditional instruction were compared, equal or better achievement using CAI was obtained in less time.

(3) Tutorial and drill modes seemed to be more effective for low-ability students than for middle or high ability students.

(4) Many reluctant learners became active and interested learners when involved in computer supported programs.

Thorkildsen et al. (1983) used an interactive video disc CAI with various special education groups including: (a) elderly, mentally retarded, (b) elementary age severe to moderate mentally retarded, (c) all age severe to moderately mentally retarded, (d) elementary-age learning disabled, and (e) the mildly mentally retarded. These researchers did not use an empirical approach and therefore their study lacked statistical analyses. However, anecdotal reports concluded that the system was most effective with learning disabled and mildly mentally retarded students.

CAI and Achievement: Quantitative Approach

Quantitative studies of CAI and achievement reported in this review used statistical analyses to manipulate data and determine relationships among variables. In addition, meta-analyses were used in several studies reviewed. Meta-analysis involves a statistical summary of many variables in many studies.

Meta-analytic research by Hartley (1978) focused on CAI drill and practice and tutorials in elementary and secondary mathematics analyzing 22 studies. A majority of the studies included grades one to eight. The average effect of CAI with grades one to eight was to raise mathematics achievement scores by .42 standard deviations.

Burns and Bozeman (1981) used meta-analysis to analyze 40 studies of drill and practice or tutorial CAI in elementary and secondary mathematics. They drew the following conclusions:

(1) A mathematics instructional program supplemented with CAI was significantly more effective in fostering student achievement, than was a program using only traditional instructional methods. The average effect of CAI in elementary grades was to raise arithmetic achievement by .37 standard deviations.

(2) CAI drill and practice programs were significantly more effective in promoting increased student achievement at both elementary and secondary instructional levels, and among highly achieving and disadvantaged students as well as among students whose distinct ability

levels had not been differentiated. The achievement of average students was not significantly enhanced by supplementary drill and practice CAI. (p. 37)

In Kulik, Kulik, and Bangert-Drown's (1985) meta-analytic study, they concluded that, in each of 28 studies of achievement, students from the CAI class received better examination scores. The authors stated that CAI appeared to have the strongest effects in elementary schools. Like other meta-analyses carried out in recent years, this one did not find strong relations between dependent variables and outcomes.

In a meta-analysis of 48 separate studies of elementary school CAI, Niemac and Walberg (1985) summarized the following results: low achievers scored at a much higher rate using CAI than did high achievers, boys' achievement was approximately double that of girls, and drill and practice (as opposed to other CAI modes) produced the greatest differences in achievement.

Third-grade students from California and Mississippi whose normal instruction was supplemented with CAI gained, respectively, 2.28 and 2.03 grade levels in computational ability in one year (Suppes, 1972). In a similar study, with third- and fourth-grade students, Martin (1973) supplemented normal instruction with CAI. Both Suppes (1972) and Martin (1973) found CAI drill and practice to be more effective for low-ability students than for average or high-ability students.

A review of studies by Visonhaler and Bass (1972) indicated that for arithmetic, there was a significant advantage of CAI over traditional instruction.

In a review of the literature on the effectiveness of alternative instructional media, Jamison, Suppes and Wells (1974, p. 56) concluded, "when small amounts of CAI are used as a supplement to regular classroom instruction (as with elementary drill and practice programs), substantial evidence demonstrates that it leads to an improvement in achievement, particularly for slower students."

The effectiveness of the Computer Curriculum Corporation drill and practice mathematics and reading curriculum was confirmed by an evaluation of a compensatory program in the Fort Worth Independent School District. A total of 2,298 educationally deprived students in 12 Title I schools, grades three to seven, received ten minutes of daily practice in reading and mathematics. Lysiak and Evans (1976) listed the following significant results:

> (1) CAI was more effective at grade three in reading and mathematics than the control group.
>
> (2) The progress of CAI students through the curriculum was greater in mathematics than in reading.
>
> (3) Elementary mathematics CAI students performed better than resource teacher students. (p. 48)

The remainder of the studies reviewed included special education students and students needing special help via compensatory education. A more extensive study of special education students, half of whom were learning disabled, applied CAI lessons written by their teachers using ASSIST (Authoring System Supplementing Instruction Selected by Teachers) (Chiang, 1978). When pretest and posttest data were compared with that of matched control groups, the treatment group showed positive achievement gains in three-fourths of the cases.

In a five-year longitudinal study sponsored by the Educational Testing Service (ETS) and the Los Angeles Unified School District (LAUSD), CAI for compensatory education was found effective. Using students in grades one to six, ETS found that tests designed specifically to look at the impact of CAI showed greater effects than the average effect reported by Kulik (1985). Results on general standard tests, however, were not as uniformly favorable. Ragosta, Holland and Jamison (1981) indicated that CAI was found to be an effective learning aid over the long-term (at least one year) as well as the short-term.

Watkins & Webb's (1981) study indicated that learning disabled students, who received mathematics CAI in place of the usual special education mathematics, achieved significantly greater posttest scores than did students who received only traditional special education services.

Trifiletti (1984) evaluated the use of mathematics CAI with learning disabled children aged 9 to 15. Mid-year assessments using the KeyMath Arithmetic Test revealed that the group using the computer had significantly better results than the traditional instruction group. The number of mathematical skills mastered and fluency of problem-solving skills were higher with the computer group.

Despite the results favoring CAI, there have been contrary findings. We presently do not know the nature of the advantage that CAI has over traditional instruction. Advantages could be due to direct effects of CAI experiences, to novelty effects which decline over a period of years, to changes induced by CAI in teacher behavior (additional classroom drill), or to changes in student behavior (voluntary additional practice).

Sandals (1975) reported nonsignificant comparative gains for mathematics and spelling CAI with junior high school pupils who exhibited a wide variety of learning problems. Carman & Kosberg (1982), in a study of 40 emotionally handicapped students aged seven to fourteen, found that attention to task behavior was significantly higher using CAI. However, while no significant difference was found in mathematics achievement scores between the CAI and traditional instruction groups, the overall average mathematics grade increase was 3.3 grade levels.

McDermott and Watkins (1983) assessed the effectiveness of computerized instruction compared to traditional instruction methods with learning disabled students. When using standardized indices of performance in elementary mathematics and spelling, the effectiveness of computerized and conventional instruction with learning disabled students appeared the same. Based on these findings, McDermott and Watkins recommended (a) assignment of such students to CAI programs to improve motivation and reduce resistance to learning so often found among such children with learning problems, and (b) assignment of such students to special teachers whenever affiliative needs and social conditioning are deemed priorities.

For two years, Griswold (1984) studied mathematics and reading achievement and attitudes of 155 fourth- and fifth-graders who did or did not participate in CAI. Results indicate that the CAI groups' attitudes (independent of minority status, gender and achievement) were significantly different from those of the non-CAI group.

The achievement and attitudes of three groups of low-achieving students in grades six, seven, and eight were measured by Hawley (1984) over a three-week time period. While the gains made by students were significantly related to time using CAI, they were not sustained one month later when the second posttest was given.

Spivey (1985) compared a traditional instruction approach versus traditional instruction coupled with a computer game approach on teaching mathematics to first graders. The study lasted 20 days, and there were no significant differences between the experimental and control groups in mathematical gains. Both groups showed significant gains.

In a review of the literature, Lieber and Semmel (1985) found mixed achievement results when comparing CAI and traditional instruction. However, their overall impression was that the longer the study lasted, the fewer the achievement gains that were maintained. In other words, a rival hypothesis, the novelty effect, could have produced the achievement gains in many of the short-term studies.

Bass, Ries, and Sharp (1986) studied low-achieving students in grades four to six. The students were given supplementary CAI in reading and mathematics. Both the experimental and control groups showed significant gains in achievement.

In summary, the controlled studies applying CAI drill and practice to mathematics have yielded contradictory evidence about the effectiveness of CAI over traditional instruction where effectiveness is measured by standardized achievement tests. What remains in question is the long-term educational significance of this finding. The study of whether CAI use may affect the achievement and motivation of special education students needs more attention, since motivation is a key element directly affecting achievement (Wittrock, 1979).

<u>CAI and Motivation: Qualitative Approach</u>

All studies of motivation were qualitative (i.e., based on anecdotal records and informal observations). Kleiman et al. (1981) studied how to best capitalize on the potential benefits of microcomputers for children with hyperactivity or other attention-deficit disorders. Their research compared children's performance on arithmetic problems administered by computer with problems given via standard paper-and-pencil format. This was a pilot study with a small number of students, 18 children from 4 to 16 years, with no discussion of research design or validity threats. The study was unique because the researchers viewed motivation from a behavioral perspective: they observed differences in the number of problems the children voluntarily chose to do in the two media (paper-and-pencil, computer). They reported the following results:

> On the average, the same children working on the same level of problems did almost twice as many problems on the computer as they did with paper-and-pencil. To be able to quantify the study of motivation can help us better understand what is in fact motivating for children with learning problems (Kleiman, et al., 1981, p. 93).

Schiffman et al. (1982) summarized their work at Johns Hopkins University where a training center was operated by teachers for students identified as learning disabled. They demonstrated how the microcomputer became an effective and important part of an educational program. Due to a quasi-experimental design, statistical analyses were problematic. However, two interesting results were observed:

(1) Computers seemed able to motivate even the most unmotivated learner. Whether this would be true after exposure to a computer for five months

rather than five weeks remains open to verification.

(2) Unanimously, parents reported that their children had positive attitude changes. Some who initially did not want to participate became impatient and annoyed when the practicum closed. (p. 558)

According to White (1983), a pilot study in the Electronic Learning Laboratory at Columbia University's Teachers College indicated that students' attention was higher with computer interaction than it was in the regular classroom. While White defined attention as time-on-task, she did not give specific behavioral indicators for attention. She alluded to the rival hypothesis, novelty effect, which included any feeling of specialness the child may have had because he or she was using the new, "fun" computer.

Clark (1984) reported Hess and Tenezakis' study of Mexican-American, low SES, middle school students. The results indicated that the students liked remedial computer-based instruction (CBI) of mathematics better than teacher-presented mathematics because they believed the computer to be fairer. The positive attitudes toward CBI over other instructional options translated into increased on-task behavior and increased scores on mathematics tests (Clark, 1984).

MacArthur (1986) performed a naturalistic study, including 24 learning disabled students observed during computer-assisted drill and practice (CADP) and seatwork. During the CADP, students spent significantly more time attending to academic content (engaged time) and waiting and significantly less time off task than the seatwork group.

In 1986, Givner indicated that computer implementation in a California school district led students to be more motivated. Likewise, a review of literature by Parry and Thorkildsen (1986) indicated that, when the computer is used as a supplement to regular instruction, it can be more motivating for low-ability students than regular instruction alone.

In reviewing the literature, it is crucial to consider Clark's (1985) notion that "editorial gatekeeping" prevents the publishing of many studies with nonsignificant results. Clark states that editors make biased decisions by publishing computer research in which the results are significantly greater than those in unpublished studies.

The study of CAI as a motivator for unmotivated students has been primarily qualitative and anecdotal in nature. There remains a need for empirical studies to determine precisely what is motivating about CAI. While all studies cited involve conclusions regarding the effective use of CAI in the schools, many are contradictory, and relatively few indicate limitations or suggest rival hypotheses for the results obtained.

In summary, limitations of prior research may have contributed to the contradictory results found in both qualitative and quantitative studies of the effect of CAI on motivation and achievement. For example, some investigators reported that CAI produced increased motivation and more achievement gains than traditional instruction. Other studies indicated that students' achievement in CAI and traditional instruction was equal. The present study was designed to further explore the impact of instructional techniques and ability levels on motivation and achievement. In addition, it was designed to remedy some of the aforementioned limitations and rival hypotheses.

Chapter III

Methods

The present study investigated the processes by which variation in format for presenting .ltiplication problems influence children's motivation and achievement. The sample included 69 fourth-grade children, who were divided into two types of achievers and labelled achievers or underachievers. The two types were derived by comparing the students' standard scores on an achievement test and aptitude test. The students were labelled underachievers because they were not classified by the school as learning disabled, although they met the definition as indicated in this report (i.e., a significant discrepancy between predicted achievement and actual achievement).

The three methods of instruction to which the students were assigned were as follows: (1) CAI multiplication drill and practice with a reward game (CAIm), (2) CAI multiplication drill and practice without a reward game (CAI), and (3) an equivalent paper-and-pencil multiplication drill and practice (Pap&pen).

Subjects

The sample included 69 fourth graders in a public middle school in Beaufort, South Carolina. The school consisted of fourth, fifth, and sixth grades, with typical support services, compensatory programs, and special education and resource instruction for learning disabled, emotionally handicapped, and mentally handicapped students. The total fourth grade included 181 children, 52% Caucasian and 48% Black. The socioeconomic status of the students ranged from lower class to upper-middle class. The students lived in the relatively rural area surrounding the school.

The fourth grade consisted of eight separate classrooms, with students changing classes for mathematics, science, English, and social studies. All the teachers were female and their teaching experience varied from 1 to 25 years. There were five Caucasian and three Black teachers.

The original sample consisted of 135 subjects (46 of the 181 fourth-grade students were unable to participate because their parents did not give consent or they moved). Due to a limitation in the number of computers available at the school, the original sample of 135 was reduced to 69. A stratified random sampling technique was employed to balance the groups on race, sex, and total number of participants. Random matching of race and sex was done within the groups. This procedure was completed for Black females, White females, Black males, and White males. The final sample consisted of 69 subjects. The underachievers group consisted of 11 Black females, 8 White females, 6 Black males, and 6 White males. The achievers group consisted of 11 Black females, 11 White females, 8 Black males, and 8 White males. Of all the subjects, 3 were in special education resource classes, and 12 received compensatory education services.

Instrumentation

For all participants the two dependent variables, motivation and achievement, were measured by determining the number of multiplication problems attempted and the number of multiplication problems completed correctly by each student each day. These numbers were recorded on the Student Record Form provided in the Math Machine manual. The form allowed for information such as date, level of competence, number of problems attempted daily, and number of correct problems completed daily (see Appendix A).

Achievement Test. A measure of mathematics achievement or basic skills was necessary to assess performance levels. The Comprehensive Tests of Basic Skills (CTBS), Forms U and V, is a widely-used test of basic skills, designed for and standardized on a large variety of students (Harris, 1982). The basic normative group for the CTBS, Form U and V, is a national sample of 212,000 students in grades two through ten. Schools were randomly selected from districts chosen by stratifying U.S. School Districts by size, socioeconomic level, and geographic region (Burkett, et al., 1984). On the CTBS at all levels, objective test items of the multiple-choice type are used. The student is to select the correct answer from four or five options. The basic skills are classified into four major tests: reading, spelling, language, and mathematics. The total mathematics test is divided into two subtests, mathematics computation and mathematics concepts and application. The total mathematics score was used in this study.

Typical of basic skills tests, a high degree of reliability exists for both subtest scores and total scores. The Kuder-Richardson formula 20 reliability coefficients for grade three level mathematics subtests and total mathematics include the following: (a) .90 for mathematics computation, (b) .92 for mathematics concepts and applications, and (c) .94 for total mathematics (Burkett, et al., 1984).

The fact that classroom teachers wrote the original test items enhances its content validity (Burkett, et al., 1984). The content validity of the CTBS is based on Bloom's taxonomy for the cognitive domain, which provided a basis for the classification of the objectives. The CTBS is a well-known, widely-used test with extensive supporting literature.

Aptitude Test. A measure of academic aptitude was necessary to determine, in conjunction with the mathematics achievement score, whether the students were achieving at the expected level. Aptitude involves a measure of ability or intelligence. Unlike a test of achievement, a test of aptitude does not require the recall of specific previously learned material, such as vocabulary words or mathematics calculations. Instead, aptitude tests emphasize skills such as reasoning, problem solving, evaluating, and remembering based on short-term memory.

The Test of Cognitive Skills (TCS) was used to assess aptitudes (Burkett, et al., 1983). The TCS is a revision of the

Short Form Test of Academic Aptitude (SFTAA). The TCS is designed to assess the academic aptitude of students in grades 2 through 12. There are four subtests in the TCS: Sequences, Analogies, Memory and Verbal Reasoning. In addition to each subtest score, the TCS provides a composite score called the cognitive skills index. In this study, the cognitive skills index was used in the comparison between aptitude and achievement.

The TCS was standardized on 83,038 students in grades 2 through 12 from public, Catholic and other private schools across the United States. A subsample of 1,001 students was randomly selected for each combination of test level and grade, and the data were analyzed by level. The scaling of the TCS was based on Item Response Theory (Burkett, et al., 1983). Item Response Theory is a method of computing the standard error of measurement, and it is contrasted to number-correct scoring. Item Response Theory scoring, as opposed to number-correct scoring, is a more accurate way of computing the standard error of measurement because it is based on more information from each test item. According to Item Response Theory, the standard error of measurement is a function of the scale score and of the parameters of the items in the particular test, form, and level from which the scale score was obtained.

While the Kuder-Richardson formula 20 (KR 20) was applied to the TCS, specific reliability coefficients were not included in the technical report. Sternberg (in Mitchell, 1985) criticized the reliability and validity information as being inadequate. However, he conceded that the TCS was a promising new instrument for assessing higher-level mental abilities. The TCS was chosen over other tests of aptitude because it:

> places less emphasis upon sheer knowledge than do most of its competitors. It does not test vocabulary nor arithmetic problem-solving which indirectly test prior knowledge by requiring substantial previously acquired information. Second, the test is one of the few current tests that have a Memory subtest...which reflect the learning of new vocabulary (Sternberg in Mitchell, 1985, p. 1557).

Criterion-Referenced Achievement Test. A microcomputer program, PRISM, was used in this study (Psychological Corporation, 1982). Unlike the norm-based CTBS achievement test, PRISM is a criterion-referenced achievement test. The results of PRISM are compared with students' classroom performance. PRISM is designed for the classroom teacher to select tests or practice sheets from PRISM by choosing from the menu of operations for which there are various concepts. For example, the operation multiplication divided into the following concepts: (a) numeration, (b) operations, (c) problem solving, and (d) applications. The level of problems given depends on the ages and ability levels of the students. The microcomputer then generates the paper-and-pencil tests or practice sheets.

In this study, PRISM was used in two ways. First, it was used to determine the initial multiplication content level of the sample. That is, the information obtained from the paper-and-pencil pretest generated by PRISM was used to determine on what multiplication content level the students were to begin the CAI or paper-and-pencil multiplication instruction. Second, PRISM was used as the pre- and posttest that measured changes in the dependent variable, achievement (see Appendix B).

<u>Microcomputer</u> <u>Software</u>. The Math Machine is a microcomputer software program designed to provide drill and practice for students in mathematics (Watkins, Johnson, and Bloom, 1981). The purpose of drill and practice is to integrate and consolidate previously learned material. Drill and practice is supplemental to regular classroom instruction. That is, a student is presented with the type of multiplication that has already been taught in a mathematics class. The goal of this practice is automaticity. That is, when presented with multiplication problems, a student is able to answer quickly, without having to think through each problem.

The Math Machine allows the teacher to store information about each student regarding the number of problems attempted, number of problems completed correctly, level of performance, and game schedule. The Math Machine enables the teacher to control the type of mathematical operations presented and the level at which the student will work. By responding to prompts on the computer screen, the teacher can choose the multiplication level; i.e., a multiplicand of 0 through 10 and a multiplier of 5 through 7 corresponds to level two. The teacher may also allow the student to select one of the eight games that are exogenous or unrelated to the multiplication instruction. The student may play a game after correctly completing a predetermined number of problems. In this manner, the teacher can determine the frequency with which a student can play the one minute arcade-like game presented on the computer screen. The teacher determines how many problems must be completed correctly before the student is able to play a game. Based on recommendations by Watkins et al. (1981), initially the game schedule should allow a student to play a game after every five problems completed correctly.

In this study, the Math Machine automatically delivered a game to the CAIm student after he or she responded correctly to any five problems. The games require the student to press appropriate keys to execute certain actions. The games include the following eight options: (a) bomb - the student's bomber goes after the computer's bomber, (b) bounce - visual and auditory display, (c) bowling - 'throw' the ball down the alley, (d) chase - chase the computer's car, (e) colors - displays color graphic patterns, (f) draw - the computer screen is a sketch pad, (g) pingball - modified pinball game, and (h) shoot - pits spaceship against the computer's spaceship (Watkins, et al., 1981).

The Math Machine problems were presented on the microcomputer screen in a vertical fashion. A student answered each problem by pressing the number keys that corresponded to his or her product. The Math Machine provided corrective feedback for incorrect responses. Comments appeared on the computer screen following the students' answers. For example, when the student answered correctly, the Math Machine displayed the word "Right!" and the number of problems correct. If the answer was wrong, the Math Machine displayed the words "Wrong! Too Low. Try Again", or "Wrong! Too High. Try Again!". This approach to feedback is consistent with current recommendations by Roblyer (1985).

Instructional Materials. Students in both CAI methods and the Pap&pen method received multiplication problems. The students in the CAI methods worked on 13 Apple IIe microcomputers, which were in the computer lab room in the school. The Pap&pen students met in the school library, where they did paper-and-pencil drill and practice work.

An effort was made to make the Pap&pen method materials equivalent to the computer-generated multiplication problems. The multiplication problems for the students in the Pap&pen method were generated by the mathematics teacher. The students received dittos of multiplication problems presented in a vertical fashion, much like the Math Machine problems.

Rewards. On a bi-weekly basis, pencils, pens, erasers and rulers were given as rewards to all the students. All students were given the rewards to keep things equal.

Procedure

Data Collection. Written consent was obtained from parents prior to student participation in the study. Due to lack of a response to the first parent consent form, a second effort to solicit parent consent was necessitated (see Appendix C). Of the 181 students in the fourth grade, 161 of their parents responded affirmatively to their children's participation.

The students' third-grade 1985 total mathematics CTBS achievement test results were obtained by reviewing student records located in the central office of the school district. If the student had taken the CTBS in another school district, the scores were used. Results from other achievement test results, such as the Metropolitan Achievement Test, were not used for students who had just moved into the school district. CTBS scores for 139 children were obtained.

Following the collection of the CTBS scores, 135 subjects (four students were absent, therefore unable to take the test) were administered the Test of Cognitive Skills. The TCS provides a practice test, which was administered on a Tuesday morning at the beginning of February. The actual TCS was administered by each homeroom teacher the following week on a Tuesday morning. Administration took place on Tuesdays because it gave plenty of time during that week for make-up testing. The make-up tests for both the practice and actual TCS were administered by the present researcher in the cafeteria at the same time of the day during the same week. To eliminate random error in test taking (i.e., filling in the wrong bubble of the test protocol), the students had test booklets in which the test response directly followed the question. The students blackened in the circle that best represented their answer choice.

The eight fourth-grade homeroom teachers were instructed about test administration as indicated in the TCS manual. All of the teachers except one had had extensive experience in the administration of group tests. Extra time was given to help the inexperienced teacher learn to administer the TCS. The TCS was computer scored using McGraw-Hill's Compu-Scan (Burkett, et al., 1983). This scoring procedure eliminated errors from hand-scoring. A printout of all test results was received and results used for data analyses.

Following stratification into the category of underachiever, achiever, and overachiever (see data analysis section), students were randomly assigned to the three instructional methods: paper-and-pencil, CAI with a game, and CAI without a game. A relatively equal number of students, matched on race and sex, were distributed among the three instructional methods. There were 23 subjects in the CAI method, 24 subjects in the CAIm method, and 22 subjects in the Pap&pen method. For data analyses, the overachiever and achiever groups were "collapsed" into one group because the overachiever group was too small to afford sufficiently powerful statistical tests. Table 1 gives a summary of the number of

Table 1

Number of Type of Achievers in Instructional Methods

Method of Instruction	Type of Achiever		
	Underachiever	Achiever	Total
CAI	9	14	23
CAIm	12	12	24
Pap&pen	10	12	22

Note. CAIm stands for computer-assisted instruction with a reward game and Pap&pen stands for paper-and-pencil.

subjects, broken down by method of instruction and type of achiever.

After assignment to one of the three instructional methods, the subjects were administered the pretest, PRISM (described earlier), to measure mathematics ability (Psychological Corporation, 1982). The three mathematics teachers in the fourth grade administered the pretest during the subjects' regular mathematics periods. The tests were scored by hand because computer scoring was not available. Following this, the Student Record Form (See Appendix A) of the Math Machine was used to estimate the beginning level of multiplication for each subject.

The computer lab could accommodate only 13 subjects in one session. Therefore, each computer condition was divided in half to make four conditions, which included CAI1, CAI2, CAIm1, and CAIm2. The CAI1 and CAIm1 conditions ran during the first month of data collection. The CAI2 and CAIm2 conditions ran during the second month of data collection. The Pap&pen condition was divided into two conditions also (11 in each) to make the exposure time per week the same as in the computer instructional conditions. Table 2 represents the schedule for the CAI and CAIm instructional conditions.

The instructional goal of the study was to have each student spend 300 minutes (5 hours) doing multiplication tables either on the computer or with paper-and-pencil. The CAI and CAIm methods ran for two months, with one month of make-up time

Table 2

Schedule of Exposure Time for Instructional Methods

	March Days				
Weeks	Mon.	Tues.	Wed.	Thurs.	Fri.
1	CAI1	CAI1	CAIm1	CAIm1	CAIm1
2	CAI1	CAI1	CAI1	CAIm1	CAIm1
3	CAI1	CAI1	CAIm1	CAIm1	CAIm1
4	CAI1	CAI1	CAI1	CAIm1	CAIm1

	April Days				
Weeks	Mon.	Tues.	Wed.	Thurs.	Fri.
1	CAI2	CAI2	CAIm2	CAIm2	CAIm2
2	CAI2	CAI2	CAI2	CAIm2	CAIm2
3	CAI2	CAI2	CAIm2	CAIm2	CAIm2
4	CAI2	CAI2	CAI2	CAIm2	CAIms

Note. The paper-and-pencil condition was assigned to the library in the same day configuration as the CAI1, CAIm1, CAI2, and CAIm2 conditions. The students who had to make up time were assigned the same schedule.

at the end of the data collection period. The schedule was the same for all three methods; however, the data collection for the paper-and-pencil method of instruction was completed in one month because there were fewer students than in both CAI and CAIm conditions. There were 22 students in the Pap&pen condition and 47 students in the CAI and CAIm conditions.

Data for this study were collected from March through May of 1986. The data collection was accomplished before school during the children's homeroom period, which was from 8:00 to 8:30. Each homeroom teacher was given a schedule of student participation and was asked to remind students on the day they were to report to the library or computer lab. Upon arrival to the computer lab or library, their check-in time was recorded on the Math Machine Student Record Form (since time was used as a covariate in the data analyses). Students in all three instructional conditions (CAI, CAIm, and Pap&pen) were given the same instructions about how to proceed with the multiplication problems.

On the first day of participation, the students went to the computer lab, were assigned a computer, and were given a password (the first four letters of their last name). Students in the computer conditions were given additional instruction concerning computer use, and questions were answered in the CAIm condition regarding the game playing.

To ensure that the multiplication problems for all instructional conditions were at the students' instructional level, not their frustration or independent level, the percentage of problems correct was calculated daily for all subjects. To remain at the same ability level of multiplication problems, the students had to score within the instructional range of 79% to 90%. If the student scored below this range, the level was made easier. If the student scored above this range, the level was made more difficult. Frustration, instructional, and independent levels were determined by consensus, obtained by asking five teachers at the middle school. The subjects' levels of multiplication content difficulty were evaluated on a daily basis.

On a daily basis, information was obtained about subjects' levels of multiplication content difficulty, numbers of problems completed correctly, numbers of problems attempted, numbers of games played (for the CAIm students), and minutes of participation. During data collection, students' group assignment (achiever or underachiever) was kept confidential. This study was "double blind" to prevent the teachers' and the researcher's expectations from affecting the results.

The PRISM achievement posttest was administered after all of the data were collected. Administration of the posttest was delayed due to students' absences and tardiness. Therefore, students in the paper-and-pencil condition made up work for two weeks and were given the test during the middle of April. Students in the computer conditions made up work for one month and were given the test at the end of May. The three mathematics teachers administered the posttests during the children's regular mathematics period.

Preliminary Data Analysis. A regression analysis was performed to determine which students were underachievers or achievers. For the purposes of this study, the students were labelled underachievers because the school had not classified them as learning disabled, (although they met the definition as indicated here, i.e., a significant discrepancy between predicted and actual achievement). The total cognitive skills index score for the TCS was used in the regression analysis with the total mathematics CTBS score. In the regression analysis, the dependent variable was achievement (CTBS), and the predictor variable was the TCS aptitude test.

The results of the regression analysis yielded columns of scores for each student's observed CTBS scores, predicted CTBS scores, and the residual. All students whose residual score was less than half the standard error of estimate (-18.25) were considered underachievers. There were few subjects at the lower portion of the underachiever group and many near the upper portion. In other words, there were underachievers whose scores were close to the achievers range. Students whose residuals were above the -18.25 and below 18.25 were considered achievers. Students whose residuals were above 18.25 were considered overachievers.

Definition of Variables. After completion of all data collection the results were tallied. The numbers of days of participation were divided into time intervals, thus creating a repeated measures design. For example, if the student participated for 15 days, the first time interval of the study was represented by collapsing the data for days one through five, the second time interval of the study days six through ten, and the last time interval of the study, days eleven through fifteen. For each student, the numbers of problems completed correctly (a measure of achievement) for each time interval of the study were added together and an average computed, thus representing the average number of problems completed correctly during the time interval of the study. Likewise, the numbers of problems attempted (a measure of motivation) for each time interval of the study were added together and an average was computed. This figure represented the average number of problems attempted for each portion of the study. This procedure was also done for the variables of exposure time and level of multiplication content difficulty.

To keep the amount of time spent in the CAI and CAIm conditions consistent, the exposure time for the conditions was equated. This was done by subtracting the time spent in a reward game each day for the CAIm condition. For example, each reward game took approximately one minute; therefore, a minute for each game played daily was subtracted from the total daily minutes for the students in the CAIm condition. This process created an artificial result; the students in the CAIm condition appeared to spend less time doing multiplication problems than did the students in the CAI and Pap&pen conditions. Therefore, exposure time was used as a covariate in the statistical analyses.

Other variables were coded for each subject; namely, sex, race, and special or remedial education. Educational placement was determined by referring to the student's school records. This variable was coded for each subject and included: (a) learning disabled resource, (b) emotionally handicapped resource, (c) educable mentally handicapped resource, and (e) compensatory mathematics. In addition, type of achiever (achiever or underachiever), method of instruction (CAI, CAIm and Pap&pen), and PRISM pre- and posttest achievement scores were coded.

As the study involved repeated measures design, the data were divided into three time intervals, and three pieces of information were coded for each subject: (a) achievement, (b) motivation, (c) level of multiplication content difficulty (level at which a student performed multiplication problems), (d) exposure time with the task, and (e) minutes spent on game participation (CAIm condition only). Based on the results of the statistical analyses, other variables were created. For example, a variable called time missed was created. It represented the actual amount of exposure time for each subject subtracted from the total expected amount of exposure time for each student.

Research Hypotheses

The research hypotheses in this study were as follows:

1. With regard to motivation and achievement the factor of type of achiever would interact with method of instruction. Specifically, underachievers in the CAIm instructional condition would attempt more problems (greater motivation) and complete more problems correctly (greater achievement) than subjects in the other five combinations of conditions.

2. Achievement level, as measured by the PRISM achievement pre- and posttest comparison, would be highest for the subjects in the CAIm condition, next highest for subjects in the CAI condition and lowest for subjects in the Pap&pen condition.

3. Achievement and motivation levels would vary as a function of students' sex, race, and remedial or special education placement.

Data Analyses. Hypothesis one was tested through a series of statistical analyses. Repeated measures analyses of covariance (ANCOVA) were performed to determine relationships among method of instruction, type of achiever, and the achievement and motivation data. Tukey post hoc analyses were calculated on significant results to determine where differences existed between the instructional methods, type of achiever, and the repeated measures.

Hypothesis two, regarding posttest differences in achievement as measured by an external achievement criterion (the Pap&pen PRISM test) was tested by ANCOVA posttest analyses, with posttest achievement measures as the dependent variable and the pretest as the covariate.

The hypothesis related to variation in achievement and motivation as a function of student sex, race, and special or remedial education was assessed through a series of repeated measures ANCOVAs.

Chapter IV

Results

The purpose of this study was to explore the impact of variation in instructional format on achievers' and underachievers' motivation and achievement. The three multiplication drill and practice instructional methods in this study were: computer-assisted instruction with a reward game (CAIm), computer-assisted instruction without a reward game (CAI), and paper-and-pencil (Pap&pen). Motivation and achievement were defined as the number of multiplication problems attempted and the number of problems completed correctly, respectively. Achievement was measured by comparing pre- and posttest PRISM mathematics achievement scores.

Analyses are reported that test the two hypotheses presented at the end of chapter three. After presentation of the analyses regarding each hypothesis, results are summarized.

Hypothesis One: Achievement and Motivation Differences Associated with Instructional Method and Type of Achiever

The testing of hypothesis one was partitioned to address questions regarding variance in achievement levels as a function of instructional method and type of achiever, and variance in motivation levels as a function of instructional method and type of achiever. Covariates were also investigated.

Covariates. In the course of the experimental procedure, in spite of efforts to have exposure time equivalent, potentially significant deviation in exposure time across groups was observed. Specifically, differences in exposure were noticed with respect to the entire exposure time rather than time intervals. To the extent that additional exposure time could have affected the principle dependent variables, achievement and motivation, determination of the differential variation in exposure time became important. Table 3 presents the results of a two-way analysis of covariance (ANCOVA) for total exposure time, with the first factor corresponding to method of instruction (CAI, CAIm and Pap&pen) and the second factor representing type of achiever (achiever or underachiever). The covariate was content difficulty of multiplication problems.

A significant main effect was found for instructional method when exposure time was the dependent variable ($F = 6.14$; $df = 2/62$; $p < .001$). The three adjusted means (with the unadjusted means displayed in parentheses) represented three methods of instruction and are as follows: CAIm = 248.69 (256.01); CAI = 248.69 (248.80) and Pap&pen = 244.96 (245.78). Tukey HSD (honestly significant difference) post hoc analyses indicated that significant differences existed among the three instructional conditions. Whereas total exposure time did not differ significantly between students in the CAI and CAIm methods, significant differences did exist between the two CAI methods versus the Pap&pen methods ($p < .01$) such that subjects receiving instruction via microcomputer had more exposure time than those in the Pap&pen condition. Thus, exposure time was

Table 3

Analysis of Covariance of Exposure Time

Source	*df*	*MS*	*F*	*p*
Method of Instruction (MI)	2	458.13	6.14	.00
Type of Achiever (TA)	1	3.22	.04	.84
MI x TA	2	122.37	1.55	.22
Content Difficulty covariate	1	288.86	2.90	.09
Students within groups	62	79.03		

Note. $N = 69$.

regarded as a potentially important covariate for subsequent analyses of student achievement and motivation.

Inasmuch as subjects in various experimental conditions had different initial competencies in solving multiplication problems, and therefore, proceeded to work with multiplication stimuli at different levels of difficulty, the content difficulty of multiplication stimuli had to be considered as a potential covariate.

A repeated measures ANCOVA was performed, with the first factor representing method of instruction and the second factor representing type of achiever. The third factor was a repeated measure with three levels equivalent to levels of content difficulty of multiplication problems over the three time intervals. The covariate was exposure time.

These results are represented in Table 4. The analysis indicated a main effect for all three variables: method of instruction ($F = 9.10$; $df = 2/62$; $p < .001$), type of achiever ($F = 12.50$; $df = 1/62$; $p < .001$) and time interval ($F = 7.66$; $df = 2/117$; $p < .001$). For the method of instruction factor, the adjusted means (unadjusted means presented parenthetically) for the three respective conditions were: CAIm = 5.47 (9.30); CAI = 4.68 (4.67) and Pap&pen = 8.32 (8.32). Post hoc analyses of content difficulty of multiplication stimuli was significantly greater ($p < .01$) for the Pap&pen condition than for the two microcomputer conditions. Moreover, with respect to the type of achiever factor, the better achieving students were

Table 4

Repeated Measures Analysis of Covariance of Conte[illegible] [illegible]ifficulty

Source	df	MS	F	p Conventional	p Geisser-Greenhouse
Between students					
Method of Instruction (MI)	2	163.84	9.10	.00	
Type of Achiever (TA)	1	225.06	12.50	.00	
MI x TA	2	18.50	1.03	.36	
Exposure Time covariate	1	34.32	1.91	.17	
Students within groups	62	18.00			
Within students					
Time Interval (TI)	2	10.41	7.66	.00	.01
TI x MI	4	1.96	1.44	.23	.23
TI x TA	2	3.75	2.76	.07	.07
TI x MI x TA	4	.88	.65	.61	.62
Exposure Time covariate	1	1.36	1.00		
Repeated measure x students within groups	117	1.36			

Note. N = 69.

found to have more difficult multiplication stimuli than underachieving students. The adjusted (and unadjusted means) for the achiever group were 7.18 (7.17) and the underachiever group means were 4.87 (4.88).

Although a signficant main effect was detected for the time interval repeated measure, tests of the assumptions for equality and symmetry of variance-covariance matrices indicated a breach of those assumptions. Therefore, the probability level for the effect was recalculated using the Geisser-Greenhouse procedure. Significance for the effect was sustained where $p < .01$. Adjusted and unadjusted means for content difficulty across the three time intervals were: 5.59 (5.59), 6.06 (6.06) and 6.42 (6.42). Tukey analyses showed that, across all experimental conditions and achiever types, levels of difficulty increased significantly ($p < .01$) from the beginning to the end of the experiment. Consequently, multiplication content difficulty was deemed an important covariate for subsequent analyses.

Variation in Achievement. Table 5 presents the results of a repeated measures ANCOVA, with the first factor having three levels corresponding to the instructional method, the second factor with two levels equivalent to the type of achiever, and the third factor (the repeated measure) with three levels corresponding to time intervals of achievement, (the number of problems completed correctly during each time interval). The two covariates used in this analysis were exposure time and content difficulty.

Table 5

Repeated Measures Multiple Analysis of Covariance of Students' Achievement

Source	*df*	*MS*	*F*	*p* Conventional	*p* Geisser-Greenhouse
Between students					
Method of Instruction (MI)	2	2881.57	26.34	.00	
Type of Achiever (TA)	1	172.46	1.58	.21	
MI x TA	2	66.18	.61	.54	
Exposure Time covariate	1	1990.61	18.20	.00	
Content Difficulty covariate	1	989.40	9.05	.00	
All covariates	2	1249.30	11.42	.00	
Students within groups	61	109.39			
Within students					
Time Interval (TI)	2	75.01	3.91	.02	.03
TI x MI	4	32.01	.73	.57	.56
TI x TA	2	16.66	.37	.69	.67
TI x MI x TA	4	57.46	1.28	.28	.28
Exposure Time covariate	1	271.07	6.05	.01	
Content Difficulty covariate	1	649.98	14.51	.01	
All covariates	2	488.97	10.91	.00	
Repeated measure x students within groups	124	44.80			

Note. *N* = 69.

Significant achievement differences existed among students across instructional methods ($F = 26.34$; $df = 2/61$; $p < .001$). The three methods of instruction are represented by the adjusted means (with unadjusted means in parentheses) and are as follows: CAIm = 48.44 (47.99); CAI = 57.88 (59.71) and Pap&pen = 43.46 (38.53). Tukey analyses revealed that students in the CAI condition manifested the greatest achievement, followed by students in the CAIm condition, followed by students in the Pap&pen condition.

The repeated measure, time interval of achievement, was significant as well ($F = 3.91$; $df = 2/124$; $p < .02$). Here, a breach of assumptions of symmetry and equality required the application of the Geisser-Greenhouse method, where the probability level for the effect was adjusted to .03. Respective adjusted means (and unadjusted means in parentheses) were: first time interval = 48.31 (48.95); second time interval = 50.07 (49.95) and the last time interval = 51.01 (51.15). Post hoc analyses indicated significant differences ($p < .01$), in achievement across all time intervals, with the general pattern of achievement levels incrementing as a function of time. The main effect of type of achiever and the interactive effect (MI x TA) were <u>not</u> statistically significant.

Therefore, hypothesis one regarding expected achievement differences as a function of instructional method and achiever type was confirmed with respect to the expectation that subjects in both conditions receiving CAI instruction would achieve better than the Pap&pen group, but it was not confirmed with respect to the notion that the CAI method having the reward game would achieve better than the CAI method without the games. Also the increase for underachievers did not differ from that for achievers.

It will be noted that, whereas preliminary analyses indicated that the content difficulty of multiplication stimuli could operate as a meaningful covariate, the intended consequence of such a covariate would be to reduce error variance in achievement, the dependent variable related to differences in stimulus difficulty across the three methods of instruction. At the same time, those preliminary analyses showed differences in content difficulty between achieving and underachieving subjects. Such a difference is not surprising and, in fact, would be expected in a circumstance where achiever versus underachiever is defined by some aspect of students' academic attainment. Thus, inclusion of content difficulty level as a covariate could serve (as in the previous analysis) to mask or obscure achiever versus underachiever differences.

To investigate this possibility, the previous analysis was repeated, this time, however, without the use of the content difficulty as the covariate. Results of this analysis are presented in Table 6. As in the previous analysis with the achievement data, the reanalysis of that data without the content difficulty covariate indicated a main effect for the method of instruction factor ($F = 41.55$; $df = 2/64$; $p < .001$)

Table 6

Repeated Measures Analysis of Covariance of Students' Achievement

Source	df	MS	F	p
Between students				
Method of Instruction (MI)	2	4831.27	41.55	.00
Type of Achiever (TA)	1	25.60	.22	.64
MI x TA	2	172.44	1.48	.23
Exposure Time covariate	1	1685.38	14.49	.00
Students within groups	64	116.28	.88	
Within students				
Time Interval (TI)	2	90.16	1.81	.17
TI x MI	4	33.39	.67	.61
TI x TA	2	63.45	1.28	.28
TI x MI x TA	4	78.32	1.58	.18
Exposure Time covariate	1	453.41	9.13	.00
Students within groups	117	49.68		

Note. *N* = 69.

but not a main effect for type of achiever or an interactive effect. The adjusted and unadjusted means for the three methods of instruction are represented as follows: CAIm = 47.92 (41.90); CAI = 57.14 (57.19) and Pap&pen = 41.67 (41.90). Post hoc tests confirmed achievement levels for students in the CAI condition to be higher than those for the other two conditions but supported no significant difference between CAIm and Pap&pen conditions. This is in contrast to what was found in the prior analysis. Moreover, contrary to the prior analysis, achievement levels were not found to vary as a function of time interval (duration) of the experiment. Most importantly, when the content difficulty covariate was removed for data treatment, no differences betweeen achievement groups became manifest, thus confirming the results in the earlier analysis employing the content difficulty covariate.

Variation in Motivation. Table 7 presents results from a repeated measures ANCOVA using motivation as the dependent variable, with the first factor having three levels corresponding to three methods of instruction, the second factor having two levels representing groups of achieving and underachieving students, and the third factor having three levels corresponding to successive time intervals. The two covariates used in this analysis were exposure time and content difficulty. The only significant effect found was the main effect for the method of instruction factor (F = 26.62; df = 2/61; p < .001). The adjusted (and unadjusted) means for

Table 7

Repeated Measures Multiple Analysis of Covariance of Students' Motivation

Source	df	MS	F	p Conventional	p Geisser-Greenhouse
Between students					
Method of Instruction (MI)	2	2743.99	26.62	.00	
Type of Achiever (TA)	1	178.70	1.73	.19	
MI x TA	2	30.96	.30	.74	
Exposure Time covariate	1	1926.35	18.69	.C0	
Content Difficulty covariate	1	1329.C1	12.89	.00	
All covariates	2	1349.92	13.09	.00	
Students within groups	61	103.09	3.09		
Within students					
Time Interval (TI)	2	120.79	.61	.06	.06
TI x MI	4	23.97	.47	.65	.63
TI x TA	2	18.42	1.22	.62	.60
TI x MI x TA	4	47.49	7.80	.30	.31
Exposure Time covariate	1	304.66	9.86	.01	
Content Difficulty covariate	1	385.50	9.42	.00	
All covariates	2	368.18		.00	
Repeated measure x students within groups	124	39.08			

Note. *N* = 69.

the respective instructional conditions were: CAIm = 48.33 (47.86); CAI = 55.56 (57.92) and Pap&pen = 43.50 (41.92). Tukey HSD analysis indicated significant differences for all pairwise differences, with manifest motivation being highest for students in the CAI method and lowest for those in the Pap&pen condition.

As with the achievement dependent variable, the foregoing analysis for the motivation dependent variable was repeated without inclusion of the content difficulty covariate to assess the possibility that the covariate was masking an achiever versus underachiever group difference. As shown in Table 8, the main effect, method of instruction, was confirmed (F = 42.32; df = 2/64; p < .001). However, post hoc comparisons, while confirming greater motivation levels for students in the CAI method (p < .01), revealed no differences between students in the CAIm and Pap&pen methods.

In summary, both achievement and motivation levels were found highest for those students receiving CAI <u>without</u> use of computer-game rewards and lowest for students receiving Pap&pen instruction. Neither achievement nor motivation levels differed as a function of membership in the groups defined as achieving or underachieving. Nor did method of instruction and type of achiever interact. Whereas achievement levels were found to increase progressively from the beginning to the end of the experiment, motivation levels were found to be stable across time.

Table 8

Repeated Measures Analysis of Covariance of Students' Motivation

Source	df	MS	F	p
Between students				
Method of Instruction (MI)	2	4962.35	42.32	.00
Type of Achiever (TA)	1	31.53	.27	.61
MI x TA	2	100.87	.86	.42
Exposure Time covariate	1	1409.06		
Students within groups	64	117.25	12.02	.00
Within students				
Time Interval (TI)	2	76.49	1.88	.16
TI x MI	4	19.11	.47	.75
TI x TA	2	60.24	1.48	.23
TI x MI x TA	4	58.63	1.44	.23
Exposure Time covariate	1	475.71	11.68	.00
Repeated measure x students within groups	117	40.71		

Note. N = 69.

In certain respects, one could argue that the exposure time variable, employed as a covariate, might just as well have served as a viable dependent variable. Of course, from the perspective that hypotheses and related analyses must focus on predetermined dependent variables, this line of thinking is somewhat flawed. Nonetheless, as will be discussed more fully in the next chapter of this work, it became clear to the investigator that, during implementation of the experimental conditions, "exposure time" was a variable quite sensitive to the fact that certain students willingly and punctually engaged in instruction, while other students became visibly resistent and tardy. Thus, exposure time, to the extent that it differed across instructional methods (as confirmed in the analysis reported in Table 3), could be viewed as a viable secondary indicator of students' motivation levels. Within this context, those results showing higher total exposure time for students in both CAI methods (as compared to those receiving Pap&pen instruction) supports further the relative utility of CAI.

Hypothesis Two: Achievement Differences Associated with Instructional Method and Type of Achiever, as Measured by an External Criterion

Differences in PRISM paper-and-pencil multiplication achievement were assessed at termination of the experimental period. Posttest PRISM scores served as the dependent variable in a two-way ANCOVA, with the first factor being method of instruction, the second factor achiever type, and PRISM pretest scores, exposure time, and content difficulty held as covariates. No significant effects were found (see Appendix D). Thus, hypothesis two, according to which higher achievement was anticipated among those receiving computerized instruction, found no support.

Hypothesis Three: Achievement and Motivation Differences as a Function of Student Sex, Race and Educational Placement

For each status variable (sex, race, educational placement), first with respect to achievement as a dependent variable and second with respect to motivation, a one-way ANCOVA was performed, where exposure time and content difficulty served as covariates. No signficant effects were detected. Therefore, hypothesis three was not confirmed.

Summary

The results reported in this chapter may be summarized as follows:

1. The achievement of children receiving CAI was significantly greater than those receiving Pap&pen instruction. Among those instructed through CAI, those who learned without the addition of computer-reinforcing games performed better than students provided games. In general, achievement levels, irrespective of instructional method or identification of a child as an achiever versus underachiever, progressively increased throughout the duration of mathematics instruction.

2. Mathematics achievement, as mediated through methods of microcomputer or conventional paper-and-pencil drill and

practice instruction, did not vary differently for children regarded as academic achievers and underachievers. To the extent that one may assume that the preponderance of children ordinarily identified for compensatory instruction or classified as learning impaired, would, in fact, be underachieving children, the experimental results indicated that the positive effects associated with CAI are not appreciably different for regular and special education students. That is, CAI appears to work equally as well for those currently demonstrating adequate and faulty academic performance.

3. With respect to motivation, as reflected in children's persistence in attempting to solve mathematical problems, CAI without the game reinforcements was appreciably more enhancing than motivation associated with CAI with games or conventional paper-and-pencil instruction. When children's "time in" the instructional process is viewed as a viable measure of motivation, children receiving either form of CAI were found to be more motivated than those not receiving CAI.

4. When labelled as an apparent underachiever or achiever, no detectable relationship existed with motivation during instruction.

5. Children's achievement and motivation, as herein measured, seem unrelated to their gender, ethnicity, or inclusion in remedial or special education.

Chapter V

Discussion

The efficacy of computer-assisted instruction drill and practice in mathematics versus paper-and-pencil drill and practice was studied using fourth-grade students from a relatively rural area of South Carolina. The study investigated how variation in method of presenting multiplication problems affected the motivation and achievement of underachievers and achievers. Instructional methods used in this study were: computer-assisted instruction (CAI), computer-assisted instruction with a reward game (CAIm), and paper-and-pencil (Pap&pen). The sample was divided into underachievers and achievers, based on a regression analysis using total mathematics achievement test scores from the Comprehensive Tests of Basic Skills and aptitude test scores from the Test of Cognitive Skills.

Results indicated significant main effects but nonsignificant interaction effects. The dependent variables, achievement and motivation, varied as a function of the method of instruction. The results of this study supported the hypotheses, stated in prior research, that the use of CAI drill and practice increases the achievement and motivation of students in elementary schools (Edwards, et al., 1975; Forman, 1982; Kulik, et al., 1985; Schiffman, et al., 1982). However, these results did not support the hypothesis that underachievers make greater achievement gains with CAI as a supplement to traditional instruction than with traditional paper-and-pencil instruction alone as reported by Forman (1982), Hallworth & Brebner (1980) and Jamison et al. (1974).

Achievement Findings

In this study, achievement was measured in two ways: by number of multiplication problems completed correctly, and by a mathematics achievement pre- and posttest comparison. When controlling for content difficulty and exposure time, students in the CAI condition achieved more than students in the CAIm condition. This could have resulted because the CAIm students played the reward games and, therefore, spent less actual time with the multiplication problems. However, this explanation seems unlikely because the CAIm students, despite time spent with the games, achieved more than the Pap&pen students.

Students in both CAI and CAIm achieved more than the Pap&pen students. This result could be a function of the "nonjudgmental" characteristic of the computer. That is, the students who used the computer did not fear judgmental responses about their performance. Likewise, the computer did not convey expectations of success or failure.

The greater achievement of the CAI and CAIm students over the Pap&pen students could have resulted from a difference in the feedback as well. Students in both CAI and CAIm received immediate feedback. Students using Pap&pen only received indirect information about their performance. For example, a student using Pap&pen might have assumed that he or she had not done well on the previous day's work if the problems were easier the next day. Conversely, a student using Pap&pen might have assumed that he or she had done well on the previous day's work if the problems were more difficult on the next day. The direct and immediate feedback provided for the students in both CAI conditions differed from the indirect information obtained by the Pap&pen students. Thus, the feedback provided by the computer may have contributed to significant increases in achievement.

Results indicated that achievement increased for all instructional methods and types of achiever; that is, the achievement of all types of students improved as the study progressed from the beginning to the end. These results are consistent with prior research on achievement, indicating that the effectiveness of CAI and traditional instruction appears to produce similar achievement gains over time (McDermott & Watkins, 1983; Bass, et al., 1986).

Pap&pen students' multiplication content difficulty levels, with exposure time held constant, was greater than that of the CAI and CAIm students. An explanation for this result was discussed in prior research (Clark, 1985). That is, when learning gains were evident in comparisons of CAI and some other classroom based, teacher-centered instruction, closer inspection revealed that greater effort was made when designing the CAI materials than the traditional paper-and-pencil materials.

In this study, however, particular attention was directed toward making the context and materials for all instructional methods (CAI, CAIm and Pa n) as equivalent as possible. Specifically, all subjects were taken out of the regular classroom. Participants were given identical instructions, similar presentation of problems, and the expectation of the same exposure time. Equivalence of materials was evaluated by a fourth-grade mathematics teacher. She compared the problems presented to the students in both the CAI conditions and Pap&pen condition and concluded that the materials were as equivalent as possible.

While similarities existed in design between the CAI conditions and the Pap&pen condition, a difference existed in the determination of level of multiplication content difficulty. That is, the Math Machine program determined the CAI students' levels of multiplication content difficulty (e.g., multiplication of 2 digits x 1 digit with no regrouping was always considered level 4). However, the teacher and the researcher, based upon the Math Machine levels, determined Pap&pen students' levels of multiplication content difficulty. Therefore, the decision-making process may have had more variability (despite attempts to be accurate and consistent).

Achievement changes were measured also by the PRISM achievement pre- and posttest when the pretest, level of multiplication content difficulty, and exposure time were held constant. Contrary to the achievement findings discussed earlier, results indicated that student achievement did not change significantly over time. This difference could, in part, be a function of the different type of data represented in each analysis. That is, the first measure of achievement was the actual number of problems the students' had completed correctly. The second measure of achievement represented very different information (i.e., the results of a paper-and-pencil test).

Lack of a significant effect for the pre- and post-achievement test comparison could have been due to a another confounding variable which may have been at work here. That is, the mathematics achievement posttest (administered in April and May, 1986) followed the administration of three major, district-wide achievement tests. These achievement tests were administered during several days in March, April, and May of 1986. The teachers reported that the students had been over-tested. In addition, the students reported that they were sick of tests. This may have rendered the posttest of the present study as an invalid representation of the students' mathematics achievement.

Motivation Findings

Most prior research about the effect of CAI on motivation used subjective, anecdotal records, and attitude changes to assess motivation. In the present study motivation was measured in two ways: number of multiplication problems attempted and, secondarily, the total exposure time with multiplication problems. When motivation was measured by the number of problems attempted, with multiplication content difficulty and exposure time held constant, motivation of the CAI students was greater than that of the CAIm and Pap&pen students. This result could have been due to the fixed-game schedule of the CAIm condition. That is, all students in the CAIm method were scheduled to play a game after they had completed five problems correctly. This was maintained over the duration of the study.

This reward-game schedule might have been motivating for some students and not for others. Consequently, the potential effects of the reinforcing games may not have been evident. This lack of adapting to individual needs might have accounted for the students in the CAI condition appearing to have made greater motivational gains than the CAIm students (M. Watkins, personal communication, October 3, 1986). Making the game schedule individualized could be a necessary condition for providing rewards that are truly motivating.

The fact that motivation of the CAI students was greater than that of the CAIm students could be explained also by exploring the impact of the reward game. The microcomputer games provided in this study were exogenous, unrelated to the multiplication task. While the students said they enjoyed the games, their concentration on the task may have been interrupted by the games, and perhaps they rushed through the multiplication problems to play the games. Therefore, it is essential to further investigate the impact of computer games as a reward.

When motivation was measured as total exposure time and multiplication content difficulty was controlled, the motivation of the CAI and CAIm students was greater than that of the Pap&pen students. That is, students in both CAI conditions spent more time in the study. Therefore, a more accurate representation of motivation may have been total exposure time, not number of problems attempted.

Explanations for Nonsignificant Interaction Findings

In this study, there were no significant interaction effects. For example, the performance of the underachievers was not significantly greater in any one instructional condition. This finding is consistent with some prior research indicating that all students (despite ability level) show achievement gains with CAI (Edwards, et al., 1975; Kulik, et al., 1985; Niemac & Walberg, 1985). However, it is contrary to other prior research indicating that CAI produces the greatest achievement gains for low ability students or underachievers (Forman, 1982; Hallworth & Brebner, 1980; Jamison, et al., 1974). The limitations (e.g., novelty effects, and inadequate definitions or descriptions of samples) cited previously may have confounded the results in these studies and may have contributed to the contradictory findings. Therefore, it is important to determine whether this study was subject to confounding variables and rival hypotheses.

The variable of type of achiever should be explored. A discrepancy model based upon a regression analysis of observed versus expected mathematics achievement test scores was used to create the achiever and underachiever groups. While many underachievers' scores were close to the achiever range, this discrepancy model was supported because those students labelled underachievers were in actuality receiving remedial instruction through the compensatory education program in the school. In addition, the levels of multiplication content difficulty of the underachievers was significantly lower than that of the achievers. Therefore, the discrepancy model is an adequate representation of group differences.

The results of this study indicate that motivation and achievement vary as a function of instructional method. However, the results did not support the hypothesis that underachievers will make the greatest gains in the CAIm condition; i.e., there were no aptitude-treatment interaction effects.

Implications and Suggestions for Future Research

Based on the limitations of prior and current research, future investigators should consider the study of CAI with regular and special education students, impact of types of feedback and reward games, impact of the novelty effect, inclusion of a no-treatment control group, inclusion of treatments in the school curricula, and alternative approaches to measuring motivation.

CAI: A Regular and Special Education Issue. In the present study, CAI was beneficial to all students (i.e., both underachievers and achievers). Thus, the use of CAI is a special education and regular education issue. Therefore, future research must explore the impact of CAI with all students.

Feedback. The role of feedback should be explored when comparing the impact of variation in instructional formats on motivation and achievement of elementary students (Swenson & Anderson, 1982). Hofmeister and Thorkildsen's (1984) study of feedback indicated that variation in timing of feedback has a cruc al effect on retention scores. Therefore, to better assess the role of feedback, future researchers should provide alternative feedback schedules such as those suggested by Hofmeister and Thorkildsen: immediate, 15-second delay, and after-lesson-feedback.

Reward Games. Future researchers should explore the impact of types of reward games on students' motivation and achievement (Swenson & Anderson, 1982). For example, comparisons should be made between student performance in exogenous versus endogenous (relevant to the task) reward-game groups. In addition, the impact of variation in the time of introduction of games should be explored. The point in time when games are introduced may have an impact upon students' motivation and achievement. For example, staggering the introduction of the games to various groups, may indicate that the distracting initial impact of games may decrease as time progresses.

Novelty Effects. The novelty effect or the "newness" of computer instruction was not operating in the present study because the students had received computer instruction during the previous year. However, the newness of the computer games may have served as a confounding variable for students in the CAIm method. This issue might be elucidated by following the recommendation cited previously regarding variation in time of introduction of computer games.

No-Treatment Control Group. A no-treatment control group should be included in future studies. The no-treatment control group would receive a pre- and post- mathematics achievement test but no treatment intervention. This would help ascertain whether the achievement of students in various treatments is significantly different from no intervention at all.

Inclusion of Treatments in School Curricula. Further researchers should consider the impact of school-related issues. For example, the implementation of this study was affected by the state of South Carolina's Education Improvement Act which emphasizes accountability in basic skills. Therefore, the school district was required to implement a specific curriculum. For example, teachers were required to spend a prespecified number of minutes with a specific curriculum. Therefore, the treatment conditions in this study could not be included as part of the regular curriculum. Because of this constraint, all treatments were offered during a homeroom period (8:00-8:30) prior to formal instruction.

The students may have resented giving up their social time for instruction. In addition, some students received breakfast in school during this time period. If they were to participate in the study, they had to give up their social time and either rush through breakfast, eat at home, or not eat at all. Future investigators should seek to offer treatments within the existing curricula. Therefore, whether treatment conditions are offered as a replacement of, or supplement to, regular instruction, they should occur within the curriculum.

Measurement of Motivation. Unlike in other studies which used subjective, anecdotal records or attitude as a measure of motivation (White, 1983; Kleiman, et al., 1981), in the current study motivation was measured in two different and objective ways (as the number of problems attempted and secondarily, as exposure time to the task). Based on the development of ideas in this study regarding the measurement of motivation, future researchers might study motivation by giving students a free choice about how they want to spend their time during a class period. For example, instead of requiring the students to go to one of three methods of instruction, the students could choose multiplication CAI, CAIm, Pap&pen, or some other school-related task (i.e., reading, writing or study hall). In this way, the researcher could obtain an objective measure of the students' actual motivation to do a certain task (M. Watkins, personal communication, October 3, 1986).

Based on the implications and suggestions mentioned, future researchers may reduce the impact of confounding variables and rival hypotheses. In addition, further study may elucidate the effect of instructional methods and ability levels on motivation and achievement. However, it is crucial to remember that learning gains may result from adequate instructional theory and not necessarily from the medium used to deliver instruction.

Summary

This study explored how variation in instructional format (CAI, CAIm and Pap&pen) affects achievement and motivation of achievers and underachievers. The results of this study confirm prior research revealing that the achievement levels of students in CAI were greater than those of the students in the traditional paper-and-pencil instruction.

Other investigators of the impact of CAI on motivation used anecdotal records or attitude as a "measure" of motivation. However, in the present study motivation was measured by using objective means. This contribution will further the study of the measurement of motivation as a dependent variable.

Unlike the results of some other studies, no interaction effects occurred. That is, the achievers and underachievers did not differ in performance under any one instructional condition. Also, CAI was beneficial for all students. The implementation of suggestions for future research should help ascertain whether an aptitude-interaction effect is ever evident.

Comparisons of CAI and traditional instruction are necessary to discover the impact of instructional technique and ability level on motivation and achievement. However, it is crucial to remember that learning results from well-designed curricula and not simply from the media used for delivery. Learning results as well from providing truly motivating learning environments. Therefore, an integration of mathematics curriculum theory and computer technology is essential.

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Appendix A

THE MATH MACHINE

Student Record Forms

Multiplication

Date ____________ Student ________________

1. Multcand=0-10 Multiplier=0-4													
2. Multcand=0-10 Multiplier=5-7													
3. Multcand=0-10 Multiplier=8-10													
4. 2-Digit x1-Digit;No Regroup													
5. 2-Digit x1-Digit;Regroup 10													
6. 2-Digit x1-Digit;Regroup 100													
7. 2-Dig x1-Dig;Regroup10;100													
8. 3-Dig x1-Dig;Regroup 100													
9. 3-Dig x1-Dig;Regroup10;100													
10. 3-Dig x1-Dig;Regroup All													
11. 2-Dig(W/O)x 1-Dig;Rnd Regroup													
12. 1-Dig x 2-Dig (W/O),Rnd Regroup													
13. 2-Dig x 2-Dig; Random Regroup													
14. 3-Dig x 2-Dig; Random Regroup													
15. 3-Dig x 3-Dig; Random Regroup													
16. 4-Dig x 3-Dig; Random Regroup													
17. 4-Dig x 4-Dig; Random Regroup													

SouthWest EdPsych Services, Inc.
P.O. Box 1870
Phoenix, Arizona 85001

Appendix B

PRISM ACHIEVEMENT PRETEST/POSTTEST

NAME: ____________
CLASS: ____________
DATE: ____________

1. Multiply: 6 x 8 =

A. 42
B. 48
C. 46
D. NOT GIVEN

2. Multiply: 5 x 9 =

A. 45
B. 54
C. 42
D. NOT GIVEN

3. Multiply: 9 x 6 =

A. 15
B. 3
C. 54
D. NOT GIVEN

4. Multiply: 7 x 9 =

A. 36
B. 2
C. 16
D. NOT GIVEN

5. Multiply: 27 x 3 =

A. 61
B. 80
C. 30
D. NOT GIVEN

6. Multiply: 10 x 91 =

A. 9,100
B. 910
C. 91
D. NOT GIVEN

7. Multiply: 68 x 10 =

A. 68
B. 6,800
C. 680
D. NOT GIVEN

8. Multiply: 17 x 5 =

A. 55
B. 58
C. 75
D. NOT GIVEN

9. Multiply: 44 x 6 =

A. 264
B. 240
C. 244
D. NOT GIVEN

10. Multiply: 62 x 5 =

A. 300
B. 400
C. 320
D. NOT GIVEN

11. Multiply: 44 x 100 =

A. 440
B. 4,400
C. 44
D. NOT GIVEN

12. Multiply: 20 x 100 =

A. 20
B. 200
C. 2,000
D. NOT GIVEN

13. Multiply: 68 x 1,000 =

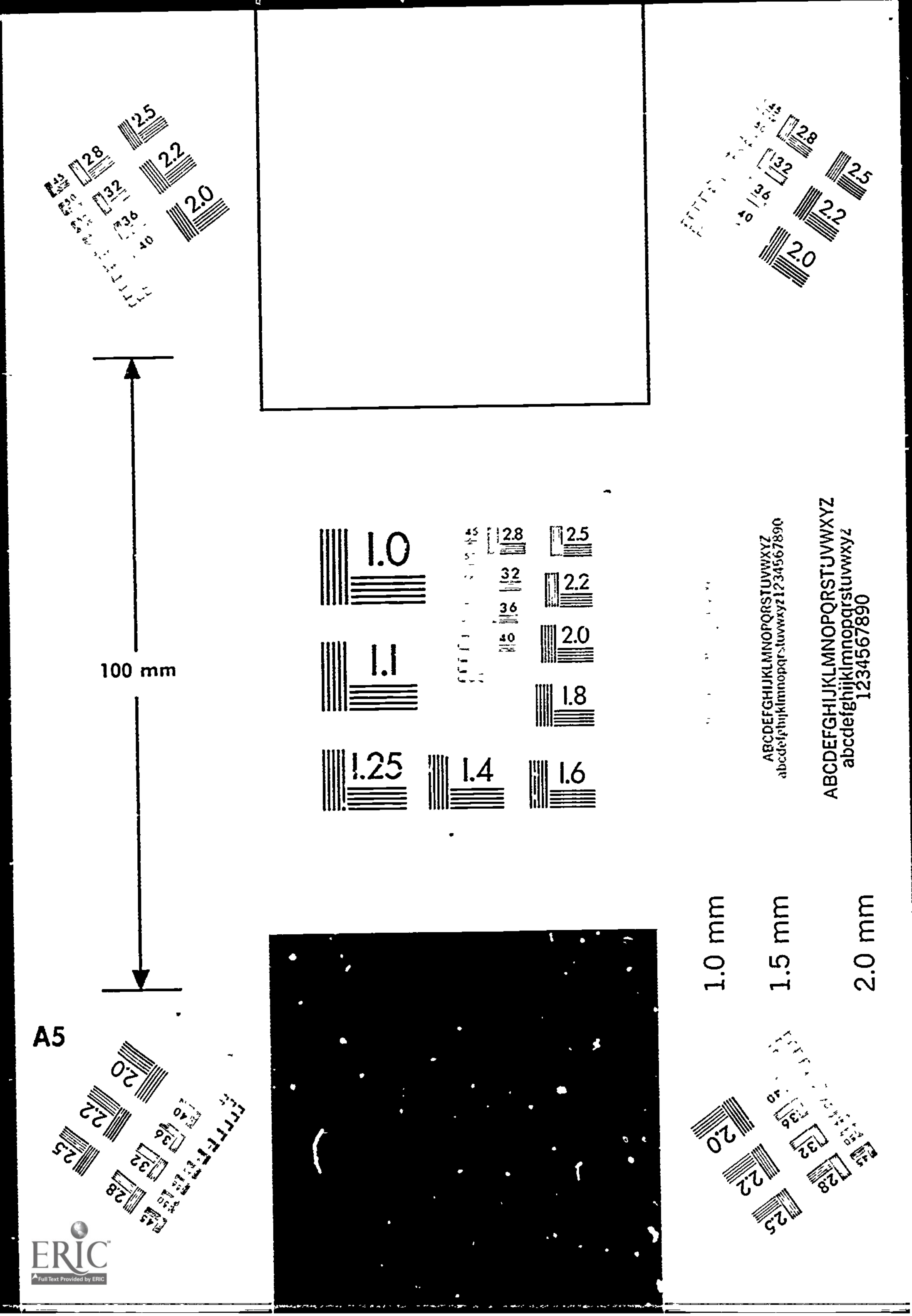
A. 6,800
B. 68,000
C. 68
D. NOT GIVEN

14. Multiply: 47 x 25 =

A. 1,075
B. 1,145
C. 1,175
D. NOT GIVEN

15. Multiply: 536 x 15 =

A. 8,040
B. 8,010
C. 3,216
D. NOT GIVEN



100 mm
A5
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
1.0 mm
1.5 mm
2.0 mm
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz1234567890
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890

Appendix C

FIRST EFFORT TO OBTAIN CONSENT FOR PARTICIPATION IN THE STUDY OF THE EFFECT OF COMPUTER-ASSISTED INSTRUCTION ON MOTIVATION AND ACHIEVEMENT

Dear Parent:

As a doctoral student in School Psychology, I am writing to request the participation of your son or daughter in a study approved by the Beaufort County School District and your principal.

The research will be conducted in January and February and will study the effectiveness of various approaches to teaching multiplication. The study will include the administration of a test and the recording of previous test information. All results will be confidential. Your child should benefit from the extra instruction which will last three months for 45 minutes per week.

If you have any question, please contact me at 524-2660. Please return this form within 2 days in the enclosed self-addressed stamped envelope.

Thank you for your cooperation.

Sincerely,

Jane Hessemer Stegemann, M.S.
Beaufort School District

My child ______________________________
(name)

(check one)

________MAY participate in the study.
________MAY NOT participate in the study.

Parent
Signature ____________________________ Date __________

THANK YOU FOR YOUR COOPERATION

Appendix C

SECOND EFFORT TO OBTAIN CONSENT FOR PARTICIPATION IN THE STUDY OF THE EFFECT OF COMPUTER-ASSISTED INSTRUCTION ON MOTIVATION AND ACHIEVEMENT

Dear Parent:

I would like to involve your fourth grader in a Math Development Program. This program is designed to assess, evaluate and improve your child's multiplication skills. Your child will benefit from the extra instruction, which will occur during the school day and will be in addition to the regular instruction. Last week , I sent a letter to your home about this program. Your child may be in the program if you sign this consent form.

Thank you for your cooperation.

Sincerely,

Jane Hessemer Stegemann, M.S.
Beaufort School District

My child ______________________________
(name)

(check one)

________MAY be in the program.
________MAY NOT be in the program.

Parent
Signature ______________________________ Date ________

THANK YOU FOR YOUR COOPERATION

Appendix D

Posttest Multiple Analysis of Covariance of Students' Prism Achievement Test

Source	*df*	*MS*	*F*	*p*
Method of Instruction (MI)	2	133.62	.49	.61
Type of Achiever (TA)	1	.34	.00	.97
MI x TA	2	335.56	1.23	.30
Exposure Time covariate	1	43.19	.16	.69
Content Difficulty covariate	1	1011.76	3.70	.06
Pretest covariate	1	4265.53	15.62	.00
All Covariates	3	3129.41	11.46	.00
Students within groups	60	273.13		

Note. *N* = 69.