DOCUMENT RESUME

ED 443 079		CS 014 013
AUTHOR	Soe, Kyaw; Koki, Stan; Chang, Juvenna M.	
TITLE	Effect of Computer-Assisted Instruction (CAI) on Reading Achievement: A Meta-Analysis.	
INSTITUTION	Pacific Resources for Education and Learning, Honolulu, HI.	
SPONS AGENCY	Office of Educational Research and Improvement (ED), Washington, DC.	
PUB DATE	2000-06-00	
NOTE	26p.	
CONTRACT	RJ96006601	
PUB TYPE	Numerical/Quantitative Data (110) -- Reports - Evaluative (142)	
EDRS PRICE	MF01/PC02 Plus Postage.	
DESCRIPTORS	Classroom Techniques; *Computer Assisted Instruction; Elementary Secondary Education; Literature Reviews; Meta Analysis; *Reading Achievement; *Reading Instruction; Reading Research	
IDENTIFIERS	Research Results	

ABSTRACT

Whether computer-assisted instruction (CAI) can improve reading achievement of students has been a crucial question addressed by studies in the past. This meta-analysis reviewed 17 research studies based on K-12 students and revealed that CAI does have a positive effect on reading achievement. Although the effects of CAI in the 17 studies were not homogeneous, there seems to be no particular study characteristic that might have caused the heterogeneity. Findings suggest computer applications to teach reading hold great promise as instructional tools. (Contains 8 tables of data, 4 figures, and 21 references. Attached is a list of the 17 studies reviewed.) (Author/NKA)

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By Kyaw Soe, Ph.D, Stan Koki, Juvenna M. Chang, Ed.D

PREL

PACIFIC RESOURCES FOR EDUCATION AND LEARNING

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PRÉL

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*Kyaw Soe is Director of the Pacific Data Center at Pacific Resources for Education and Learning (PREL); Stan Koki is a Program Specialist at PREL; and Juvenna Chang is Director of the Regional Educational Laboratory, a PREL program.

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Abstract

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The work reported herein was supported under the Regional Educational Laboratory program, contract number RJ96006601 (CFDA 84.RD), as administered by the Office of Educational Research and Improvement, U.S. Department of Education. The findings and opinions expressed in this report do not necessarily reflect the positions or policies of Pacific Resources for Education and Learning, the Office of Educational Research and Improvement, or the U.S. Department of Education.

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ACKNOWLEDGEMENTS

The authors would like to express their thanks to the following individuals who shared their valuable expertise with us by reviewing this meta-analysis:

For technical review—Dr. Shuqiang Zhang, Professor, Department of Educational Psychology, College of Education, University of Hawai'i; and Dr. Chuanfa Guo, Assistant Professor, Cancer Research Center of Hawai'i;

For content review—Dr. Zoe Ann Brown, Program Director at PREL, whose background includes reading development and achievement.

We benefited greatly from the comments and wisdom these reviewers generously shared with us. In spite of their many contributions, the authors assume ultimate responsibility for the content of this report.

Kyaw Soe
Stan Koki
Jeve Chang

INTRODUCTION

Background

There is general agreement that reading is essential to success in our society. The ability to read is highly valued and important for social and economic advancement (Snow, Burns, & Griffin, 1998). The consensus supports the belief that reading is fundamental.

Most children learn to read fairly well. However, there are children in America whose educational concerns are at risk because they do not read well enough to ensure understanding or to meet the demands of an increasingly competitive economy and changing demographics. It is the opinion of Pacific educators that not all of the children in Pacific schools are learning to read as well as they should. Many of them are experiencing serious difficulty in learning to read, and as they progress through the grades, they continue to lag in reading achievement.

While the actual number of children who are poor readers is being debated, one widely accepted indicator is that 40 percent of all U.S. nine-year-olds score below the "basic" level on the National Assessment of Educational Progress (National Center for Education Statistics [NCES], 1999b). However "poor reader" is defined, the number of poor readers in our midst is too high (McPike, 1998).

According to Learning First Alliance, the reading problems of U.S. children are not new. Overall reading performance has remained about the same since the first NAEP report was issued. Clearly, our children still need much support in learning to read and in using reading as a tool for learning (Snow, Burns, & Griffin, 1998).

Computer-Assisted Instruction (CAI) is among the range of strategies being used to improve student achievement in school subjects, including reading. Programs for CAI have come a very long way since they were first developed over two decades ago. These programs tutor and drill students, diagnose problems, keep records of student progress, and present material in print and other manifestations. It is believed that they reflect what good teachers do in the classroom (Kulik, Bangert, & Williams, 1983).

Students are expected to benefit from CAI. Among the benefits that have been expected are better and more comfortable learning for students, since they learn at their own pace and convenience; opportunities to work with vastly superior materials and more sophisticated problems; personalized tutoring; automatic measurement of progress; and others.

Teachers as well are expected to gain from CAI, as they experience less drudgery and repetition, greater ease in updating instructional materials, more accurate appraisal and documentation of student progress, and more time to work directly with students (Kulik, Bangert, & Williams, 1983). With increasing advances in computer technology, computer-assisted instruction (CAI) is now seen by many as a method of providing relevant instruction for large numbers of students.

A number of different approaches to the use of computers in education are reflected in educational practices. A useful classification of these approaches is that of Goldberg and Sherwood (1983). Of these categories—*Learning from computers*, *Learning about computers*, and *Learning about thinking with computers*—the most relevant to this study is *Learning from computers*.

Learning from computers encompasses approaches to CAI in which the computer is used as a means for transmitting specific subject matter, such as reading. The flow of information is basically from the computer to the student, with the computer presenting learning material or activities for student responses. The computer retains records of the student's progress through the course of study. Based on the degree of interaction between student and computer, researchers have identified three levels of CAI:

Drill and practice: The computer provides the student with exercises that reinforce the learning of specific skills taught in the classroom, and supplies immediate feedback on the correctness of the response. Used in this manner, CAI functions as a supplement to regular classroom instruction, and may be especially useful when a teacher does not have the time to work individually with each student. Drill and practice on the computer may also motivate students more than traditional workbook exercises.

Tutorial: Tutorial CAI provides some information or clarifies certain concepts in addition to providing the student with practice exercises. In this sense, the computer begins to take over actual instructional functions, tailored to the student's individual level of achievement.

Dialogue: With this type of computer use, the student takes an active role in interacting with the computer, giving instructions in the form of a computer language so as to structure the student's own curriculum. The computer provides information, exercises, and feedback. Dialogue CAI is believed to come closest to actually substituting for regular instruction (Gourgey, Azumi, Madhere, & Walker, 1984).

The verdict for the use of computers in education seems to be in. As stated by the National Center for Education Statistics (NCES):

> *Computers have become an essential tool in our society. Early exposure to computers may help students gain the computer literacy that will be crucial for future success in the workplace. Access to computers at school and at home allows students to retrieve information, manipulate data, and produce results efficiently and in innovative ways. Examining the extent to which students have access to computers at school and at home may be an indicator of how well-prepared students will be to enter an increasingly technological workplace. (NCES, 1999a, p.64)*

Has computer-assisted instruction (CAI) produced benefits that result in greater achievement for students, in this case in reading?

Soon after the introduction of CAI, educational researchers began to develop evaluation studies to answer this question. Although these evaluation studies produced potentially useful information on the effects of CAI, their messages were shrouded in ambiguity. One reason for unclear messages was that each evaluation report was published separately, making the total picture somewhat murky.

Another problem had a deeper and more serious nature. These evaluation studies were never exact replications of one another. They differed in experimental design and execution, setting, and the type of computer applications investigated. To confound matters, evaluation findings or results tended to differ from one investigation to another. Findings from different studies differed from each other, with some studies producing contradictory results. As well, many of the reviews are typically narrative and discursive in presentation, resulting in their multiplicity of findings not capable of being absorbed by the reader without quantitative methods of reviewing (Kulik, Bangert, & Williams, 1983).

Because of the shortcomings of the traditional approach of narrative reviews of research studies, attempts have been made to identify more promising methods of research investigation and research evaluation. Glass (1976) was the first to deal with the information overload problem by introducing a novel and comprehensive method that allows one to estimate the average effect of treatments on outcome variables across numerous studies. He coined the term "meta-analysis," and distinguished it from primary analysis and secondary analysis.

Primary analysis is the original research that includes data collection, data processing, and publication of results. Secondary analysis requires a different investigator who, following the same research question, conducts an analysis of the original data from either a different perspective or with different techniques. Meta-analysis draws upon the summary statistics of a variety of studies without having access to the original data. According to Glass, the aim of meta-analysis is to integrate a large number of results, with the focus not on statistical significance but on the size of treatment effects (Schwarzer, 1998).

In 1977, Hartley was the first to apply meta-analysis to findings on CAI. Her study focused on mathematics education in elementary and secondary schools. She reported that the average effect of CAI was to raise student achievement by .41 standard deviations, or from the 50th to the 66th percentile. She also reported that the effects of CAI were not so large as those produced by programs of peer and cross-age tutoring. However, they were far larger than effects produced by programmed instruction or use of individual learning packets. As well, Hartley discovered only small effects of study features on study outcomes (Kulik, Bangert, & Williams, 1983).

PREL Meta-Analysis

This meta-analysis conducted by Pacific Resources for Education and Learning (PREL) attempts to shed further light on the effectiveness of CAI on student achievement in reading by synthesizing diverse studies that have been conducted on the topic. The **problem** being addressed is: *What is the effect of CAI on the reading achievement of students in grades K-12?*

This problem is posed within the larger context of whether or not computers present a workable method of instruction—that is, are they efficient and cost effective as an educational tool? Educators hope that computer use will inspire children turned off by traditional paper and pencil methods to achieve at levels beyond those currently being achieved. Concerns for fiscal feasibility may become negligible if it can be demonstrated that children exposed to computer-assisted instruction are happier, more productive members of society, gaining more academically and becoming better equipped to compete globally through computer use (Hamilton, 1995). With technology and software changing so rapidly, researchers must continue to explore their different aspects on achievement.

Major Challenges

Two major challenges were encountered in conducting this meta-analysis. First, the process is described through a plethora of terminology. This diversity includes computer-assisted instruction (CAI), computer-based instruction (CBI), computer-based learning (CBL), computer-based teaching (CBT), computer-managed instruction (CMI), and a generous sprinkling of other terms. For the purpose of this report, computer-assisted instruction (CAI) is used consistently.

The second challenge refers to the rapidly evolving nature of computer technology. From reliance on the use of a mainframe computer in the Stanford project (Stanford Computer Assisted Instruction) to develop programs capable of individualizing reading instruction for students in kindergarten through third grade (Singhal, 1998) to use of individual computer stations for students independent of a main frame, the field is now characterized by a tremendous range of uses of computer technology that includes sophisticated WEB-based distance learning and hypermedia. Hypermedia programs allow the user to integrate sound, animation, graphics, and text through a variety of paths into one document. Hypermedia was designed to allow the student control of his own learning by using a variety of stimuli and his own interests as guides (Hamilton, 1995). Indeed, developments in computer technology have been occurring so swiftly that one would be hard pressed to predict with confidence what the next few years will bring in computer-assisted instruction (Kulik, Bangert, & Williams, 1983).

In reviewing the integrative analysis that follows, the reader may easily lose touch with the kinds of research being integrated. The statistics and graphs that represent the findings of this meta-analysis of the impact of CAI on reading achievement will seem very remote from the studies themselves. And, in a real sense, the statistical manipulations carried out in order to arrive at general conclusions may undoubtedly place the reader in a position of losing qualitative or personal familiarity with the research (Glass, McGaw, & Smith, 1981).

Objectives and Hypotheses

This meta-analysis seeks to answer the following questions:

- How effective is computer-assisted instruction in teaching students to read?
- Is it especially effective for certain types of outcomes or certain types of students?
- Under what conditions is computer-assisted instruction most effective for the teaching of reading?

In the research reported here, an attempt has been made to correct technical shortcomings of available research studies in order to determine if the huge body of research literature on reading achievement really is hopelessly confusing, or whether the messages are merely buried in myriad results awaiting discovery through application of more advanced methods of research investigation. An underlying belief is that computer-assisted instruction and computer programs to teach reading may hold great promise for becoming powerful instructional tools that increase students' engagement in reading, enhance reading comprehension, and improve reading skills (Singhal, 1998).

METHODOLOGY

In this section, the methods described are those by which the studies were identified, selected for this review, and coded; and the quantitative findings integrated.

Literature Search

The literature search for this report was carried out in three phases: (1) document retrieval and abstracting resources; (2) previous reviews of the CAI and reading achievement literature; and (3) the bibliographies of studies once found, including footnote chasing.

Studies were obtained by initially conducting computerized database searches of Educational Resources Information Center (ERIC) from September 1982 to September 1998, and PsycINFO from 1982 to 1998. Key terms entered for these databases were "reading and computer," "reading and CAI," and "reading achievement and CAI." Studies that were already known to the researchers were also included. In addition, footnote chasing was carried out as part of the reading process, and bibliographies of the study reports that were read were carefully reviewed to collect additional studies. A total of 33 studies were identified and collected for this analysis.

Criteria for Inclusion

To be included in this analysis, each study had to meet the following criteria:

- The study was published between January 1982 and January 1999.
- The study report contained sufficient data for calculations in the meta-analysis.
- The study focused on the effect of computer usage (CAI/CBI), and at least one of the dependent variables was related to reading achievement or reading comprehension.
- The subjects in the study were students in grades K-12.

Of the 33 studies collected, 17 studies met the above criteria and served as the basis for this meta-analysis.

Coding of Studies

In case there was variation among the effect sizes of the 17 studies, it was necessary to trace the cause of such variation. Therefore, characteristics of the included studies were coded. The primary study characteristics for this analysis were as follows:

- Sampling method (some form of random sampling vs. convenient sampling)
- Control group (present or absent)
- Duration of treatment (one week, one month, one semester, etc.)
- Population of subjects (from special populations—such as minority groups, educationally disadvantaged, or low income—or not)
- Software used for CAI (commercial software or not)
- Computer platform used (Macintosh, DOS, Windows, Mainframe, etc.)
- Instrument used to measure reading achievement (standardized or not)
- Grade level of subjects
- Actual sample size
- Published year of study report
- Statistics used (e.g., Chi-Square, t test, F test)
- Publication type (thesis/dissertation, journal, etc.)

Three researchers at Pacific Resources for Education and Learning (PREL) discussed how to code the study characteristics. Then, studies included in this meta-analysis were coded independently, and the three researchers met again to compare the results of the coding process and discussed and solved the differences in coding to obtain the final coding results.

Analysis and Findings

Description of Selected Studies

Seventeen studies met the criteria for inclusion in this meta-analysis. The characteristics of the studies are presented in Tables 1 - 7. Of the 17 studies since 1982, 41 percent of the studies were published since 1994 (see Table 1). Only 29 percent of the studies were published in journals (see Table 2). Most of the studies (88%) used standardized instruments to measure the reading achievement of the students (see Table 3). Subjects in two-thirds of the studies came from low-income backgrounds or minority families, or were educationally disadvantaged (see Table 4). The majority of the studies (53%) used sample sizes less than 50 (see Table 5). About 18 percent of the studies were conducted with students in high schools (see Table 6). In 65 percent of the studies, treatments were between five months to one school year, while 24 percent were short-term, lasting four months or less (see Table 7). The 17 studies included in this meta-analysis are listed at the end of this report.

Table 1
STUDY REPORTS BY YEAR OF PUBLICATION

Publication Year	Number of Studies	Percentage of Studies
1982-85	1	6
1986-89	4	24
1990-93	5	29
1994-97	7	41
Total	17	100

Table 2
STUDY REPORTS BY PUBLICATION SOURCE

Source	Number of Studies	Percentage of Studies
ERIC Document	11	65
Journal	5	29
Thesis	1	6
Total	17	100

Table 3
STUDY REPORTS BY INSTRUMENT USED

Instrument	Number of Studies	Percentage of Studies
Standardized	15	88
Non-Standardized	1	6
Unknown	1	6
Total	17	100

Table 4
STUDY REPORTS BY POPULATION OF SUBJECTS

Special Population	Number of Studies	Percentage of Studies
Minority/Migrant	4	24
Educationally Disadvantaged	3	18
Low Socio-Economic Status	4	24
Rural	1	6
Urban/Suburban	2	12
Other	3	18
Total	17	102 *

* Note: Percentages may not add to 100 due to rounding.

Table 5
STUDY REPORTS BY SAMPLE SIZE

Sample Size	Number of Studies	Percentage of Studies
Less than 30	1	6
30 - 49	8	47
50 - 99	4	24
100 - 199	2	12
200 or more	2	12
Total	17	101 *

* Note: Percentages may not add to 100 due to rounding.

Table 6
STUDY REPORTS BY GRADE LEVEL OF SUBJECTS

Grade Level	Number of Studies	Percentage of Studies
1-2	2	12
2-8	2	12
3	1	6
3-6	2	12
3-8	1	6
4	2	12
5	1	6
6	2	12
7	1	6
9	2	12
10-11	1	6
Total	17	102 *

* Note: Percentages may not add to 100 due to rounding.

Table 7
STUDY REPORTS BY TREATMENT DURATION

Treatment Duration	Number of Studies	Percentage of Studies
1 - 4 months	4	24
5 months - 1 SY	11	65
More than 1 SY	2	12
Total	17	101 *

SY = School Year

* Note: Percentages may not add to 100 due to rounding.

Computation of Effect Sizes

Most of the studies included tests of significance and significance levels. However, reports on tests of significance were more accurate than those on the levels of significance. For example, when a study reported t value, degree of freedom, and p value as 8.53, 45, and $p < .01$ respectively, it would be more accurate to estimate the effect size based on the t value and its degree of freedom than estimating from $p = .01$. Therefore, tests of significance were used to compute the effect sizes in this meta-analysis.

In deciding whether the d-type effect size or r-type effect size should be used in this study, the researchers decided to use the r-type effect size, primarily because r-type effect size is more useful for the following reasons:

- Given a d-type effect size, r makes perfectly good sense in its point biserial form if the independent variable has just two levels.
- The r-type effect size requires no computational adjustment in going from the two-sample or multi-sample to the one sample case. This is not the case with the d-type effect size.
- R-type effect size can be interpreted more simply in terms of practical importance than can d-type effect size (Cooper & Hedges, 1994).

It is a well-known fact that the farther the r value of a population is away from zero, the more the distribution of r values sampled from that population becomes skewed. This will complicate the combination of r values (Fisher, 1928). If r values are transformed into Fisher's Z_r values, the distribution will be nearly normal (Cooper & Hedges, 1994). Therefore, each r-type effect size was later transformed into Fisher's Z_r using the following formula:

$$Z_r = \frac{1}{2}\log_e\left[\frac{1+r}{1-r}\right]$$

Most of the studies reported t test results for independent groups. In those cases, effect sizes were computed using the following formula:

$$r = \sqrt{\frac{t^2}{t^2 + df}}$$

In very rare cases, effect sizes were computed from the raw data when raw data were provided and the test used was deemed inappropriate in computing the desired effect size.

Combining Effect Sizes

Two steps were taken prior to the computation of the overall effect size. First, it was decided that effect sizes with larger samples should be more heavily weighted. Thus, each Z_r value was multiplied by (n - 3) to obtain the weighted effect size, where (n - 3) was the inverse of the conditional variance of Z_r.

Second, the problem of studies with more than one test of significance had to be resolved. In the current analysis, some studies employed more than one test of significance yielding more than one effect size. Thus, the 17 studies in this meta-analysis yielded 40 effect sizes, as shown in Table 8. If all of these 40 effect sizes were used to compute the overall effect size of CAI on reading achievement, studies contributing more than one effect size would have more weight on the outcome of the meta-analysis. Rosenthal's recommendation is to have each study contribute only a single effect size (Rosenthal, 1991, p. 27). Therefore, for each study yielding more than one effect size, an overall effect size for that study was computed.

Table 8
FORTY INDIVIDUAL EFFECT SIZES FROM 17 STUDIES

No.	Study	Sample n	Effect Size Z_r	Weighted ES $(n - 3)Z_r$
1	Marcinkiewicz. 1988	30	0.147	3.971
2	Ngaiyaye & VanderPloge, 1986	138	0.191	25.762
3	Ngaiyaye & VanderPloge, 1986	190	0.108	20.180
4	Ngaiyaye & VanderPloge, 1986	137	0.027	3.655
5	Ngaiyaye & VanderPloge. 1986	116	0.039	4.449
6	Hamilton. 1995	46	0.054	2.333
7	Jones. 1993	30	0.129	3.496
8	Saracho. 1982	256	0.172	43.434
9	Peak & Dewalt. 1993	50	0.243	11.440
10	Mathis. 1996	60	0.244	13.924
11	Hardman. 1994	42	0.247	9.644
12	Greenlee-Moore & Smith, 1994	31	0.254	7.099
13	Davidson. Elcock & Noyes, 1996	60	0.313	17.855
14	Williams. 1993	108	0.472	49.611
15	Arroyo, 1992	30	0.621	16.761
16	Tillman. 1995	30	0.762	20.566
17	Casteel. 1989	20	0.228	3.875
18	Heise. Papalewis. & Tanner. 1991	56	0.249	13.198
19	Heise. Papalewis. & Tanner. 1991	56	0.030	1.575
20	Reitsma. 1988	35	0.255	8.149
21	Reitsma. 1988	35	0.121	3.868
22	Reitsma. 1988	35	0.118	3.777
23	Reitsma, 1988	35	0.311	9.940
24	Reitsma. 1988	34	0.221	6.855
25	Reitsma, 1988	34	0.096	2.988
26	Reitsma. 1988	35	0.084	2.694
27	Reitsma. 1988	35	0.062	1.977
28	Reitsma, 1988	34	0.074	2.298
29	Paul. Swanson. Zhang, & Hehenberger, 1997	689	0.089	60.981
30	Paul. Swanson. Zhang. & Hehenberger, 1997	689	0.209	143.111
31	Paul. Swanson. Zhang, & Hehenberger, 1997	687	0.079	54.004
32	Paul, Swanson. Zhang. & Hehenberger, 1997	687	0.220	150.283
33	Paul, Swanson. Zhang. & Hehenberger, 1997	672	0.023	15.657
34	Paul, Swanson. Zhang, & Hehenberger, 1997	672	0.196	130.928
35	Paul. Swanson. Zhang. & Hehenberger. 1997	504	0.065	32.611
36	Paul, Swanson, Zhang, & Hehenberger, 1997	504	0.167	83.430
37	Paul, Swanson. Zhang, & Hehenberger, 1997	399	0.004	1.501
38	Paul, Swanson. Zhang, & Hehenberger, 1997	399	0.131	52.051
39	Paul, Swanson, Zhang, & Hehenberger, 1997	395	0.077	30.149
40	Paul. Swanson. Zhang. & Hehenberger. 1997	395	0.155	60.863

Table 9 shows the resulting 17 calculated composite effect sizes from the 17 studies.

Table 9
CALCULATED COMPOSITE EFFECT SIZES OF 17 STUDIES

No.	Study	Sample n	Effect Size Z_r	Weighted ES $(n - 3)Z_r$
1	Marcinkiewicz. 1988	30	0.147	3.971
2	Ngaiyaye & VanderPloge. 1986	148	0.095	54.046
3	Heise. Papalewis. & Tanner. 1991	56	0.139	14.773
4	Reitsma. 1988	35	0.045	12.683
5	Paul. Swanson. Zhang. & Hehenberger. 1997	558	0.123	815.569
6	Hamilton. 1995	46	0.054	2.333
7	Jones. 1993	30	0.129	3.496
8	Saracho. 1982	256	0.172	43.434
9	Peak & Dewalt. 1993	50	0.243	11.44
10	Mathis. 1996	60	0.244	13.924
11	Hardman. 1994	42	0.247	9.644
12	Greenlee-Moore & Smith. 1994	31	0.254	7.099
13	Davidson. Elcock. & Noyes. 1996	60	0.313	17.855
14	Williams. 1993	108	0.472	49.611
15	Arroyo. 1992	30	0.621	16.761
16	Tillman. 1995	30	0.762	20.566
17	Casteel. 1989	20	0.228	3.875

From Table 9, the overall effect size of 0.1316 was obtained by using the following formula:

$$Overall\ Z_r = \frac{\Sigma(n-3)Z_r}{\Sigma(n-3)}$$

Standard error of the Overall Z_r was computed using the following formula and was found to be 0.0109.

$$Standard\ Error = \sqrt{\frac{1}{\Sigma(n-3)}}$$

Thus. the overall effect size of 0.1316 was significantly different from zero since Z for the studies combined = 0.1316/0.0109 = 12.04, which exceeded the critical value of 1.96 for $\alpha = .05$ in the standard normal distribution. The lower and upper limits of the 95% confidence interval of the overall effect size were found to be L_L = 0.1316 - [1.96(0.0109)] = 0.1101 and L_U = 0.1316 + [1.96(0.0109)] = 0.1530 respectively.

For interpretability, the overall effect size Z_r and its lower and upper 95% confidence limits were transformed back into estimates of correlations using the formula $r = (e^{2Z} - 1)/(e^{2Z} + 1)$. It was found that the overall correlation and its lower and upper limits were 0.1308, 0.1097, and 0.1518 respectively. These results indicate that CAI promotes higher achievement in reading than instruction without CAI.

0.7	6
0.6	2
0.5	
0.4	7
0.3	1
0.2	34455
0.1	023457
0.0	55

Figure 1. Stem-and-leaf plot of the sample distribution of effect size in 17 studies

However, a closer look at the stem-and-leaf plot of effect sizes in 17 studies (Figure 1) showed that they looked very heterogeneous. Thus, a test of homogeneity of the effect sizes was performed. Using the formula $Q = \sum[(Z_r - \text{overall effect size})^2 (n - 3)]$, the value of Q for homogeneity was found to be 182.236, which exceeds the critical value of the chi-square distribution for $k = 17 - 1 = 16$ degrees of freedom. Thus, the 17 effect sizes in the studies are clearly heterogeneous.

To understand the reasons for the heterogeneity of effect sizes, the researchers consulted the studies to search for the study characteristics that might have caused the variation among the studies. Since the number of included studies was only 17, scatter plots were used to check whether there was systematic variation among the effect sizes due to some characteristics of the 17 studies. Figures 2 - 4 indicate that there seem to be no systematic variation among the effect sizes due to the sample size, the duration of CAI treatment, or the grade level of students in the 17 studies.

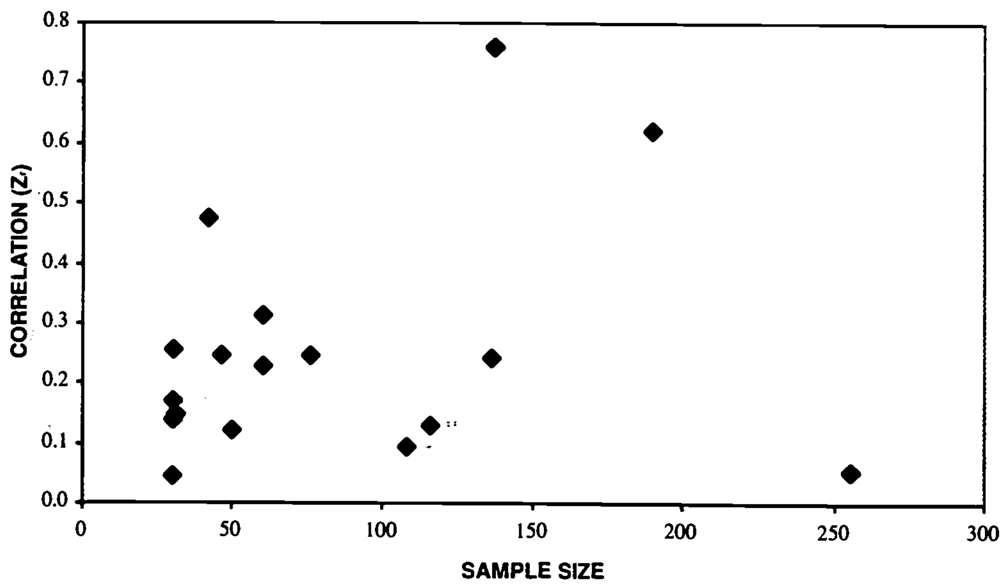


Figure 2. **Effect size (estimated Fisher's Z_r between CAI and Reading Achievement) displayed as function of sample size (n = 17)**

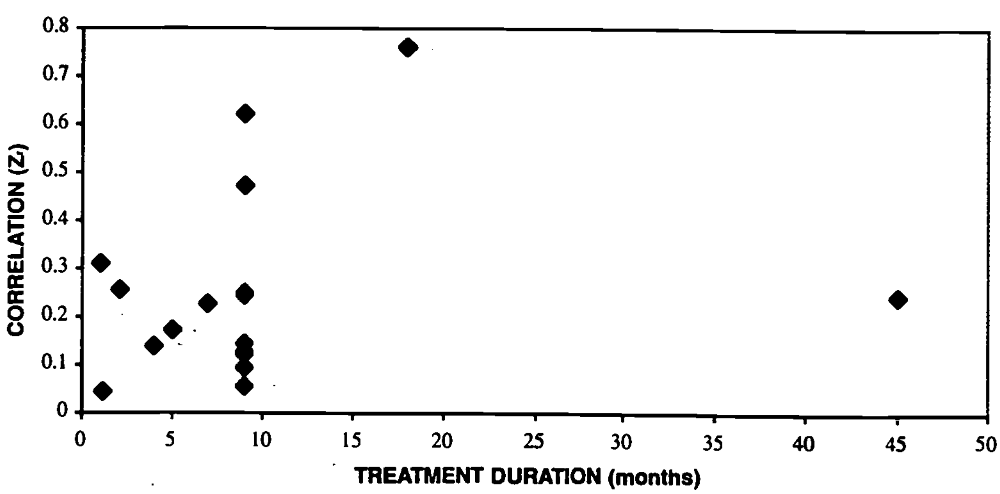
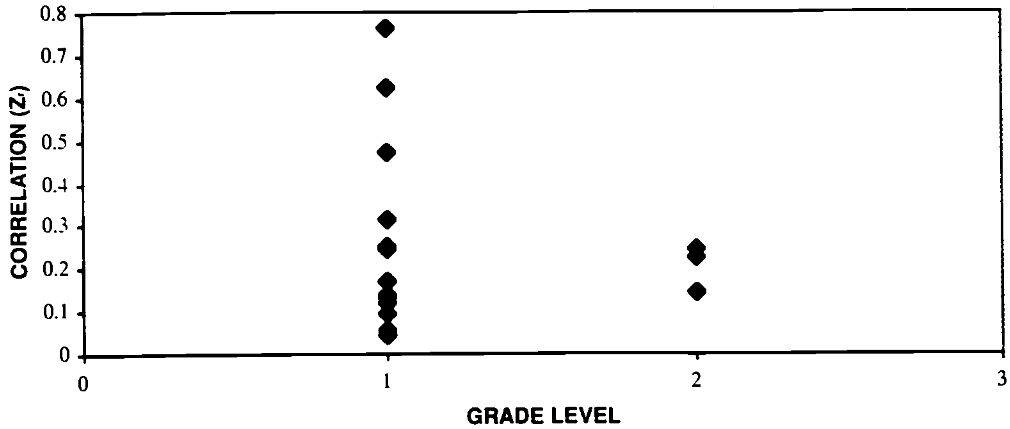


Figure 3. **Effect size (estimated Fisher's Z_r between CAI and Reading Achievement) displayed as function of duration of treatment (n = 17)**



1 = Grades 1 - 8, 2 = Grades 9 - 12

Figure 4. **Effect size (estimated Fisher's Z_r between CAI and Reading Achievement) displayed as function of grade level of subjects (n = 17)**

The File Drawer Problem

There is suspicion among statisticians and researchers that 5 percent of the published studies contain significant results that in reality are not significant, while the majority of the unpublished studies contain nonsignificant results (Rosenthal, 1979; Rosenthal & Rubin, 1988). Therefore, many believe that the published studies are a biased sample of the studies actually carried out (Bakan, 1967; McNemar, 1960; Smart, 1964; Sterling, 1959). In this meta-analysis only 17 studies were included, and the finding was that CAI promotes higher reading achievement. What would happen to this finding if there were studies that could have been included in this meta-analysis, but were not?

There are three possible types of non-retrieved or new studies for this meta-analysis:

1. The studies in which the average result is that CAI promotes reading achievement (i.e., positive effect). These studies would not change the finding of this meta-analysis. Thus, there should be no concern about them.
2. The studies in which the average result is that CAI is harmful for reading achievement (i.e., negative effect). There was no indication of such a finding among the 17 studies in this meta-analysis. Theoretically, there is no indication that CAI is harmful for reading achievement.
3. The studies in which the average result is that CAI does not promote reading achievement. These studies could change the finding of this meta-analysis. Therefore, this type of study always concerns meta-analysts.

The number of non-retrieved or new studies indicating no CAI effects that would be required in order to change the conclusion that CAI promotes higher reading achievement was estimated using the formula:

X = [K(K(Mean Z) - 2.706] / 2.706] where X is the number of non-retrieved or new studies and K is the number of studies in the meta-analysis (Rosenthal, 1991, p.104).

In the above formula, mean Z of the 17 studies was substituted with the expression (Z for the studies combined)/$\sqrt{K}$ where K is the number of studies in the meta-analysis.

It was found that a total of 893 non-retrieved or new studies, averaging no CAI effect results. are necessary to conclude that there is no evidence of CAI effect on reading achievement.

Conclusions

Summary

This study tried to statistically combine the results of the studies that dealt with the important question of whether computer-assisted instruction is effective in raising the reading achievement of students in K-12. Literature searches were carried out using the ERIC database, the PsycINFO database, and relevant Internet sites followed by footnote chasing. Seventeen studies met the criteria for inclusion in the meta-analysis. Study characteristics were coded by three meta-analysts at Pacific Resources for Education and Learning.

The method of meta-analysis was employed in the following order. (i) The r-type effect sizes were computed. (ii) These correlations were transformed into Fisher's Z_r values. (iii) The Z_r values were weighted by the sample size of each study. (iv) The overall effect size Z_r and its lower and upper 95% confidence limits were computed and found to be 0.1316, 0.1101, and 0.1530 respectively. (v) The overall effect size Z_r was tested using the standard normal distribution. It was found to be highly significant ($Z = 12.04$, $p < .0000$). (vi) For interpretability, the overall effect size Z_r and its lower and upper limits at 95% confidence level were transformed back into estimates of correlations between CAI and reading achievement. The lower and upper limits were found to be 0.1097 and 0.1518 respectively. The fact that 95% confidence interval did not include zero confirmed the finding that the effect of CAI on reading achievement was significantly higher than zero. (vii) The tolerance of this finding was checked for non-retrieved or new studies. Using Rosenthal's formula. the number of studies not included in this meta-analysis that could change the current finding, provided that their findings indicated no CAI effect on reading achievement, was found to be 893. Thus, the finding of this meta-analysis was deemed highly tolerant.

A test of homogeneity revealed that the effects of CAI on reading achievement in 17 studies were not homogeneous. Scatter plots were used in an attempt to find the cause of variation among the effect sizes in 17 studies. But, there seemed to be no particular study characteristic that might have caused the variation systematically.

Discussion

The overall finding of this meta-analysis is that computer-assisted instruction has a positive impact on reading achievement. However, there is a wide range in the foci, procedures, materials, and findings among the studies included in this meta-analysis. In some cases, a scarcity of acceptable studies was evident in many categories. Therefore. the results given here must be interpreted with caution until a greater number of similar studies with similar reporting styles is available to confirm or refute the findings.

Lack of sufficient numbers of studies in key areas could perhaps be the greatest barrier to the systematic assessment of the impact of CAI on the teaching of reading. Findings indicate that computer applications can play a significant role in teaching and learning. However, the precise nature of that role still needs to be researched with greater depth and precision.

Learning is a complex endeavor. Therefore, it goes without saying that the use of CAI alone may be insufficient in the teaching of reading. While CAI as an instructional tool has been effective in raising reading achievement, especially when used to supplement traditional instruction, other variables need to be considered in the teaching of reading.

Implications

In light of the finding that computer-assisted instruction (CAI) promotes higher reading achievement, it is important to note the implications of this meta-analysis. Consideration could be given to programmatic implications as well as to implications for further research by posing the following questions:

1. What currently available software focuses on the improvement of reading achievement for grades K-12?
2. What developmental products are on the horizon that would support CAI instruction to increase reading achievement?
3. What do schools need to have in place to provide equal access to CAI in reading for all students?
4. What components of a reading curriculum and of reading instruction provide the most positive results with CAI?
5. What effect does CAI have on reading achievement for special populations (i.e., minority/migrant, educationally disadvantaged, low socio-economic status)?
6. What are the most effective strategies for implementing CAI in reading (i.e., stand-alone vs. integrated instruction; in-classroom vs. pull-out program; length of time for instruction; distance learning; web-based instruction)?
7. What is the role of the teacher in the effective use of CAI?
8. What implications do new technologies have for CAI in reading?

Computer applications to teach reading hold great promise as instructional tools to increase students' engagement in reading, promote reading comprehension, and improve reading skills. CAI can assist teachers in developing a more individualized approach to reading instruction to meet the diverse range of students' needs in classrooms. Teachers can be empowered to vary the pace of instruction, review student learning, teach and reinforce specific skills and strategies, improve motivation, and provide students with relevant and timely feedback.

Reading instruction aligned with computer-assisted instruction can serve as a powerful teaching tool to assist teachers in helping students reach their potential in reading.

REFERENCES

Bakan, D. (1967). *On method.* San Francisco, CA: Jossey-Bass.

Cooper, H., & Hedges, L. V. (1994). *The handbook of research synthesis.* New York: Russell Sage Foundation.

Fisher, R. A. (1928). *Statistical methods for research workers* (2nd ed.). London: Oliver & Boyd.

Glass, G. V. (1976). Primary, secondary, and meta-analysis of research. *Educational Researcher. 5,* 3-8.

Glass, G. V., McGaw, B., & Smith, M. L. (1981). *Meta-analysis in social research.* Beverly Hills, CA: Sage.

Goldberg, K., & Sherwood, R. (1983). *Microcomputers: A parent's guide.* Somerset, NJ: Wiley.

Gourgey, A., Azumi, J., Madhere, S., & Walker, E. (1984). *Computer-assisted instruction evaluation report, 1983-84 school year.* Washington, DC: U.S. Department of Education. Office of Educational Research and Improvement.

Hamilton, V. (1995). *Computers and reading achievement.* (ERIC Document Reproduction Service No. ED382923)

Kulik, J. A., Bangert, R. L., & Williams, G. W. (1983). Effects of computer-based teaching on secondary school Students. *Journal of Educational Psychology, 75*(1), 19-26.

McNemar, Q. (1960). At random: Sense and nonsense. *American Psychologist, 15,* 295-300.

McPike, E. (1998). The unique power of reading and how to unleash it. *American Educator, 22*(1, 2), 4-5.

National Center for Education Statistics (NCES). (1999a). *Conditions of education.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement. (NCES No. 1999-022)

National Center for Education Statistics (NCES). (1999b). *NAEP 1998 Reading: Report card for the nation and the states.* Washington, DC: U.S. Department of Education. Office of Educational Research and Improvement. (NCES No. 1999-500)

Rosenthal, R. (1979). The "file drawer problem" and tolerance for null results. *Psychological Bulletin, 86,* 638-641.

Rosenthal, R. (1991). *Meta-analytic procedures for social research.* Newbury Park, CA: Sage.

Rosenthal, R, & Rubin, D. B. (1988). Comment: Assumptions and procedures in the file drawer problem. *Statistical Science, 3,* 120-125.

Schwarzer, R. (1998). *Statistics software for meta-analysis.* [Online]. Available: http://userpage.fu-berlin.de/~health/meta_e.htm [1999, November].

Singhal, M. (1998). *Using computers as reading instructional tools: Applications and implications.* (ERIC Document Reproduction Service No. ED419225)

Smart, R. G. (1964). The importance of negative results in psychological research. *Canadian Psychologist, 5a,* 225-232.

Snow, C. E., Burns, M. S., & Griffin, P. (1998). *Preventing reading difficulties in young children.* Washington, DC: National Research Council.

Sterling, T. D. (1959). Publication decisions and their possible effects on inferences drawn from tests of significance—or vice versa. *Journal of the American Statistical Association, 54,* 30-34.

RESEARCH STUDIES

These 17 studies met the inclusion criteria and thus were included in the meta-analysis.

Arroyo, C. (1992). *What is the effect of extensive use of computers on the reading achievement scores of seventh grade students?* (ERIC Document Reproduction Service No. ED353544)

Casteel, C. A. (1989). Effects of chunked reading among learning disabled students: An experimental comparison of computer and traditional chunked passages. *Journal of Educational Technology Systems, 17*(2), 115-121.

Davidson, J., Elcock, J., & Noyes, P. (1996). A preliminary study of the effect of computer-assisted practice on reading attainment. *Journal of Research in Reading, 19*(2), 102-110.

Greenlee-Moore. M. E., & Smith, L. L. (1994). *Interactive computer software: The effects on young children's reading achievement.* (ERIC Document Reproduction Service No. ED384019)

Hamilton, V. (1995). *Computers and reading achievement.* (ERIC Document Reproduction Service No. ED382923)

Hardman, R. (1994). *The effect of CAI on reading achievement.* (ERIC Document Reproduction Service No. ED373311)

Heise, B. L., Papalewis, R., & Tanner, D. E. (1991). Building base vocabulary with computer-assisted instruction. *Teacher Education Quarterly, 18*(1), 55-63.

Jones, Z. (1993). *Writing to read: Computer-assisted instruction and reading achievement.* (ERIC Document Reproduction Service No. ED365980)

Marcinkiewicz, V. (1988). *The effects of computer assisted instruction on reading.* Unpublished master's thesis. Kean College. (ERIC Document Reproduction Service No. ED293097)

Mathis, D. (1996). *The effect of the Accelerated Reader program on reading comprehension.* (ERIC Document Reproduction Service No. ED398555)

Ngaiyaye, M. S. W., & VanderPloge, A. (1986). *Differential effectiveness of three kinds of computer-assisted instruction.* (ERIC Document Reproduction Service No. ED 277335)

Paul, T., Swanson, S., Zhang, W., & Hehenberger, L. (1997). *Learning information system effects on reading, language, arts, math, science, and social studies.* (ERIC Document Reproduction Service No. ED421686)

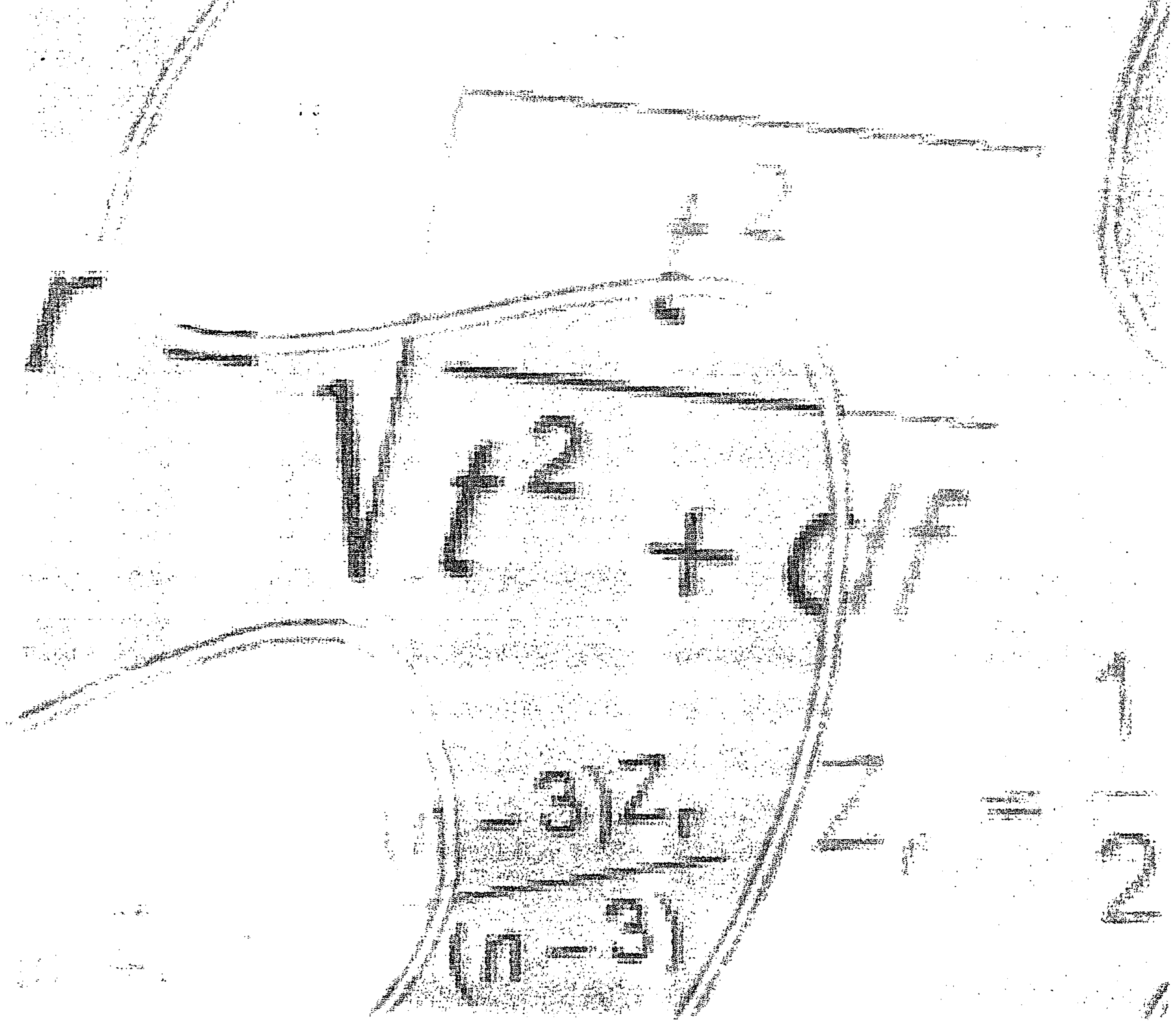
Peak, J., & Dewalt, M. W. (1993). *Effects of the computerized Accelerated Reader program on reading achievement.* Paper presented at the annual meeting of the Eastern Educational Research Association, Clearwater Beach, Florida, February 17-22. (ERIC Document Reproduction Service No. ED363269)

Reitsma, P. (1988). Reading practice for beginners: Effects of guided reading, reading-while-listening, and independent reading with computer-based speech feedback. *Reading Research Quarterly, 13*(2), 219-235.

Saracho, O. N. (1982). The effects of a computer-assisted instruction program on basic skills achievement and attitudes toward instruction of Spanish-speaking migrant children. *American Education Research Journal, 19*(2) 201-219.

Tillman, G. (1995). *Will implementing reading computer assisted instruction compared to traditional reading instruction produce more effective comprehension at the elementary school level?* (ERIC Document Reproduction Service No. ED392025)

Williams, G. R. (1993). *Efficacy of computer assisted instruction in the areas of math application and reading comprehension.* National Institute of Education. (ERIC Document Reproduction Service No. ED371752)



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