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Learning Technologies in the Classroom: A Study of Results

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LEARNING TECHNOLOGIES IN THE CLASSROOM
A
Study of Results

Submitted by:

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Executive Summary

Learning Technologies in the Classroom

The research reported in this paper focuses primarily on the short term question, "Do learning technologies effect student learning?" It utilizes a meta analytic technique to review comparative studies of differing technologies under different conditions.

A study had to meet the following criteria to be included in this analysis: it 1) took place in a classroom; 2) had a control and treatment group structure; 3) was free of major methodological flaws, and 4) provided either an effect size or the data to calculate one. The 184 studies selected for this review represent a diverse array of district and vendor evaluations, independent research projects published in scholarly journals, and dissertation studies.

A typology of three learning technology applications: computer-assisted instruction (CAI), computer-managed instruction (CMI), and computer-enriched instruction (CEI) was created to categorize the studies. Specific applications for each category were also used to describe study results, i.e., writing to read (WTR), integrated learning systems (ILS), and multimedia (MM).

FINDINGS

1. The analysis and synthesis of 184 studies point to an educationally significant enhancement of learning by learning technologies. Students taught with computer-based learning technologies scored .32 standard deviations higher than students taught by traditional instruction. The study suggests that on average, a student performing at the 50th percentile will perform at the 62nd percentile on the standard normal curve when taught with computer-based learning technologies.

2. The study implies that different methods of implementing or managing learning technologies greatly influence student performance. A wide range of variability was found across the studies indicating that factors other than a specific learning technology are important to achieving substantial student performance gains. For example:

    a) 32% of the 184 studies had a negligible effect, 19% had a moderate effect and 49% had a substantial effect on student performance. This variability of results was demonstrated in each type of technology reviewed.

    b) 58% of the CAI applications demonstrated substantial results.

c) In 51 ILS studies, 54% demonstrated substantial effects, 15% had moderate effects, and 31% produced negligible effects.

3. A tendency for more recent studies to produce stronger results was found. The findings support the notion that recent improvements produce more effective and adaptable learning technology applications, courseware and instructional design allowing decision-makers to target their purchase decisions to specific learning outcomes.

4. The effect sizes found in mathematics, language arts, and science were educationally significant for all combinations of learning technologies. In particular, CAI and ILS applications were particularly effective for teaching mathematics and language arts. There is preliminary evidence that MM may produce similar results in science.

5. ILSs proved to be a powerful application for at-risk, disadvantaged and low ability students.

6. The manner in which a learning technology is assessed effects the results. In general, learning technologies raised scores: a) substantially on locally developed teacher and researcher developed examinations; b) moderately on state developed criterion referenced examinations; and c) moderately on standardized norm-referenced tests. For example, WTR showed negligible results when standardized tests were used to test reading achievement. On the other hand, substantial results were found when local teacher or researcher developed tests were used to judge writing. And, ILSs demonstrated higher results on standardized norm-referenced tests than on state criterion referenced tests.

7. The study suggests several ways purchasing decisions and the acquisition process can be improved by determining a) the reason to purchase the technology application, b) the results the technology application produced in similar environments, and c) the manner in which the learning was assessed.

RECOMMENDATIONS

In the final analysis, the technology in and of itself can accomplish very little in educational reform. How the technology is used, the functions it serves, and the extent to which it advances sound instructional practice is critical to improving learning (Kulik, 1989a, 1989b). A primary goal of future investigations is to identify those conditions which optimize the cost-effectiveness of learning technologies. Until then, adoption of the following recommendations should strengthen purchase and implementation decisions as well as help optimize the cost-effectiveness of learning technologies.

1. It is **recommended** that decision-makers target a learning technology to their intended purpose. Prior to purchase decisions adopters should clearly identify the learning problem or opportunity they are trying to address or provide. Then, analyze the results vendors present to sell their product in terms of alignment of courseware, assessment strategies, and ability to improve student performance in the manner expected by the school division.

2. It is **recommended** that an analysis of the cost-effectiveness of different approaches to achieving the identified goal be conducted prior to purchase or expansion of a learning technology. The results be incorporated into the decision processes. It is also **recommended** that an analysis of the net benefit to the primary user be conducted. Specifically, will the processing and transaction value be seen as a benefit by the teacher?

3. It is **recommended** that a continuous improvement process to optimize cost-effectiveness ratios be established. Specifically, it is **recommended** result areas be identified for improvement, the current processes be documented, a search for the best in class installation be conducted, and a benchmarking visit be scheduled. The results of this process, practice, and protocol analysis should be incorporated into the school divisions' continuous improvement process.

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Preface

The research reported in this paper focuses primarily on the short term question, "Do learning technologies effect student learning?" This task is pursued by reviewing experimental comparative studies of differing technologies under different conditions and illuminating the effectiveness side of the cost-effectiveness equation. A second MERC paper will investigate decision protocols and the measurement of costs to complete a cost- effectiveness equation decision makers can utilize as a guide to enhance or expand learning technologies in their school divisions. A cost-effectiveness software package will be produced to enhance decision-making capability in this area. The final MERC paper in this series will investigate state of the art implementations to determine a set of protocols to optimize the cost-effectiveness of learning technologies. A process for continuous improvement and will be produced and school division personnel will be trained in its application.

Background

In February, 1992, the Metropolitan Educational Research Consortium's (MERC) Policy and Planning Council developed a far reaching research agenda to assist them in enhancing the use of technology in schools. The agreed on long term research agenda seeks answers to the following questions:

1. Does technology have a discernable effect on teachers and students? Does the use of technology in classroom instruction make a difference in student outcomes? How do teachers judge the effectiveness of technology? How do students judge the effectiveness of being taught in learning technologies? Does the introduction of technology in a classroom have a threshold of diminishing returns?
2. Are there cost-effective ways to integrate technology into on-going instructional practice? Do teachers see technology as an instructional enhancement or replacement tool? How has technology changed the way they deliver instruction?

How should technology change the way instruction is delivered? What kind of instructional technologies are best for learning facts, reasoning problem solving and critical thinking? Are there more effective instructional strategies? Is their effectiveness modified by the skills being delivered? Have these teachers been able to individualize instruction? Are there cost-effective ways to organize the use of technology, i.e., number of hours in class, number of dollars, number of personnel?

3. Are there cost-effective ways to organize and deliver staff development? How did successful users gain the knowledge to incorporate technology into their teaching? How can the learning curve for teachers be shortened?

4. Are there state of the are models that can be emulated and pilot-tested in Consortium schools?

A study group was formed from MERC's membership to guide the research and dissemination activities. They include: Shirley Wilson, Chesterfield County Public Schools; Julia Summey, Colonial Heights City Public Schools; R. Wes Batten, Hanover County Public Schools; R. Scott Gardner, Henrico County Public Schools; Lydia Bell, Henrico County Public Schools; Delores Pretlow, Richmond City Public Schools; and Thelma Pettis, Richmond City Public Schools.

A research team was appointed which included John Pisapia, Principal Investigator and Stephen Perlman, MERC Research Fellow to work with the study group and conduct the research. Susan Goins assisted the team and study group in meeting arrangements and document preparation. Amanda Parks assisted in editing the document.

John Pisapia
Principal Investigator

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> Learning technologies encompass a wide range of equipment and applications which directly or indirectly affect student performance.... Technologies are tools; their effectiveness as instruments of learning is not inherent; their power is derived from the teachers and students who use them. Their effectiveness is measured by whether they improve student performance and help students reach their full potential. (CCSSO, 1991).

The Context of the Study

The question whether to install computers in schools is, by now, moot. Realistically, however, the expansion of appropriate learning technology applications is not a certainty to proceed. On the one hand, teachers must be convinced that effective learning technologies exist. On the other hand many decision-makers still must be convinced that they are not only effective, but also affordable.

In an ideal world, the use of learning technologies in education should not have to be rationalized. Many advocates believe technology can make a unique and valued contribution to learning by providing the constant interaction individualized instruction requires and is currently available only from a teacher. They also point out that the technology imperative is so strong in the American culture that schools will have to become more prolific users of learning technologies.

However, given the lack of acceptance of technology in the classroom by large numbers of teachers and the high capital investment required, many school boards and chief executives maintain a state of "purchase anxiety" when it comes to technology. Having been told that not much can be done unless an expensive investment is made, many decision-makers take the position, "Don't talk to me about technology, it is just one big sinkhole. Systems that predict to cost pennies per hour cost dollars per hour."

Realistically, more and more school divisions are forced to rationalize their plans in terms of cost or measures of relative effectiveness.

Although using cost-effectiveness to rationalize the use of learning technologies in education appears to be valuable to both teachers and decision-makers, it is fraught with problems. At the heart of the matter are the twin goals of education - imparting knowledge and 'teaching for understanding.' The 80s "Nation At-Risk" agenda, driven by an accountability imperative, caused the educational system to emphasize imparting knowledge - - characterized by the teaching of basic skills. The 90s economic imperative is vigorously pushing us in the direction of higher order skill development such as critical thinking and reasoning characterized by a movement to "teach for understanding."

These twin goals are the center of at least three problems. First, when teachers face pressure for results on test scores, they are more inclined to focus on test content and engage students in worksheets resembling multiple choice tests which address the basic skills goal. On the other hand, many teachers think that the main value of computer-based learning technologies lies in their ability to promote new activities and skills (the teaching for understanding goal) which may not be measurable by current testing techniques. The problem is that current student assessment practices may not be able to effectively measure the ability of learning technologies to achieve these goals in full. Most observers conclude that techniques now widely used may assess basic skills; however, learning technologies supporting higher order thinking require sensitive assessment strategies and expanded evaluation models combining quantitative and qualitative methods.

Secondly, the short term and long term effects of employing such technologies are more different than similar. This divergence creates a complex dilemma for educators and policy makers. In the short term, public accountability demands force teachers and policy makers to continue to use standardized testing instead of more effective procedures. The fact that an integrated learning system is a proven method to raise achievement test scores is a significant example. However, the long term appeal of computer-based technologies is that they will push traditional frontiers of student learning (USOTA, 1988). If the adage - nothing succeeds like success - is true, then administrators and teachers may lose faith in the ability of technology to improve students' learning without evidence of short-term gains. This loss of confidence could lead to difficulties garnering the necessary political and financial resources to support continued enhancement or expansion of learning technologies in the schools in the long run.

Finally, the current state of the economy forces us to confront these twin educational goals at the same time without expenditures of new funds. Can efficient ways be found to address both educational goals in a more effective way? Can the technology and excellence imperatives be married in ways that further these larger educational goals but not at the expense of basic knowledge? It is clear that before many policy makers will be willing to reallocate portions of the budget from one program strategy to another, they will have to be sure it will be an effective use of these funds.

The Study

The purpose of this study is to investigate the effectiveness of learning technologies which can advance teaching and learning goals in mathematics, science, language arts, history and geography. The following questions will be addressed in this report:

1. Do learning technologies make a difference in student learning?
2. Are the learning technology applications developed in the last seven years more effective than previous applications?
3. Are there more effective types of learning technology applications?
4. Do effective learning technologies exist which can further teaching and learning goals in mathematics, science, language arts, history and geography?
5. Are learning technologies more effective with different groups of students?
6. Are learning technologies more effective with different types of performance assessment measures?

METHOD

Several major reviews of learning technologies have appeared in educational literature the past 15 years. Each review tried to aggregate the results from diverse evaluations in order to reach general conclusions about the effectiveness of Computer-Based Learning (CBL). The term CBL is used here as the most general term describing computer applications in the schools. It is preferred to computer-based instruction, which relates to the computer or teacher delivering instruction, because it encompasses the notion of the computer as a tool.

The reviews used either a box score, narrative, or quantitative methodology to integrate study findings. Box score reviews generally report the proportion of studies favorable or unfavorable to CBL. Narratives provide descriptions of each study or review and then draw intuitive conclusions. Researchers feel narrative and box score analyses may give too much weight to anecdotal reports and studies of marginal quality. Narrative reports are found in the literature in smaller numbers. But the box score approach used in early reports has been replaced by quantitative studies using the meta-analytic process identified by Glass, McGaw and Smith (1981). There are two types of quantitative studies: "horse race studies" compare traditional methods to learning technology applications, and "instructional design studies" compare student performance before and after the use of a specific learning technology. Instructional design studies compare technology applications to each other, as opposed to a control group. The effectiveness of four types of integrated learning systems may be compared in this type of study.

Meta-Analysis

A strength of meta-analytic methods is in their ability to tease out generalizations from a group of studies. Generally, meta-analytic techniques allow for a more precise estimate of treatment effect size; overcome the futility of expecting definitive results from any single study; extend our knowledge base by aggregating across studies; and allow practitioners to place confidence in findings that converge. A second strength is their ability to present as much of the available evidence on effectiveness of learning technologies in a consistent format. This allows reliable conclusions to be drawn on overall effectiveness and identifies the factors influencing effectiveness which provide guidance to decision-makers who are planning to increase or enhance the use of learning technologies.

On the other hand, although superior to box scores or narratives, some observers say meta-analysis seems to oversimplify the analysis of data from numerous studies because it lacks a common, research design or measures of achievement. Reviews using individual studies for meta-analytic approaches are further complicated by two factors: 1) Studies with a narrow, limited focus do not lend themselves to use by decision-makers trying to target learning technologies for specific purposes; and 2) The variety of ways reviewers select studies, code and analyze data, and report their findings. Despite these factors, most researchers believe meta-analysis is justified when specific common criteria are met by the studies included in the analyses.

This review used meta-analyses to integrate findings from independent evaluations of computer-based technologies in grades K-12 which met established criteria. The investigation utilized normal meta-analytic protocols requiring the researcher to use a) objective procedures to locate, select, and code studies by their features; b) quantitative or quasi-quantitative techniques to describe study outcomes on a common scale; and c) statistical methods to summarize overall findings and explore relationships between study features and outcomes. Each of the studies reviewed in this paper meet these criteria and address a range of learning technologies applied in many different settings.

Sources of Data

The collection process was conducted by computer search of three databases through ERIC: Research in Education and Current Index to Journals in Education; Comprehensive Dissertation Abstracts International (DAI); Psychological Abstracts; and the Government Printing Office. Meta-analytic and empirical studies retrieved in these computer searches were the primary sources of data. A second source was the supplementary set of studies located by branching from the bibliographies in articles retrieved by computer searches. A third source was unpublished evaluative documents, acquired by a direct mailing of 3000 requests for studies using the mailing lists of the Association for Educational Communications and Technology and American Association of School Administrators and the Chief State School Officers.

Selection and Characteristics of the Database

The bibliographic search produced over 300 titles, 50 of which were discarded based on a review of the abstracts. The remaining 250 titles and their bibliographies were examined. The studies demonstrated variability in design procedure and foci.

A study had to meet the following criteria to be included in this analysis: it 1) took place in a classroom; 2) had a control and treatment group structure (performance of students with learning technologies had to be compared to performance of students by traditional teaching methods); 3) was free of major methodological flaws such as substantial differences in experimental and control groups or substantial student dropouts from groups being compared; and 4) provided either an effect size, or the data required to calculate one.

Most frequent design flaws found were: lack of standard deviations data, no pre-test, no control group, a small number of students in sample, sample size, and duration of the intervention not being reported. For the important studies, the researchers telephoned for missing information.

Studies which were excluded were: studies which exclusively investigated attitudes, studies of less than two week duration, studies lacking evidence that the experimental and control group were initially equivalent, narrative review studies, studies containing obvious methodological flaws such as small sample size, studies lacking numerical data to compute effect size such as means, standard deviation, T-Test, F value, studies comparing two more learning technologies (instructional design studies), and studies of learning technologies that were not computer-based.

Studies contained in previous meta-analyses that had similar inclusion criteria were included. When the reviewer corrected results form studies; the corrected sizes were accepted. Studies reporting achievement outcomes involving performance measures for control and comparison groups were included.

One hundred eighty-four studies remained for use in this meta-analysis after all eliminations. The studies selected for this review represent a diverse array of district and vendor evaluations, independent research projects published in scholarly journals, and dissertation studies. Most studies were in mathematics and reading, and basic skills. One half were in grades K-4. Studies of integrated learning systems (ILS), computer-assisted instruction (CAI) and writing to read (WTR) made up 90% of the database. The fact that no studies were found which totally replaced traditional instruction indicates that learning technology applications are seen as supplements to be integrated into classroom instruction rather than total systems of instruction. The researchers were disappointed with the small number of computer-enriched and multimedia instruction studies available for review.

Study Features

The selected studies were first categorized by type of learning technology application: computer-assisted instruction, computer-managed instruction, or computer-enriched instruction. These applications were further described by the major type of instructional approaches they utilized -- drill and practice, tutorial, review, management, exploration, problem-solving and simulation. The typology is further described below.

In **Computer-Assisted Instruction** (CAI), the computer takes over some instructional components by presenting lessons and the student responding to questions pertaining to the lesson through a computer. The teacher retains control of managing classroom activities with the computer serving as a supplement to the teacher's instruction. Some individuals use the term CAI broadly to describe all educational software. It is used here to describe the computer delivering information to the student through drill and practice of tutorial instructional approaches in a stand-alone computer mode. CAI uses drill and practice courseware to master concepts and techniques that have been learned from another source by eliciting student response and providing immediate feedback to then proceeding to another problem of appropriate difficulty. Tutorial courseware presents new material allowing students an opportunity to interact with the concepts. In this instructional approach the courseware does the teaching -- typically in a lecture or workbook manner. Student learning is monitored and more complex activities are presented as the student progresses.

Writing to Read (WTR), a specific form of computer-assisted courseware, was separately coded because the large number of studies (46) might mask other CAI effects. The principle purposes of WTR is to increase the reading and writing performance of students in kindergarten and first grade. Students in the program rotate among five work areas, two of which involve computers. In one of these, students work with computers to learn phonics skills. In the other, students type stories on computers (or electric typewriters). In a third learning station, students listen to tape recorded stories which they can follow in books. In yet another area students receive paper and pencils with which to write stories, and in a fifth they get additional practice with letter sounds and phonics skills (Slavin, 1991). In a typical application, students receive approximately 26 hours of CAI -- 15 minutes a day -4 days a week for 26 weeks. Applications with the characteristics described above were categorized as CAI and Level I applications when the management software played a less important role.

In **Computer-Managed Instruction** (CMI), the computer replaces regular course elements such as teacher presentations, readings, student testing and diagnosis, and assignments. CMI courseware traditionally perform instructional management functions which evaluates the student, guides him or her to appropriate instructional resources, and keeps records of progress. CMI programs running on computers networked to a disk file server and providing a delivery system that can be mass produced were categorized as Level II applications. CMI professional systems with greater storage capacity and ability to relate the computers were categorized as Level III applications. Some Level IIIs run off the mainframe. Others, like **Integrated Learning Systems** (ILS), run off personal computers and are found in Labs and **Distributed Integrated Learning Systems** (DILS). An ILS (a specific form of CMI) is a system which includes both courseware and management software running on networked hardware. The courseware generally covers one or more curricular areas in targeted grade ranges. The management software generally provides tracking and reporting capabilities to assign students to specific lesson sequences in the system. This software also provides supplemental instruction which is often structured to be review and remedial in nature (USOTA, 1988).

In **Computer-Enriched Instruction** (CEI), the computer does not replace regular course elements. Rather, it serves to enrich instruction and enhance the teaching of higher order skills through simulation, problem-solving instructional approaches, and student productivity applications. In courseware utilizing these instructional approaches, students are generally placed in situations where they can manipulate variables and receive feedback on results of the manipulation. These instructional approaches allow students to generate or explore spreadsheets and databases illustrating relationships in models; to execute programs they develop; and to expand their experiences through productivity applications such as telecommunications, word processing, databases, spreadsheets, graphics, and exploration. Instructional approaches such as simulations, and problem-solving were categorized as computer-enriched instruction (CEI). CEIs in a stand-alone or networked mode were classified as a Level V application.

The marriage of the computer with a host of optical storage technologies - - the interactive video disc (IVD), the compact audio disc (CD), compact disc read only memory (CD-ROM), digital video interaction (DVI), compact disc interactive (CDI), and other emerging technologies - - has created a specific type of computer-enriched instruction.Christopher Dede describes this type of CEI as a cognition enhancer (such as multimedia, microworlds and hypermedia) which enables humans to extend their cognitive powers.

This form of CEI, commonly known as **multimedia**, is so closely identified with interactive video and hypermedia that all three terms are many times used synonymously. This study uses the term Multimedia (MM) to describe virtually any combination of text, video, graphics, sound, audio and animation that is controlled, coordinated and delivered on the computer screen. It also implies interactivity, where the student is not a passive observer of a fixed procession of sights and sounds. MM can be used by teachers or students in presentation and exploration by using a hypermedia link structure to allow the user to quickly and easily explore the content in a non-linear, random, and interactive way (Knussen, Christen, et al., 1991). Instructional approaches which meet these characteristics, whether in a stand-alone or networked mode, were classified as multimedia applications.

Studies were further categorized in the database by the variables found in Table I of Appendix A. These variables were selected after the researchers analyzed features in other quantitative reviews. No direct review of courseware content or features such as quality of graphics or clarity of text was attempted, other than what could be determined through description of the instructional approach and the evaluation results.

Effectiveness Measures

The measure used in this study to determine effectiveness of learning technologies was student performance as indicated on achievement examinations given at the end of a period of instruction. The studies measured student performance by standardized norm-referenced tests, standardized criterion-referenced tests, and examination scores on teacher or researcher designed tests and assessments. The studies also included other performance measures which were not the focus of this investigation such as: performance on follow-up or retention examination; changes in student attitudes toward computers, instruction, and school subjects; school attendance; course completion; amount of time needed for instruction. (See Table I in Appendix A).

The seemingly simple approach of comparing student performance after being taught with or without learning technologies presents several problems. The most difficult problem is the impossibility of creating a comparable control group. Clark (1985) concluded that there are many differences other than the use of computers in most comparison studies that confound the results of these type of studies. The point is worth noting. More rigorous controls by researchers are required to produce reliable results. However, most reviewers who point to this weakness also go on to use the results as evidence of effectiveness (Clark, 1985; Roblyer, Castine & King, 1988; Jurkat et al., 1992; USOTA, 1988). After reviewing the Clark argument and rejoinders, and noting the continued use of the comparison studies, we conclude comparison studies can be valuable and reliable guidelines for policy decisions when the effect of the learning technology is isolated as much as possible, when it is supplemented by evaluations focusing on the process and learning situations, and when the results are used as interpretative trends.

The use of traditional achievement measures is of concern to researchers and practitioners in several ways. These measures do not account for actual conditions occurring during implementation of learning technologies. For example, the fact that implementation is a process that proceeds over a period of several years; computers are used in a variety of ways for a range of purposes by teachers; widespread use of learning technologies are too new to have been supported by a body of systematic research about what works and what doesn't work; and generally schools have only loosely specified objectives for the learning technologies they adopt (Wilder and Fowles, 1992).

Furthermore, as discussed previously, while current testing techniques are relatively advanced in assessing whether or not students have learned basic content knowledge, they are immature in assessing more complex thinking skills (USOTA, 1988). The insensitivity of standard measures to assess higher order skills is a challenging problem since teachers mention problem-solving, global awareness, motivation, writing and cooperative learning as positive benefits of using learning technologies. Without appropriate techniques to measure these skills, the effects of learning technologies can only be inferred in regard to complex thinking and problem-solving abilities.

Finally, since teachers and students continue to use CEI to emphasize the development of problem-solving and meta-cognitive skills, it seems clear that effective measures of these skills must be developed. Several studies using teacher or researcher generated assessments are pointing the way to this development on a small scale. However, while alternative measures are in the process of development for the most part, they either are not yet available or not yet accepted as large scale measures for accountability purposes. (An example of alternative measures being developed by the New Assessment Measures Committee of the Maryland Education Project is found in Appendix C.)

On the other hand, until the availability and accountability issues are decided, decision-makers can be guided by the assertion of the National School Boards Association in a report on the transfer of technology to education which states: "We cannot improve the productivity of education if we don't know what it is, and that requires accepted measures of performance and cost...'[N]o measure' is the worst of all possible worlds." (Perelman, 1987, p. ES-14). Therefore, this research accepts the student performance measures used in the 184 studies as our best estimates of the effect of learning technologies on student performance currently available.

DATA ANALYSIS

The data were analyzed by 1) calculating effect sizes resulting from the difference between students taught with computer-based technologies and those taught in traditional ways; 2) classifying each study by the size of its effect; corrected for sampling errors; and 3) using descriptive statistics to analyze the educational significance of the findings.

Effect Size

A common scale, an effect size (ES), was created to conduct the statistical analysis and overcome the difficulty caused by different scales of measurement used in the various studies. Study effects corrected for sample errors, are presented in standard deviation units. Effect size (ES) describes the difference between students taught with computer-based technologies and those taught in traditional ways.

Effect size, defined as the difference between the means of two groups divided by the standard deviation of the control group (Glass, McGaw & Smith, 1981), has several strengths. It provides a standard metric to judge achievement using computer-based technologies. It allows comparisons of treatment (experimental) to a control group across studies (Glass, McGaw, and Smith, 1981).

Effect Size Calculations

Effect sizes for studies reported in meta analyses that met the criteria for inclusion in this study were accepted. Effect sizes for studies that met the inclusion criteria, but were not included in previous meta analyses, were calculated directly from reported means and standard deviations. Effect sizes had to be calculated from T and F ratios for less fully reported studies. The formulas suggested by Glass, McGaw, and Smith (1981) were used to estimate effect size. When results from a true experiment comparison and a quasi experiment were available in the same study, results of the true experiment were used. When results from long and short CBI implementations were available in the same study, the long implementation was used.

Following guidelines established by Kulik & others (1986), our procedure was to calculate effect size from the measures that provided the most reliable estimate of the treatment effect when more than one value was available for use in the numerator or the denominator of the formula. This meant using co-variance - adjusted differences when available rather than raw-score differences. And, using differences in gains when available rather than differences on post tests alone.

Effect Size Interpretation

Although effect size appears to be an excellent index for aggregating many different studies, its implication for the practical world of instruction is not readily evident. Effect sizes are objective, but their interpretation is subjective, and therefore open to error and criticism (Roblyer, Castine & King 1988). However, the literature portrays several ways the interpretation of effect sizes can be strengthened.

Significance. What is an educationally significant effect? Roblyer, Castine & Kind (1988) indicate that the joint dissemination review panel's guidelines on evaluating the effectiveness of instructional programs notes that "theory, past experience, expert judgments, and statistical rules of thumb have been used in weighing the size of educational effects. A widely applied rule is that the effect must equal or exceed some proportion of a standard deviation -- usually one-third, but at times as small as one-fourth to be educationally significant" (Tallmadge, 1977, p. 34).

They offer as a second opinion the Department of Health and Welfare's notion that "Before we would declare an apparent effect 'real,'... we required it to be statistically significant (at the conventional p < = .05 level) and also to exceed a quarter of a standard deviation of the outcome measure.... "The Department offers further support, we note that a quarter of a standard deviation corresponds to about two months progress in terms of grade equivalents...." A year would be too much to ask, a week to little. In our judgment, two months is a comfortable criterion" (Tallmadge, 1977).

Thirdly, Roblyer, Castine and King, in their 1988 review considered these guidelines, and asserted that an individual technology application is determined to be more powerful than other instructional methods when it has an effect size of .25 or greater. They assert that the use of trends in the sizes of the effects is justified when the number of studies is large.

Considering the above guidelines and following Becker's analytic scheme, each study was classified by the size of the effect to determine its significance into the following three categories: 1) negligible = ES less than .15; 2) moderate = ES greater than .15 but less than .30; and 3) substantial = ES greater than .30 (Becker, 1990a).

Normal Distribution. Furthermore, assuming that the test scores for treatment and control group students are normally distributed, the link between effect size and standard deviation can be used to establish the comparative percentage gains or decreases attributed to computer-based learning technologies. Using this rationale, an effect size describes how far to the left or right of the control group's mean the treatment group's mean is located. For example, a mean effect size of .51 suggests that a teacher can expect to increase the performance of his/her students by about one-half a standard deviation above their present level of achievement. That is to say that the average student (50th percentile) could perform at the level of students now at the 70th percentile through use of learning technologies.

FINDINGS

ES scores were sorted in a number of tables displaying the data by the following criteria: significance of the ES, publication year, grade level, subject, skill level, student characteristics, and type performance examinations utilized to help analyze the study's data. A literature review provided conclusions from other researchers. MERC researchers used the findings from this study to confirm or reject their conclusions. This study links to their collective body of work but also advances it in several ways as demonstrated below.

Overall Student Performance. Evidence on the effectiveness of using computer-based technologies in instruction has accumulated for over 30 years. Effect Size tends to vary from study to study. However, CBL appears to have a rather consistent positive effect on achievement. The evidence in reviews by Becker (1990a), Bennett (1991), McNeil & Nelson (1991), Bialo & Sivin (1990a), Fletcher et al. (1990), Kulik & Kulik (1989), Debloois (1988), Roblyer, Castine & King (1988), Kulik & others (1986), Samson, Niemiec, Weinstein & Walberg (1986), Kulik, Kulik & Bangert-Drowns (1985), Bangert-Drowns, Kulik & Kulik (1985), Hartley (1978), Visonhaler & Bass (1972) found increases in achievements from .27 to .56 standard deviation for computer-based technologies when compared to traditional approaches.

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Table II About Here

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In Table II, the average effect size for all learning technologies were calculated. There were 184 achievement outcomes extracted. Effects were positive in 166 of the 184 studies and negative in 18 studies. The overall effect size found in this study was similar to those reported in other studies and constitutes a conventional measure of practical educational significance. Students taught with computer-based technologies scored .32 standard deviations higher than students taught by traditional instruction. This suggests a rise of the 50th percentile student in the traditional class to the 62nd percentile for students using learning technologies - - an overall 12 percentile point gain in achievement for students using learning technologies.

Performance Variability. The overall analysis indicates technology applications are effective. But, Table II indicates that 1) 32% of the studies had a negligible effect, 2) 19% had a moderate effect, and 3) 49% had a substantial effect on student learning. It also illustrates a wide range of effects (from -.07 to .61) across the 184 studies indicating that factors other than the learning technology cause variability.

Performance by Type of Learning Technology. Table II also reports effect sizes of .40 for computer-assisted instruction, .30 for computer-managed instruction, and .04 for computer-enriched instruction. Each of these application effects is described below.

Computer-Assisted Instruction studies focusing on drill and practice and tutorials composed 27% of the database. Of the 50 studies reviewed, 58% of the CAI applications demonstrated substantial results, 24% moderate results and 18% negligible results. The average effect size for the twenty-nine studies with substantial results was .61, suggesting that a teacher could expect a 50th percentile student to improve to the 71st percentile when supplementing traditional instruction with drill and practice of tutorial instructional approaches.

Writing to Read (WTR), a specific form of computer-assisted instruction courseware, is also reported in Table II. CAI studies using the WTR courseware could expect negligible effects in 39% of the studies and substantial effects in 39% of the studies. Examination of the studies utilized for this review indicate that WTR is more effective than traditional methods in teaching writing in kindergarten and less so in the first grade. WTR's effect on reading is less pronounced at either level. Critics suggest that these results are to be expected since writing is not a strong component of traditional kindergarten and first grade curricula.

The results of the 13 **Computer-Managed Instruction** studies were dichotomous in nature; 5 studies demonstrated negligible results and 6 studies produced substantial results. In the fifty one (51) **Integrated Learning System** studies, however, 54% had substantial effects, 15% had moderate effects and 31% had negligible effects. Overall, the achievement effect of 69% of the ILS applications constituted a conventional measure of practical educational significance. In fact, in 54% of the cases, teachers could expect the 50th percentile student in their class to move to the 72nd percentile, a 22% gain in achievement.

In the 15 **computer-enriched** studies, 8 produced negligible results, 3 produced moderate results and 4 produced substantial results. In the 6 MM studies, 5 produced substantial effect and 1 study produced negligible effects. MM can be used by the teacher to supplement conventional teaching by controlling the pace and presentation of information. On the other hand, the learner can also use MM applications independently of the teacher by controlling the sequence and selection of content. Tutorials, programmed textbooks and free exploration of simulated situations are examples of this.

The results for computer-enriched instruction are promising. Although the achievement effects found do constitute practical educational significance, the limited number of studies available for this review does not allow full confidence in the estimate of effect size found in this study. However, the findings of Barbara McNeil and Karyn Nelson in a meta-analysis of 63 Interactive Video Instruction studies conducted in the last ten years found a substantial effect size of .53 (McNeil and Nelson, 1991). While the data found in their report did not lend themselves to our analysis, they lend support to our findings on multimedia applications.

Performance by Timespan. Bangert-Drowns, Kulik & Kulik (1985) projected that differences between earlier mainframe-age studies and later microcomputer-age studies may be due to improvements in instructional technology. And, Niemiec & Walberg (1987) in their review of reviews reported an average improvement of .38 standard deviations in achievement for mainframe based studies. This compared to an average improvement of 1.12 standard deviation for micro computer-based studies.

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Table III About Here

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A tendency for more recent studies to produce stronger results was found in this study. The years 1978 and 1985 were selected as benchmark dates because they marked approximate periods when new technology applications were introduced; for example, videodiscs in 1978 (Gindele and Gindele, 1984). One can see in Table III that the average effect of studies prior to 1978 was .28, .32 between 1978 and 1985 and .35 post-1985. However, much of this timespan increase was found in ILS and WTR applications.

Table III also points out the changes occurring in use of learning technologies. For example, 62% of the CAI results, 62% of the CMI results and 100% of the CEI results were recorded prior to 1978. Whereas, 61% of the WTR, 88% of the ILS and 100% of the MM results were recorded since 1985. This change in courseware complemented the increases found in the three time frames examined. It lends further support that the improvements in the instructional design of courseware and the move to more adaptable learning technologies produce more effective technology applications.

The practical significance of this time scale discovery is that more recent learning technology applications have demonstrated more substantial effects which supports current efforts to reframe instruction to utilize more learning technologies to greater advantage.

Performance by Grade Level. The results of this study displayed in Table IV lend modest support to the claim existing in the literature younger students seem to profit more than older ones from the highly structured materials (small steps and immediate feedback) supplied in drill and practice, tutorial, and managed instruction. In this case, CAI proved effective at all grade levels. It had similar effects at each system level: grades K - 4 (ES .49); grades 5 - 8 (ES .36); and at grades 9 - 12 (ES .41).

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Table IV About Here

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Overall, 55% of the learning technology applications were used in grades K-4. ILS and Writing to Read were the predominate applications used in these grades. CAI, on the other hand, was utilized at each grade set -- heavier in grades K-4, lighter in grades 9-12 -- with substantial results at each grade level.

Generally, in elementary and middle grades, CAI and ILSs produced better results. At the high school level, CAI was less effective and CMI was more effective. The data demonstrates that CEI and MM applications, with their emphasis on higher order skills, are being used primarily at the middle and high school levels, and the basic skill approaches of ILSs are primarily used at elementary and middle school levels.

Performance by Subject. The literature provides strong support for the effectiveness of CAI in mathematics, some support in language arts and negligible support in other subjects.

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Table V About Here
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One hundred sixty eight studies in the data base could be categorized by subject area. Thirty eight percent of the 168 studies describe mathematics results; 50% language arts results including reading and writing; and 11% science results. No studies were located in history or geography. Sixty five percent of the CAI studies were in math, 33% in language arts and 2% in science. The CMI studies were evenly dispersed across math, language arts and science. The ILS applications were evenly divided between math (53%) and language arts (47%) CEI studies were found in math (65%) and science (33%). The newer MM applications were used primarily in science. Studies of data base use in social studies were found in the literature but did not meet the criteria of inclusion for this study.

In general, the effect sizes found in mathematics, language arts and science are educationally significant. In fact, the mathematics effect sizes for CAI (ES .49) and ILS (ES .40) were substantial. The language arts effect sizes for CAI (ES .32) and CMI (ES .36) and WTR (ES .31) were substantial as were the science effect sizes for CMI (ES .36) and MM (ES .50). Although the number of multimedia studies is small, the results lend some credence to their increased use of MM in science.

Wise in a 1989 meta-analysis of the use of computers in science found ESs ranging from -.62 to 1.21, with mean of .34, indicating that students receiving CBL exhibited superior achievement. For example, videodisc-based applications in the laboratory had an ES of .40. Microcomputer-based laboratory lessons had an ES of .76. In biological science laboratories the ES was .22. While these studies were not included in this analysis they support our findings regarding the use of computers in science.

Performance by Student Characteristics. The results of this study, displayed in Tables VI and VII, clearly indicate that ILS is a powerful application for at-risk, disadvantaged and low achieving student populations. In 34 ILS studies, the ES was substantial (ES .41) for low achieving students. And, in 41 ILS studies, the ES was substantial (ES .39) for at-risk students. The practical significance of these findings lies in the fact that a teacher of low achieving or at-risk children could expect the 50th percentile student to move to the 63rd percentile.

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Tables VI and VII About Here

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ILSs focusing on basic skills proved to be effective in teaching reading, math, and language achievement to low achieving students. The ILSs also produced similar results for regular students on basic skills. While the number of studies reviewed is small, the results for gifted students (ES .03) are consistent with reports indicating that high achieving students operate at a ceiling level which interferes with the ability of learning technologies to show powerful results on basic skills assessment.

Performance by Effectiveness Measure. Student learning in each of the 184 studies was measured by achievement documented at the end of a program of instruction. The data in Table VIII indicate that learning technologies raised scores 1) substantially on locally developed teacher and researcher developed examinations; 2) moderately on state-regionally developed criterion-referenced examinations; and 3) moderately on standardized norm-referenced tests. The most powerful effects were demonstrated when local teacher or researcher assessments were utilized.

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Table VIII About Here
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In particular, ILSs demonstrated higher ESs on standardized norm-referenced tests than on state level criterion-referenced tests. This finding was not unexpected since ILS courseware is primarily developed for a curriculum supported by national standardized tests and not by local or state assessments. Of course for additional fees, ILS vendors will customize to state or local curricula.

On the other hand, WTR applications were more effective with local school division, teacher or researcher developed assessments than standardized tests of any type. In the WTR studies, the standardized tests were generally used to measure reading gains. The WTR results for reading were negligible and not educationally significant. The local and researcher developed assessments used to measure gains in writing generally produced educationally significant results.

In general, the findings lend themselves to two interpretations. First, it appears that the closer the test development is to the teacher and to the learner, the more significant the results. The implication for future studies and the development of cost-effective models is that different outcome measures and assessment techniques should be utilized when testing for basic skills and higher order skills.

Secondly, the fluctuation of results by the type of achievement measure indicates that teachers must be sure to address alignment and assessment issues prior to assessing the results of instruction. For example, as indicated by the results on norm- and criterion-referenced tests in ILSs, alignment problems may exist between instructional objectives, computer courseware, and the tests used to measure achievement. These alignment problems possibly mask significant differences in student achievement which were not measured in a particular experiment.

DISCUSSION

A strength in this study is that it looks at the full picture rather than a narrow view of learning technologies. The study design permitted a review across applications, instructional processes, and outcomes to discover the best way to assess the effectiveness of learning technologies and to target learning technologies toward specific purposes. Reliable estimates of performance and the conditions under which computer-based learning has stronger or weaker effects were discovered.

Several implications supporting the use of learning technologies to promote educational reform, decision-making, and further research efforts, can be teased out of the findings. The results demonstrate that student performance can be improved through the use of learning technologies. Secondly, purchase decisions can be improved when based on a clear description of the educational problem the user is trying to solve - - or the opportunity they are trying to provide students through these technologies. Thirdly, implementation decisions can reduce variability of results and optimize cost-effectiveness ratios by increasing the net benefit to primary users.

Student Performance. Does the use of learning technologies make a difference in student learning? The findings indicate that, in general, students can learn more effectively from computers. Although ultimate final answers or guarantors of success can not be assured, the synthesis and analysis of 184 studies point to a significant enhancement of learning in environments supplemented by CAI, CMI, and CEI. Perhaps students learn with computer-based learning technologies because of the improved instructional strategies and materials utilized by the technology application rather than the hardware - but at least they are learning.

Specifically, the study implies that decision-makers can expect the following results:

a. On average, a student performing at the 50th percentile will perform at the 62nd percentile on the standard normal curve when taught with computer-based learning technologies.

b. Strengthening implementation processes and protocols will produce substantially better results. Over 50% of the 184 studies demonstrated educationally significant results. At these sites, students taught with CAI, CMI or an ILS performed at the 73rd, 73rd and 70th percentiles respectively on the standard normal curve. This compares to the 50th percentile for students not using these learning technologies. The fact that substantially different results are achieved at different sites supports the strengthening of implementing decisions.

c. CAI and ILS applications are effective for teaching mathematics and language arts. In these subject areas, students performed at or above the 60th percentile on the standard normal curve for all technology applications in these subject areas. There is preliminary evidence that MM may produce similar results in science.

The cost-effectiveness of any of the applications reviewed cannot be determined from this study. For example, from these results, it seems that the more expensive networked ILSs while attractive, may not get results that are more effective than standard stand-alone CAI applications. However, others argue that while results may be similar, ILSs are used by many more students than classroom stand-alone applications. Decision-makers can only get these answers from evaluating their own purchase decisions.

Purchase Decisions. Vendors have focused their selling activities based on a description of decision-making in education characterized in the K-12 Marketing News. The February 1992 issue describes the K-12 market as using technology, and approaching acquisition and implementation of technologies differently than any other organization. It goes on to say that decision-making in education is driven by pressure from the outside rather than drawing on planning and implementation strategies from research, development, and trend analysis as in other organizations (The Center for SmartSchool Development, February, 1992). If this description is true, then educational decision-makers should become more proactive in technology acquisitions by developing strategic technology plans. They should incorporate cost-effectiveness reviews and optimization strategies into their purchase and implementation decision processes.

The study suggests that the acquisition process can be improved by determining, 1) the reason to purchase the technology, 2) the results the application achieved in similar environments, and 3) the manner in which the learning was assessed. The alignment of educational purpose, instructional, and assessment strategies - creates special problems when finalizing purchase decisions and attempting to improve cost-effectiveness ratios.

The study implies that purchase decisions can be improved when the problem one is trying to solve, or, the opportunity one is attempting to provide through the purchase of learning technologies is clearly understood. The task is made more difficult because the educational goals of imparting knowledge and "teaching" for understanding cannot be considered separately. Surely, all students must learn to read, write, multiply and divide. They must learn that all matter is composed of atoms and molecules, and the location of Paris, New York or Bejing on a map. At the same time, students must make knowledge work for themselves, their communities and the nation. They must understand how to pose problems, conduct critical inquiry and develop informed insight. They must know how to produce and criticize a written agreement, understand what compels the adoption of an atomic theory of matter, understand the events that led to and flowed from the Civil

War, and be able to analyze the factors that determine where cities spring up and prosper. (Educational Technology Center; 1988).

Following this line of reasoning, the is first imperative is to target the purchase of learning technologies by aligning courseware with the purpose being pursued. The task can be difficult simply because courseware varies greatly in philosophy, design and content. They are designed for remediation, for comprehensive instruction, and for higher order thinking skills. They can present a lesson from a skill or concept base and are designed primarily to provide diagnostic/prescriptive intervention for remediation of precise skills. Therefore, if the premise of the decision is to improve precise skills then skill based courseware would be appropriate.

On the other hand, concept-based courseware pays more attention to problem-solving and higher order thinking skills and is a more appropriate match for "teaching for understanding." Problem-solving courseware many times uses verbal analogies, inductive/deductive reasoning, logical reasoning and problem analysis. An exploratory activity, for example, is seldom a good match for the curriculum. Therefore, its impact on core educational experience tends to be limited, but expansive in enriching the educational experience.

Secondly, the challenge the educational reform movement presents to teachers is much harder than conventional teaching. The study results clearly demonstrate that no single learning technology can help teachers achieve both educational goals. Unfortunately, some learning technology applications do little to support these educational reform goals. For example, Newman (1990) makes the case that ILSs have found their niche within the schools because they fit readily into the existing structure of compartmentalizing learning and drilling selected students on basic skills. On the other hand, learning technologies emphasizing exploration, problem-solving and communication instructional approaches are highly compatible with the reform movement's project-based constructionist approach in terms of student learning goals. Though these "higher order" learning technologies are potentially powerful and hold the most hope for many educators, they can be very expensive to develop and integrate into instructional activities. The concept of matching purpose with courseware seems simplistic. Yet, it is also apparent that teachers are often faced with a bewildering array of courseware and hardware options. In most cases there is no research evidence to guide their decision-making. If developers and publishers would routinely provide this information, policy makers and practitioners would have greater confidence that specific applications are more effective under particular conditions (Herman, 1992). In the absence of this information decision-makers must rely on their own studies and analyses.

Finally, the study strongly implies that assessment strategies impact cost-effectiveness ratios. Identifying and analyzing assessment strategies used to determine effectiveness prior to purchase decisions insures that vendors are presenting results which match the purpose the school division seeks to achieve. For example, it is apparent that standardized tests, which are easily interpreted and familiar to the public and educational decision-makers, may not be able to describe the full impact of particular learning technologies. These assessment strategies may be appropriate for ILSs which strengthen basic skills, but not for CEIs which focus on strengthening problem-solving and reasoning skills. Quizzing CEI vendors as to how their product engages students in authentic, challenging tasks of the sort they might encounter in the world outside of school, or how, the product equips students with the kind of tools they will work with in that world. The answers to such questions will strengthen decision-maker judgment when the purpose of the purchase is to enhance teaching for understanding.

Cost-Effectiveness Optimization. The study's findings clearly indicate it is possible to get varying degrees of effectiveness with the same learning technology application implemented at different sites. This finding implies that different methods of implementing or managing learning technologies may greatly influence student performance, even though it's expected that the technology application should produce the same level of achievement at different sites.

The best available data suggest that optimization of cost-effectiveness performance will not result from improvements in technology features alone. Surveying traditional experimental studies such as those used in this review reveals the success rate of a treatment in a particular setting. But, they generally omit information about why a particular treatment worked.

The study results suggest that decision-makers should support the use of consistent, systematic management protocols which are most likely to influence the relationship between student performance and the cost to acquire, implement and operate a learning technology. Additional studies have identified critical factors which may improve these cost-effect relationships. For example: student/staff ratios, extent of teacher involvement, number of students involved, number of computers networked, amount of time spent on the computer, training of staff and teachers, number of specialized staff utilized, the extent and kind of feedback, the nature of remediation features, and the extent of classroom integration, are factors which effect the successful use of learning technologies. Of these factors, training and support continue to be the most crucial major components of learning technology implementation.

Secondly, the results of this study implies that just because a technology application is effective, does not mean it will be successfully adopted by users. Some observers suggest improving the cost benefits to the primary user - the teacher - as an important strategy to optimizing cost-effectiveness ratios. A cost benefit relationship is achieved when the overall benefits to the primary user are significantly greater than costs to acquire, implement and operate the system. In a sense, if teachers believe their students will learn, and/or the learning technology reduces the time they have to work on some activities and/or it provides information useful to them in directing student learning programs, then they will work at increasing the effectiveness of the technology. With these conditions satisfied, administration must only then work at reducing the costs of operation to increase the overall cost-effectiveness of the installation.

Keyes (1989) reports that the key to successful acceptance by any organizational implementation is the satisfaction of the needs of the primary user (teachers). The value gained by secondary users (students) is a by product of the operation of the system by the primary user. Secondary users, therefore, neither contribute to the net benefit nor assure the operational success of the system (Bullock, et. al, 1983).

In the case of CMI systems, Keyes' central argument is that their failure to provide sufficient cost benefit to their primary user - the classroom teacher - can lead to a lack of acceptance and support. Lomerson and Knezek (1991) support the importance of the teacher. For example, they reported that teachers can manage their classroom without the information generated by the CMI system. An opinion, they say, is substantiated by recent studies of Whitney and Lehmar (1990) Evertson (1989) and Fuchs (1987). The implication is that to optimize cost-effectiveness ratios, one should not only address the organizational and management factors, but also attend to the needs of the primary user.

The net benefit can be improved by increasing the information value, the processing value, or reducing the costs of operation. As noted in the case of CMI, until the teachers' needs for information are carefully analyzed and appropriate data is accumulated and reported, the CMI system's data will not be seen as beneficial. It is not sufficient that the use of CMI produces increased learning; that "learning" must have a value to the teacher that is substantially larger than its production costs and large enough to justify the initial effort to install, learn, and manage the system.

RECOMMENDATIONS

In the final analysis, the technology in and of itself can accomplish very little in educational reform. How the technology is used, the functions it serves, and the extent to which it advances sound instructional practice is critical to improving learning (Kulik, 1989a, 1989b). A primary goal of future investigations is to identify those conditions which optimize the cost-effectiveness of learning technologies. Until then, adoption of the following recommendations should strengthen purchase and implementation decisions as well as help optimize the cost-effectiveness of learning technologies.

1. It is **recommended** that decision-makers target a learning technology to their intended purpose. Prior to purchase decisions adopters should clearly identify the learning problem or opportunity they are trying to address or provide. Then, analyze the results vendors present to sell their product in terms of alignment of courseware, assessment strategies, and ability to improve student performance in the manner expected by the school division.

2. It is **recommended** that an analysis of the cost-effectiveness of different approaches to achieving the identified goal be conducted prior to purchase or expansion of a learning technology. The results be incorporated into decision processes. It is also **recommended** that an analysis of the net benefit to the primary user be conducted. Specifically, will the processing and transaction value be seen as a benefit by the teacher?

3. It is **recommended** that a continuous improvement process to optimize cost-effectiveness ratios be established. Specifically, it is **recommended** result areas be identified for improvement, the current processes be documented, a search for the best in class installation be conducted, and a benchmarking visit be scheduled. The results of this process, practice, and protocol analysis should be incorporated into the school divisions' continuous improvement process.

CONCLUSIONS

Some readers might feel the view presented through these findings is overly optimistic, while others might feel it is overly pessimistic. Kasten Tallmadge (1977) offers the following conditions which must be met when determining if a practice is effective: 1) the evidence must be valid and reliable, 2) the effect must be of sufficient magnitude to have educational importance, and 3) it should be possible to reproduce both the intervention and its effects at other sites.

In comparing these conditions with the best available data, we conclude that the use of learning technologies in classrooms can produce educationally significant achievement gains in student performance over traditional methods. These achievement gains may be reproduced if attention is given to reducing the variability of results by strengthening purchase and implementation decisions. However, although the available data are promising, some cautions are noted.

First, a real weakness of the evaluation of any new technology is that there is nothing else like it. Even in the best situations, new approaches are unlikely to be used to their optimum advantage. Most likely, the optimal learning technology has not yet appeared. The best may be yet to come.

Secondly, a related problem exists in comparing new instructional approaches to existing ones. Very often the materials prepared for new approaches are trimmed down and focused on specified instructional outcomes, but the traditional approach is left as it is. Where this occurs, some evaluations may be unilaterally biased in favor of the new approach.

Thirdly, researchers currently have accepted the effectiveness of computer-based learning and are moving their focus to determine what specific instructional approaches are most effective. These researchers are focusing on applications that have the potential to improve problem-solving and information handling skills. If these applications are to be accurately evaluated, new outcome measures and assessment tools will be required. And, it is a daunting challenge. The newly designed assessment system must accurately measure and promote the complex thinking and learning goals known to be critical to student academic success and his/her contributions as a citizen.

Finally, the learning technologies reviewed were applied in a wide range of settings with diverse student populations and teachers. Therefore, teachers and other decision-makers should not expect to see the aggregate research results of ES .32 replicated exactly in their classrooms or schools. A more productive use of the data comes from the fact they support the general notion that under certain conditions learning technologies can have a significant, educational impact - - if they are tailored to their schools' and students' needs.

APPENDIX A

TABLE I

INPUT FORM CATEGORIES

DESCRIPTION

1. Reference (Type in citation APA style) (CITATION)

2. Study (Type in name of the author/s) (ST)

3. Place (Type in place study was conducted) (PLACE)

4. Begin Date (Type in date yy/mm/dd) (WHEN)

5. Publication Date (Type in year of publication, 19xx) (PYR)

6. Type of application (TAP) Type in initials ( )

   a. Computer-Assisted Instruction (CAI)
   b. Computer-Managed Instruction (CMI)
   c. Computer-Enriched Instruction (CEI)
   d. Computer-Assisted Visual Instruction (CAVI)
   e. Distance Learning (DL)
   f. Integrated Learning System (ILS)
   g. Writing to Read (WTR)

7. Hardware components (COMPONT)

   a. Computer
      1) Classic II
      2) MAC S1
      3) PS/35-IBM
      4) others
   b. CD ROM
   c. VCR
   d. hypermedia/multimedia
   e. calculator
   f. Videodisc I
   g. Videodisc II
   h. Videodisc III
   i. laserdisc
   j. monitor
   k. Projection
      1) portable overhead
      2) LCD panel
      3) MAC LCII
      4) others
   l. Image Writer
   m. camcorder
   n. probes
   o. scanner
   p. bar code reader
   q. modem
   r. lap top computer

TABLE 1 - continued

8. Type of tools used (TOOL)

   a. word processing
   b. spread sheet
   c. data base
   d. telecommunications
   e. graphics

9. Source (SOURCE)

   a. unpublished
   b. dissertation
   c. published
   d. review

10. Materials Author (Name in Description) (Author)

    a. local
    b. commercial
    c. other

11. Vendor Name (write in vendor or program name) (VENDOR)

12. Technology Control (TECHCONTRL)

    a. student controlled
    b. teacher controlled
    c. software controlled
    d. group controlled

13. Type of Computer Interaction (CINTERACTN)

    a. off-line
    b. terminal with mainframe
    c. microcomputer

<u>**INSTRUCTION**</u>

14. Grade Level (write in grade application was tested at, i.e., 1, 2, 10, 12) (GDL)

15. Generic Course Content (CURR)

    a. mathematics
    b. language arts
    c. science
    d. geography
    e. history
    f. social science
    g. interdisciplinary
    h. other (write on comment section)

16. Specific Subject (Name the content, i.e., calculus rather than mathematics) (SUB)

17. Instructional Approach (IAP)

    a. tutorial
    b. drill and practice
    c. simulation
    d. review
    e. enrichment
    f. program
    g. management
    h. databases
    i. dialogue
    j. tool
    k. problem-solving

18. Length of Instruction (WRITEIN)

    a. number of weeks of instruction (WEEKS)
    b. number of hours per week (HOURS)
    c. number of minutes per week (TIME)
    d. number of minutes per day (TIME2)
    e. number of class hours (CLASSHOURS)

19. Duration of Instruction (DURATION)

    a. one semester or less
    b. more than one semester

20. Educational Track (INSTTRACK)

    a. general
    b. academic
    c. vocational

21. Skill Level (SKILL)

    a. low ability
    b. average ability
    c. high ability
    d. mixed ability

22. Population Served (POP)

    a. gifted
    b. at-risk
    c. regular
    d. other

TABLE 1 - continued

23. Location (LOCATION)

    a. classroom
    b. laboratory
    c. library
    d. other

24. Target (TARGET)

    a. group
    b. individual
    c. combined

METHODOLOGY

25. Measurement (MES)

    a. standardized norm-referenced tests
    b. standardized criterion-referenced tests
    c. classroom teacher objective assessment
    d. courseware test
    e. school division/researcher designed tests or assessments
    f. classroom teacher subjective assessment
    g. student grades

26. Name of Test (Write the name of the test) (TEST)

27. Controlled Group (CONTRLGRUP)

    a. yes
    b. no

28. Sample Size (NOSTUD)

29. Testing sequence

    a. post-test
    b. pre- and post-test

30. Pilot Test (PILOTTEST)

    a. yes
    b. no

31. Sources of Comparison Data ( )

    a. longitudinal studies
    b. cohort comparisons
    c. comparison schools
    d. norming population

32. Subject Assignment (SUBASSIGN)

    a. random - subjects assigned to experimental and control groups
    b. non-random - a quasi-experimental design was used

33. Control for Instructor Effects (INSTRUCTOR)

    a. same instructor (teacher or teachers taught both the experimental and control groups)
    b. different instructors (different teachers taught the two or more groups)

34. Control for Historical Effect (CHISTEFECT)

    a. same semester (subject in experimental control groups were taught concurrently)
    b. different semesters (two groups were not taught concurrently)

35. Control for Bias in Test Scoring (CBIASTESTG)

    a. objective (objective machine scored examinations were used to measure student achievement)
    b. non-objective (subject decisions had to be made in scoring tests; for example, essay tests)

<u>Effects</u>

36. Comparative Gain (CES)

37. Technology Gain (TECHGAIN)

38. Retention Gain (RETGAIN)

39. Attitude Towards Computers (COMPATGAIN)

40. Attitude Towards Instruction (INSTATTGAIN)

41. Attitude Towards Subject (SUBATTGAIN)

42. School Attendance (ATTENDGAIN)

TABLE II

THE EFFECTIVENESS OF COMPUTER-BASED TECHNOLOGIES

	STUDIES			NEGLIGIBLE Less than .15				MODERATE Between .15 and .30				SUBSTANTIAL Greater than .30			
	#	ES	% TOT	#	ES	% TYP	% TOT	#	ES	% TYP	% TOT	#	ES	% TYP	% TOT
CAI	50	0.40	27%	9	-0.01	18%	5%	12	0.22	24%	7%	29	0.61	58%	16%
WTR	46	0.31	25%	18	-0.11	39%	10%	10	0.23	22%	5%	18	0.77	39%	10%
CMI	13	0.30	7%	5	-0.06	38%	3%	2	0.25	15%	1%	6	0.61	46%	3%
ILS	54	0.31	29%	17	0.04	31%	9%	8	0.21	15%	4%	29	0.49	54%	16%
CEI	15	0.04	8%	8	-0.21	53%	4%	3	0.20	20%	2%	4	0.44	27%	2%
MM	6	0.62	3%	1	-0.30	17%	1%	0	NA	0%	0%	5	0.80	83%	3%
TOTAL	184	0.32		58	-0.07		32%	35	0.22		19%	91	0.61		49%

LEGEND

# = number of studies
ES = Effect Size
% Tot = percentage of the total number of studies
% Typ = percentage of the number of studies in the type of technology application
CAI = Computer Assisted Instruction
WTR = Writing to Read
CMI = Computer Managed Instruction
ILS = Instructional Learning Systems
CEI = Computer Enriched Instruction
MM = Multimedia

TABLE III

THE EFFECTIVENESS OF LEARNING TECHNOLOGIES BY PUBLICATION DATE

	STUDIES	PRE-1978				1978-85				Post 1985			
	#	#	ES	% TYP	% TOT	#	ES	% TYP	% TOT	#	ES	% TYP	% TOT
CAI	50	31	0.40	62%	17%	12	0.52	24%	7%	7	0.23	14%	4%
WTR	46	0	0	0%	0%	14	0.19	30%	8%	32	0.36	70%	7%
CMI	13	8	0.28	62%	4%	5	0.34	38%	3%	0	0.00	0%	0%
ILS	54	0	0	0%	0%	6	0.19	11%	3%	48	0.32	89%	26%
CEI	15	15	0.04	100%	8%	0	0	0%	0%	0	0.00	0%	0%
MM	6	0	0	0%	0%	0	NA	0%	0%	6	0.62	100%	62%
TOTAL	184	54	0.28	29%	29%	37	0.32	20%	20%	93	0.35	51%	51%

LEGEND

#	=	Number of Studies
ES	=	Effect Size
%tot	=	Percentage of the total number of studies
%typ	=	Percentage of the number of studies by type of application
CAI	=	Computer Assisted Instruction
WTR	=	Computer Assisted Instruction
CMI	=	Computer Managed Instruction
ILS	=	Instructional Learning Systems
CEI	=	Computer Enriched Instruction
MM	=	Multimedia

TABLE IV

THE EFFECTIVENESS OF COMPUTER-BASED TECHNOLOGIES BY GRADE LEVEL

STUDIES	K-4					5-8				9-12			
	#	% #	ES	% TYP	% TOT	#	ES	% TYP	% TOT	#	ES	% TYP	% TOT
CAI	42	19	0.49	45%	11%	11	0.36	26%	6%	12	0.41	29%	7%
WTR	46	46	0.31	100%	46%	0	0	0%	0%	0	0	0%	0%
CMI	13	2	0.01	15%	1%	2	0.14	15%	1%	9	0.40	69%	5%
ILS	54	33	0.29	61%	33%	21	0.33	39%	12%	0	0.00	0%	0%
CEI	15	0	0	0%	0%	3	0	20%	2%	12	0.05	80%	7%
MM	5	0	0	0%	0%	4	0.7	80%	80%	1	0.60	20%	1%
TOTAL	175	100	0.33		57%	41	0.35		23%	34	0.29		19%

Legend

# = number of studies
ES = Effect Size
% Tot = percentage of the total number of studies
% Typ = percentage of the number of studies in the type of technology application
CAI = Computer Assisted Instruction
WTR = Writing to Read
CMI = Computer Managed Instruction
ILS = Instructional Learning Systems
CEI = Computer Enriched Instruction
MM = Multimedia

TABLE V

THE EFFECTIVENESS OF COMPUTER-BASED TECHNOLOGIES BY SUBJECT

SUBJECT		MATH				LANG ARTS				SCIENCE				HISTORY				GEOGRAPHY			
	STUDIES	#	ES	% TOT	% TYP	#	ES	% TOT	% TYP	#	ES	% TOT	% TYP	#	ES	% TOT	% TYP	#	ES	% TOT	% TYP
CAI	43	28	0.49	18%	65%	14	0.32	9%	33%	1	0.38	0%	2%	0	0	0	0	0	0	0	0
WTR	46	0	0	0%	0%	46	0.31	30%	100%	0	0	0	0%	0	0	0	0	0	0	0	0
CMI	12	3	0.14	2%	25%	3	0.36	2%	25%	6	0.36	4%	49%	0	0	0	0	0	0	0	0
ILS	32	17	0.4	11%	53%	15	0.23	10%	47%	0	0	0%	0%	0	0	0	0	0	0	0	0
CEI	15	10	0.7	17%	65%	0	0	0%	0%	5	0	3%	33%	0	0	0	0	0	0	0	0
MM	6	1	1.1	2%	17%	0	0	0%	0%	5	0.52	3%	83%	0	0	0	0	0	0	0	0
TOTAL	154	59	0.38	38%		78	0.3	50%		17	0.26	11%		0	0	0	0	0	0	0	0

Legend

- # = number of studies
- ES = Effect Size
- % Tot = percentage of the total number of studies
- % Typ = percentage of the number of studies in the type of technology application
- CAI = Computer Assisted Instruction
- WTR = Writing to Read
- CMI = Computer Managed Instruction
- ILS = Instructional Learning Systems
- CEI = Computer Enriched Instruction
- MM = Multimedia

TABLE VI

THE EFFECTIVENESS OF COMPUTER-BASED TECHNOLOGIES BY STUDENT ABILITY

	STUDIES	LOW				AVE				HIGH			
	#	#	ES	% TYP	% TOT	#	ES	% TYP	% TOT	#	ES	% TYP	% TOT
CAI	3	1	0	33%	2%	2	0.45	67%	4%	0	0	0%	0%
WTR	0	0	0	0%	0%	0	0.00	0%	0%	0	0	0%	0%
CMI	0	0	0	0%	0%	0	0.00	0%	0%	0	0	0%	0%
ILS	51	34	0.41	67%	60%	17	0.30	33%	30%	0	0	0%	0%
CEI	0	0	0	0%	0%	0	0.00	0%	0%	0	0	0%	0%
MM	3	0	0	0%	0%	3	0.47	100%	5%	0	0	0%	0%
TOTAL	57	35	0.30		61%	22	0.33		39%	0	0		0%

Legend

# = number of studies
ES = Effect Size
% Tot = percentage of the total number of studies
% Typ = percentage of the number of studies in the type of technology application
CAI = Computer Assisted Instruction
WTR = Writing to Read
CMI = Computer Managed Instruction
ILS = Instructional Learning Systems
CEI = Computer Enriched Instruction
MM = Multimedia

TABLE VII

THE EFFECTIVENESS OF COMPUTER-BASED TECHNOLOGIES BY STUDENT CHARACTERISTICS

	STUDIES	GIFTED				AT-RISK				REGULAR			
	#	#	ES	% TYPE	% TOTAL	#	ES	% TYPE	% TOTAL	#	ES	% TYP	% TOT
CAI	4	0	0	0%	0%	0	0	0%	0%	4	0.23	100%	4%
WTR	46	0	0	0%	0%	46	0.31	100%	43%	0	0	0%	0%
CMI	0	0	0	0%	0%	0	0	0%	0%	0	0	0%	0%
ILS	54	3	-0.03	6%	3%	41	0.33	76%	38%	10	0.33	19%	9%
CEI	0	0	0	0%	0%	0	0	0%	0%	0	0	0%	0%
MM	3	0	0	0%	0%	0	0	0%	0%	3	0.47	100%	3%
TOTAL	107	3	-0.03		3%	87	0.32		81%	17	0.33		16%

Legend

# = number of studies
ES = Effect Size
% Tot = percentage of the total number of studies
% Typ = percentage of the number of studies in the type of technology application
CAI = Computer Assisted Instruction
WTR = Writing to Read
CMI = Computer Managed Instruction
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CEI = Computer Enriched Instruction
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TABLE VIII

THE EFFECTIVENESS OF COMPUTER-BASED TECHNOLOGIES BY TYPE OF ASSESSMENT

ASSESSMENT		STANDARDIZED NORM-REFERENCED				STANDARDIZED CRITERION REFERENCED				LOCAL ASSESSMENT			
	STUDIES #	#	% ES	% TOT	TYP	#	% ES	% TOT	TYP	#	% ES	% TOT	TYP
CAI	7	0	0	0%	0%	0	0	0%	0%	7	0.23	0%	100%
WTR	46	36	0.11	32%	78%	0	0	0%	0%	10	1.01	9%	22%
CMI	0	0	0	0%	0%	0	0	0%	0%	0	0	0%	0%
ILS	54	42	0.32	37%	78%	11	0.25	10%	20%	1	0.30	1%	2%
CEI	1	0	0	0%	0%	1	1.10	1%	0%	0	0	0%	0%
MM	5	0	0	0%	0%	0	0.00	0%	0%	5	0.52	4%	100%
TOTAL	113	78	0.23	69%		12	0.32	11%	12%	23	0.63	20%	20%

LEGEND

# = number of studies reporting type of assessment used
ES = Effect Size
% Tot = percentage of the total number of studies
% Typ = percentage of the number of studies in the type of technology application
CAI = Computer Assisted Instruction
WTR = Writing to Read
CMI = Computer Managed Instruction
ILS = Instructional Learning Systems
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APPENDIX B

BIBLIOGRAPHY

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APPENDIX C
OUTCOMES ASSESSMENT

TABLE I

OUTCOMES MEASURED IN STUDIES OF LEARNING TECHNOLOGIES

Program Objective	Measure of effectiveness
Program completions	Number of student completing program
Reducing dropouts	Number of potential dropouts who graduate
Employment of graduates	Number of graduates placed in appropriate jobs
Student learning	Test scores in appropriate domains utilizing appropriate test instruments
Student satisfaction	Student assessment of program on appropriate instrument to measure satisfaction
Physical performance	Evaluation of student physical condition and physical skills
College placement	Number of students placed in colleges of particular types
Advance college placement	Number of courses and units received by students in advance placement, by subject

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Attachment #1

EDUCATIONAL TESTING SERVICE PRINCETON, N.J. 08541

609-921-9000
CABLE-EDUCTESTSVC

November 11, 1992

Sue Goins
Virginia Commonwealth University
Box 2020
Richmond, VA 23284-2020

Dear Ms. Goins:

Enclosed are "Levels of Progress in Using Computers in the Classroom" and the "Maryland Education Project Assessment Measures Task Force Report." Because of an extraordinary number of requests, additional booklets had to be printed and were therefore delayed in being sent out.

Although the report and matrices are probably self-explanatory, I should make the following points.

-- The Maryland Education Project "Levels of Progress" is the assessment piece of a much larger effort in Maryland to train teachers to integrate computers into their classrooms. If you would like to receive a report of the project, please contact Barbara Reeves, Maryland State Department of Education, 200 West Baltimore Street, Baltimore, MD. 21201.

-- How To Use These Documents Remember that the "Levels of Progress" is a working document created by (and for) a specific group of teachers. As other teachers reflect on the ways they and their students use computers, additional domains will undoubtedly emerge. In fact, the version you are receiving shows how Maryland's Frederick County language arts teachers have already adapted the Integration of Reading and Writing Domain to suit their local curriculum. If you create a new domain or make revisions to the matrices, we invite you to share your thoughts with us.

-- Future Plans The Maryland teachers also analyzed how computers changed the kinds of assignments they gave, how their students collaborated and learned, and what the actual worksamples their students created. Describing this rich source of information and materials was beyond the scope of the project, but if computers are to be used more effectively, we need good examples of assignments and student work to illustrate how computers can facilitate learning.

My colleague, Gita Wilder, is currently working on a new program in New York City with PBS Children's Television Workshop, but we hope to continue our work when she returns to ETS. In the meantime, I would appreciate hearing about any efforts you have made to integrate computers into classroom instruction.

With all best wishes,

Mary E. Fowles

Mary E. Fowles
Principal Measurement Specialist
School and Higher Education Programs

MARYLAND EDUCATION PROJECT

Assessment Measures Task Force Report

Prepared by:

Mary E. Fowles and Gita Wilder

Educational Testing Service. Spring, 1991

Executive Summary

This report describes the progress of the Assessment Measures Task Force of the Maryland Education Process (MEP) as the Task Force in its efforts to devise innovative ways to assess the efforts of the MEP. The report also presents a framework developed by the Task Force for assessing progress made by schools, teachers, and students in integrating computers into instruction.

Through MEP, computers have been introduced into six local school systems. The local school systems decide how to allocate and use the computers, resulting in a wide range of applications and activities. Working with staff members from the Maryland State Department of Education (MSDE) and Educational Testing Service (ETS), the Task Force reviewed the variety of structures and activities that characterize the MEP schools and classrooms. Then the group identified a set of domains in which computers appeared to be capable of enhancing instruction across the activities. Teachers provided samples of student work that were reviewed by the group. Finally, a framework was developed that delineates levels of progress in computer use in several of the domains.

The Task Force anticipated a number of uses for the framework, including

- a guide for district administrators in assessing the overall progress of the district in integrating technology
- a way for district and/or school administrators to describe how teachers and students use computers and the progress made by their districts/schools in using computers, when talking with parents or school boards
- a basis for tracking the progress of schools in the implementation of technology
- a self-evaluation tool for use by groups of school administrators or teachers in assessing their own goals and progress in using technology
- a basis for discussions within schools about goals and progress in integrating technology across the curriculum
- aids to a process of goal-setting in districts, schools, or classrooms related to the uses of technology
- guidelines for individual teachers wishing to assess their own or their students' progress in working with computers

The Task Force welcomes the suggestions of others who may find their own uses for the framework.

MARYLAND EDUCATION PROJECT

Assessment Measures Task Force Report

This document is both a report and an invitation. As a report, it describes the work of the Assessment Task Force of the Maryland Education Project (MEP) in developing a framework to assess the progress made by schools, teachers and students in integrating computers into instruction. It also offers suggestions about how school administrators and teachers might use the assessment framework. As an invitation, it encourages readers to apply the framework to their own situations. Readers are invited to develop new uses for it, share these uses with MEP staff, and make suggestions about how the framework might be adapted or revised on the basis of their experiences.

Background

The Maryland Education Project is an effort to integrate computers into the learning processes of all disciplines represented in the Maryland public schools, grades K through 12. The project represents a partnership among the Potomac Edison Company, the Maryland State Department of Education (MSDE) and six local school systems and seven institutions of higher education served by the utility company. Potomac Edison has supplied labs of networked computers to a number of schools and colleges in their service area to support the application of technology to instruction. Each local school system and college chooses the sites to be served, prepares for the implementation of the labs, and allocates funds for the purchase of software and the training of teachers. The MSDE has provided technical support and additional funds for training.

Since the start of the project in 1987-88, a phased implementation of technology has proceeded, with primary emphasis on mathematics and writing, at the elementary school level. How the computers are actually used, what grades are involved in their use, and how many teachers are trained each year are matters decided by individual schools and/or districts.

From the beginning, the project has sought broad participation in its activities. A Project Coordinating Committee provided overall direction and a series of Action Teams focused on different needs that emerged from an initial working conference: teacher training, instructional implementation, hardware, software, evaluation/research, and public relations. After a year of planning, the Evaluation/Research Team formed an Assessment Task Force and asked research and development specialists from Educational Testing Service (ETS) to work with the task force in developing a framework to assess the use of computers in the classroom.

instructed to provide a context for each sample:

- the configuration of hardware with which each sample was generated;
- the software that was used;
- the class and subject area in which the computer-based work was produced;
- the assignment and process that led to the work sample;
- the ability level(s) of the students;
- what the work sample demonstrates about the student's learning; and
- the feasibility of this as a model or prototype assignment for other classes.

At the second meeting of the Assessment Measures Task Force, participating teachers brought work samples collected according to these general guidelines and supplied information about the contexts in which the work samples had been generated. What was immediately apparent was the range of circumstances within which the teachers worked (from labs of 15 or more computers to single computers shared by four teachers), and the variety of solutions they had applied to their particular circumstances.

The most common application was word processing; the teachers provided numerous examples of student work that illustrated how students engaged in the writing process. The second most common application was the organization and presentation of information from diverse sources, often facilitating complex problem-solving that could not have taken place without the computer. A third was drill-and-practice as a way to support and expand upon classroom instruction, most commonly in mathematics.

As the teachers discussed how computers had enhanced teaching and learning in their own classrooms they began to recognize that the ways in which computers clearly made a difference in the way students learn and the way teachers teach clustered into a limited number of categories. These categories, called "domains" for the purposes of this project, were further discussed and refined by the Task Force in a subsequent meeting.

Identifying domains. As they discussed the effects of using computers in their classrooms, the teachers agreed to focus on areas (domains) in which the computer appeared to be making a real difference in instruction, rather than offering an alternative medium for "usual" classroom activities. The distinction is perhaps best illustrated by the example of writing. Many teachers reported leading their students through the writing process. Most agreed that the unique contributions of the computer to the writing process revolved around the capacity of the computer for making revisions easy and for creating products that increased students' pride in their own writing and interest in reading the levels of performance related to the work samples that members brought for the consideration of the group. The corpus of work samples was marked by its range, diversity and richness. In their deliberations, the larger Task Force and smaller working groups focused on

- identifying distinct levels of achievement or accomplishment demonstrated by students' work samples,
- achieving consensus about the definition of each level, and
- devising descriptors that communicate the levels of achievement to others.

During the limited time that the Task Force was able to work together, it became clear that some domains were more easily documented through work samples than others. There were several reasons for this. One was that some applications were more common than others among the teachers on the Task Force. For example, many teachers used the computer in the service of integrating reading and writing and for enhancing the writing process; relatively few teachers were using the computer to help students solve complex problems. Another reason was that certain of the domains are reflected more in overall use of the computer than in individual projects or samples of work. The end result was that preliminary descriptions of levels were developed for some domains but not others.

Refining the framework. Through continued discussion and the review of work samples in the context of the framework, the framework was refined and enhanced and became the document that is attached. One important addition at this point was the need to reflect the speed with which technology and its applications develop. The Task Force agreed that, however the framework develops and is revised, there should always be a level of performance that exceeds the most advanced level that is specified. This allows for the expansion of computer use to exceed the capacity of the Task Force to anticipate it.

Applying the framework. The final discussion of the Task Force focused on the ways in which the framework might be applied. The following suggestions, intended to be illustrative rather than exhaustive, were contributed by the Task Force:

- As a guide for district administrators in assessing the overall progress of the district in integrating technology
- As an heuristic for use by district and/or school administrators in explaining the ways in which teachers and students use computers and the progress made by their districts/schools in using computers
- As a basis for school administrators to track the progress of their schools over time in the implementation of technology

ETS

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LEVELS OF PROGRESS

IN

USING COMPUTERS IN THE CLASSROOM

A Working Document Developed by

the Maryland Education Project Assessment Measures Task Force

and Educational Testing Service, Spring, 1991. Revised, 1992.

INTRODUCTION

This document delineates levels of progress in integrating computers for instruction in several areas, or domains:

The various Levels within each area provide "indicators" of progress in teacher and student attitudes, behaviors, and skills related to the use of technology as a teaching and learning tool. Level 5 accommodates a level of progress that exceeds the most advanced specified level. The information can be used to set goals and assess progress in technology integration.

I. MOTIVATION (TO ENGAGE IN LEARNING ACTIVITIES)

Level 1	Level 2	Level 3	Level 4	Level 5
Beginning Level	Becoming Proficient	Proficient	Highly Proficient	Creative Application of Skills and Software
The teacher: is gaining confidence in using computers; understands basic computer functions; sees how some packages could be integrated into classroom instruction; begins to use software packages.	**The teacher**: begins to individualize computer use; begins to use computer as tool for personal and professional use.	**The teacher**: recognizes and accepts new challenges in the use of technology for instruction; feels confident using and teaching with computers; is positive about effects of technology on learning and on making classroom management more efficient; can identify software that meets the students' needs.	**The teacher**: uses resources outside the classroom (e.g., in the community) to enhance students' use of computers; explores research and journals to enhance use of technology; serves as a resource to other teachers.	**The teacher**: develops inventive and unique instructional strategies; helps students explore new arenas in technology to complement new instructional/learning patterns and strategies.

(Continued on next page)

II. USE OF WORD PROCESSING IN THE WRITING PROCESS

Students will use computers to increase fluency in oral, written, and visual communication of ideas.

(MEP Goal)

Students will develop as writers through frequent writing experiences and many opportunities to interact with each piece of writing, having had occasions to prewrite, draft, revise, and proofread.

(Maryland School Performance Program Learning Outcome)

II. USE OF WORD PROCESSING IN THE WRITING PROCESS (Continued)

Level 1	Level 2	Level 3	Level 4	Level 5
Beginning Level	Becoming Proficient	Proficient	Highly Proficient	Creative Application of Skills and Software
Additional note: Differences between handwritten and word processed versions are primarily visual, not textual.	**Additional note:** Students who will not revise their handwritten pieces do so willingly on the computer.	**Students:** produce carefully edited final text that is: • correctly spaced between words, sentences, paragraphs, and pages; • indented appropriately; • spelled correctly; • formatted appropriately (business letters, science reports, etc); • visually attractive, often integrating text and graphics.		

III. PRODUCTION AND PERFORMANCE FOR PURPOSES OF COMMUNICATION

Level 1	Level 2	Level 3	Level 4	Level 5
Beginning Level	Becoming Proficient	Proficient	Highly Proficient	Creative Application of Skills and Software
The teacher: plans the communication projects; may have students follow simple sets of published directions; may create the final product for the students.				
Students: create products that may be difficult to read or understand due to errors, crowded text, experimental use of fonts and graphics, or poor organization; may use the computer for only certain steps in the process of creating the product	**With litte teacher guidance, students:** can explain what they plan to create and why; give some evidence of planning to make use of graphics, fonts, and other ways of communicating ideas; may create easy-to-read and well-organized products, but fonts and graphics may not be balanced or give much support to the content; are able to use the computer for most steps in the creation process, including making minor revisions.	**With little teacher guidance, students**: consider appropriate software and other resources and make purposeful choices; use technology to create products that are visually inviting and easy to read and understand--fonts and graphics support content; use computers to make necessary improvements in content, style, and layout; can fully describe the process they used to create the product.	**Working independently or on teams, students**: demonstrate skill and knowledge in developing a plan and identifying and using appropriate hardware and software to implement the plan; use technology to create products that are visually inviting, well-organized and formatted, and easy to understand in ways that effectively, even creatively, convey meaning; use a variety of software and multimedia technology effectively throughout the process of creating and sharing a product; can explain the process they used, answer complex, detailed questions, and reflect on their efforts.	

IV. INTEGRATION OF READING AND WRITING

Level 1	Level 2	Level 3	Level 4	Level 5
Beginning Level	Becoming Proficient	Proficient	Highly Proficient	Creative Application of Skills and Software
The teacher: may use computer to create instructional materials for basic reading and writing skills.	**The teacher:** helps students use single computer software to create their own reading/writing products; reviews, selects, and uses software programs to encourage reading skills and motivate writing about text.	**The teacher:** uses the computer to integrate reading/writing process and extend it; has integrated reading and writing on the computer as a natural extension of the normal process in the classroom environment.		
Students: may be using Drill and Practice types of software.	**Students:** may be using software that helps them read and respond to text	**Students:** understand the relationship of "computer tools" to reading/writing process; can use multiple tools (computer programs); can use the computer to access information for research reports, etc.; publish the products they compose on the computer.	**Students, with teacher guidance:** use multiple programs and electronic technologies to create integrated reading/writing products for their use and broader audiences; use computer to access information for reports, research, written communication in all classes.	

IV-A. INTEGRATION OF READING AND WRITING (Continued)

Level 1	Level 2	Level 3	Level 4	Level 5
Beginning Level	Becoming Proficient	Proficient	Highly Proficient	Creative Applications of Skills and Software
Students: may be using drill and practice language arts software; are learning correct keyboarding methods, may use a word processor as the vehicle for learning keyboarding.	**Students:** use assigned graphic organizers [illegible] ideas [illegible]; learn [illegible] process [illegible] about text may be [illegible] individually or cooperatively on a computer to input ideas about text they have read in the classroom.	**Students:** [illegible] feeling to reflect [illegible] respond to what was read use the computer as a tool to adequately extend and expand their ideas about the text; become selective in their application of skills and strategies; work individually or cooperatively to input ideas and clarify meaning; become proficient in using all of the features of the word processor to manipulate ideas.	**Students:** [illegible] how to prepare for [illegible] reading [illegible] how to monitor [illegible] reading and how [illegible] respond [illegible] text in any content area [illegible] computer as a [illegible] to fully extend and expand their ideas about the text; are independent in their selection and application of skills and strategies; choose whether to work individually or cooperatively to input ideas and clarify meaning; transfer word processing skills to other software packages.	**Students:** are independent, skilled, and satisfied readers and writers.

V. GATHERING, INTEGRATING, ANALYZING, AND USING INFORMATION

Level 1	Level 2	Level 3	Level 4	Level 5
Beginning Level	Becoming Proficient	Proficient	Highly Proficient	Creative Application of Skills and Software
The teacher: introduces students to simple methods of data collection and manipulation; uses tutorials and/or identifies simple questions for students to answer.	**The teacher**: is teaching students to generate questions that they can answer through data analysis; introduces guides and templates that help students learn the process of collecting and analyzing data.			**The teacher and students**: are integrating new technologies in the process (e.g., modems for gathering and communicating information, CD ROM Encyclopedia, Scanner for collecting data).
Students can: use simple data collection programs (templates and tutorials); enter data to answer simple questions (e.g., "how many," "which ones," "what kind.") recognize the role of the computer in facilitating these and similar tasks.	**Students**: are learning how to collect and enter larger amounts of data and use larger databases to answer questions; can manipulate data in simple ways (e.g., sorting, reordering); can design a simple database, table, or spreadsheet; recognize that computers can help collect and analyze data.	**With teacher guidance, students are able to**: discuss content and plan organization of database; design a database that contains (describes) 2 or 3 variables; write explanatory text and create graphs to report results; collect and manipulate fairly complex and/or large amounts of information; describe the process they used and assess its effectiveness; generate new questions based on the data; apply the skills they learned to solve different kinds of problems.	**Students assume a highly active role in**: identifying possible sources, both technological and traditional, and methods for collecting data; obtaining data efficiently and effectively; integrating various software programs as needed; analyzing data to answer questions, new questions, and make logical connections across data; interpreting the data, drawing reasonable conclusions, and providing logical rationales; effectively communicating their interpretations in written reports, oral presentations, and graphs or other visuals.	

VI. SOLVING COMPLEX PROBLEMS

Level 1	Level 2	Level 3	Level 4	Level 5
Beginning Level	Becoming Proficient	Proficient	Highly Proficient	Creative Application of Skills and Software
The teacher: demonstrates use of computers to solve problems.	**The teacher:** identifies problems for student to solve.			
With assistance, students can: solve simple problems by using simulation software or simple templates.	**Students:** can construct a template, given specific guidelines; are gaining experience in understanding how to identify and solve problems.	**With teacher guidance, students are able to:** identify important problems that need to be solved; identify software that can be used to help solve problems; systematically work through a process of solving a complex problem; describe their process, the role of the computer, and the effectiveness of the results; apply the results in a meaningful way; design and construct their own templates to solve problems.	**Students become problem finders and work collaboratively to:** propose complex projects and justify their importance; figure out how to work effectively together and with others to complete the project; choose their own procedures and software to solve problems and explain the process to others.	

VII. ADAPTING INSTRUCTION TO THE NEEDS OF INDIVIDUAL STUDENTS

Level 1	Level 2	Level 3	Level 4	Level 5
Beginning Level	Becoming Proficient	Proficient	Highly Proficient	Creative Application of Skills and Software
The teacher: is beginning to target individualized computer instruction for students (esp special needs and g/t) whose needs are not being met with traditional instruction; is becoming aware of and exploring the use of the computer to monitor student progress.	**The teacher**. targets computer instruction based on individual student needs to support specific curriculum objectives; selects software based on student needs and learning objectives; monitors student progress and reviews reports generated, but may not yet use results in purposeful ways.	**The teacher**: routinely identifies or adapts computerized instruction to help individual students reinforce certain skills concepts or develop new ones; chooses appropriate software to diagnose student needs, to address specific learning objectives, and to monitor and assess student progress; routinely reviews progress reports and shares with students and parents.	**The teacher**: effectively monitors student progress and uses data to plan computer instruction as an on going, integral process for instructional program; is effectively using the management capabilities of the computer.	**The teacher**: creates programs for individual students
Selected students: are receiving individual instruction via computer and may be positive about it, but purpose and impact may be unclear.	**Selected students**: are aware of the computer's role in providing individualized instruction and positive about using the computer to address their specific needs.	**With teacher direction, students**: pace themselves/can monitor their own progress. are involved in selecting software or parts of software to fit their learning needs.	**Students**: recognize how the computer can help diagnose, instruct, and assess their knowledge and skills; understand how computer software packages offer specific help, such as accessing research information and managing their own files, and are able to select appropriate software.	**Students**: create programs for other students (e.g. 4th graders create for 2nd graders).
Impact is unclear.	Impact may be seen on progress of selected students.	Positive impact on overall instructional program is evident.	Individualized computer instruction contributes in significant ways to student learning outcomes.	