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THE EFFECTIVENESS OF INTERACTIVE DISTANCE EDUCATION TECHNOLOGIES IN K-12 LEARNING: A META-ANALYSIS

by

CATHERINE CAVANAUGH

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
in Curriculum and Instruction with an emphasis in
Instructional Technology
Department of Secondary Education
College of Education
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Major Professor: James White, Ph.D.

DEDICATION

This dissertation is dedicated to my parents, Carolyn and Del Goodrich, who taught me by their example the value of setting goals, working with persistent effort, and lifelong learning.

This work is dedicated with love to my husband, Terry, who introduced me to a rewarding and fun career in education, and provided the just-in-time support I needed along the way.

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THE EFFECTIVENESS OF INTERACTIVE DISTANCE EDUCATION TECHNOLOGIES IN K-12 LEARNING: A META-ANALYSIS

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An Abstract

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This meta-analysis estimated the effectiveness of interactive distance education using videoconferencing and telecommunications for K-12 academic achievement. The variables emphasized in the literature were the grade level and ability level of the learners, the duration and frequency of use of distance education, the subject area, instructional design model, and technology system used. The study features investigated for their contribution included sample size, learning environment, source of study, date, type of achievement measure, and testing sequence.

Studies for this meta-analysis were located using systematic searches of databases and literature, followed by direct requests for data from researchers. Of the 59 studies reviewed, 19 experimental and quasi-experimental studies met the established inclusion criteria for the meta-analysis. The pool of studies could have tripled if sufficient data were available. Recommendations are made for researchers to include complete details in published accounts and requested reports. The selected studies represent an array of research completed between 1986 and 1997 from published and unpublished sources. The 929 student participants ranged from grades 3 to 12, both regular and advanced learners of diverse content areas, learning in school environments, over one to 15 weeks or more. The study features were coded for the meta-analysis variables and characteristics by independent coders, with 85% overall agreement.

Student evaluation data provided material for weighted average effect size calculations for each study. The effect sizes ranged from 1.474 to -1.152 standard deviation units. The 19 study effect sizes were checked statistically for homogeneity and heterogeneity. Analysis of variance tests revealed no significant difference in effect for each variable and feature, however power was limited due to the small N. When the

effect sizes were found to be significantly heterogeneous, they were combined using the random effects model, suited for heterogeneous data with unexplained variance. The overall effect size was 0.147, a small positive effect in favor of distance education, with a 95% confidence interval from -1.113 to 1.407. The foreign language studies analyzed were statistical outliers with large negative effect sizes. The overall effect size without those studies was 0.344 standard deviation units, but the confidence interval still included zero.

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CHAPTER I: INTRODUCTION

In light of the enormous resources now being spent on educational technology for distance education, a summative review of the effectiveness of interactive distance education in K-12 schools is overdue. This proposal outlines a study of K-12 interactive distance education research for the purpose of quantifying and comparing effectiveness outcomes. The study described here synthesizes the findings in this area in order to evaluate and identify effective practices. The vehicle for the synthesis is a meta-analysis.

Technology Use in Schools

Instant access to information is available to growing numbers of students at all levels of education thanks to educational technology. Although educational technology is more than hardware, software, and infrastructure, it is these components that are receiving current attention. Between 1989 and 1996, the number of instructional computers in schools increased over 200% and by 1997, the number of schools with Internet access had reached 70% (Software Publishers Association, 1998). In today's education climate, use of current technology becomes increasingly critical in schools for several reasons. With the advent of school choice, magnet schools, and charter schools, competition for students and the funding that follows them is growing. Schools that are able to demonstrate innovative educational strategies using technology are at a distinct advantage in attracting and keeping top students, and in earning further funding through grants, endowments, and programs. Of course, having technology does not ensure

effective use of the tools, and therefore may not translate into education benefits. As schools work to provide students with expensive technology involving continual upgrades they are pressured by their communities to show that the investment is paying dividends. Payers of taxes and tuition want assurances that the students are not only receiving experiences sufficient to keep them competitive with their peers worldwide, but also that the use of technology results in educational achievement. Educational administrators and decision-makers are challenged with providing increased educational opportunities without increased budgets. Many educators are responding to this challenge by developing distance learning projects.

Distance Learning Technology in Schools

Current technology funding initiatives such as the Florida Distance Learning Network are concentrating on providing distance learning capabilities to all students. In his 1996 State of the Union address, President Clinton announced, "Every classroom in America must be connected to the information superhighway…by the year 2000." Recent national Net Day events have coordinated corporate and government resources to bring distance education to schools across the country. As of 1995, 60% of all personal computers in K-12 schools were networked to another computer. Forty one percent of school districts engaged in distance learning, driven by demand for time and place independence and by economic issues. Half of all school districts were using distance learning in the "business of education": academic modules and credit courses (CCA Consulting, 1996). Eighty two percent of the states reported that equality of educational experience in all schools was the principal need addressed by distance education projects that provide courses to homebound and remotely located learners (Quinn & Williams,

1987). Most state governments support an agency to oversee distance education. Florida Distance Learning Network is soliciting applications from school districts for millions of dollars in funding for distance learning equipment.

Distance learning applies physical technology and education processes to serve the needs of students when they are removed from the source of instruction and resources by either time or distance. "As with most instructional tools, the purpose of distance learning is to help schools meet the instructional needs of their students and to enable students to access information more effectively and apply what they learn in school to the world in which they live" (ESA, 1995). Distance learning uses a group of systems to bring teaching and learning together by transmitting information or expertise from one place to another for learner benefit. Formally, distance education is characterized by physical separation of learners from the information, an organized instructional program, use of technological media, and two-way communication (Heinich, Molenda, & Russell, 1993).

The benefits of distance education as outlined by Kerka (1996) include flexibility to meet specific needs, providing equity of educational opportunity to students in varying localities, low-cost alternatives, new learning experiences, and expanded resources. Distance learning systems worldwide have been installed to enrich existing school curricula with supplemental activities like electronic field trips such as the Jason Project to the ocean floor, interactive communication with peers and experts, or to offer courses when a classroom teacher is impractical. Full courses are delivered via distance learning from elementary through graduate school, as well as in business and industry. As of

1995, an estimated 300,000 participants had enrolled in on-line courses with schools and universities worldwide (Hirumi & Bermudez, 1996).

Applications recently developed for industry are rapidly being adapted to education as school-to-career movements gain importance in American schools. Distant mentoring is an instructional tool that pairs workers or learners in new roles with skilled advisors. Learning-on-demand was designed for upgrading skills and knowledge for current and immediate job needs. These applications add realistic school-to-career component to K-12 education. Organizational learning forms infrastructures to enhance and extend the capabilities of the individual to collaborate and to utilize specialized knowledge of others (Molnar, 1997). Teacher and community development opportunities abound. All forms of education are enhanced by the increased access to information and communication afforded through distance education.

Disadvantages of distance education include sound and video that may be less than broadcast quality, reliance on learner initiative to work in a situation with less supervision than a classroom, the need for technical skills to work with the delivery technology, and the possibility of social isolation (Kerka, 1996).

A primary goal of distance educators is to humanize and improve distance learning by facilitating interaction among learners and with others in the learning community. When students become part of a distance education community using text-based communication, studies show that writing skills increased significantly more than when the learners wrote to strangers or teachers (Software Publishers Association, 1998). Distance education that features collaboration with distant peers and cooperation with

diverse individuals not only increases learning but develops skills needed in the global workplace (Dede, 1996).

Distance Learning and Academic Performance

Distance acquisition of knowledge is often an expensive and time-consuming process to institute and maintain. It is important to know whether it actually improves student performance. It is also critically important to know which distance education delivery methods and techniques are more effective, so students get the most benefit from society's investment in distance learning technology. The Florida Distance Learning Network has identified 13 distinct distance learning delivery systems with 32 various applications for learning (1996). Nearly every subject imaginable is offered via distance education, with the bulk of expenditures to provide increased access to high school courses (Quinn & Williams, 1987). Faced with so many new, rapidly changing options, schools need data in order to make quality decisions regarding distance education.

Holmberg's theory of distance teaching (1985) states that distance teaching will support student motivation and promote learning pleasure and effectiveness if learners are engaged in discussions and decisions, and the program provides for real and simulated communication to and from the learners. As in any classroom, interaction is the core of teaching.

Distance education is believed to work very well, and produce results as effective as traditional classroom instruction (Kearsley, 1996). However, the distance education currently in practice has the potential to provide more effective learning with updated pedagogy, more experience, and greater understanding and knowledge of methods. Numerous studies have evaluated student achievement in specific distance learning

programs in higher education. According to Abrami and Buras (1996), learning at a distance is seldom superior to traditional instruction, particularly for promoting higher level achievement and complex skills. These weaknesses may stem from social and intellectual isolation. Improved distance education practices have the potential to enhance educational outcomes, especially when the amount and kind of learner interaction is increased using technology-supported collaborative learning.

Although distance learning is well documented with adults, fewer studies of effectiveness exist that center on the primary and secondary levels. At a point when all states offered distance education in schools, very few had conducted formal evaluations (Quinn & Williams, 1987). While it is possible that our knowledge of distance education technology in higher education is relevant with precollege learners, there is no empirical evidence for this assertion. Additionally, previous research has spread across grade levels, content areas, and technologies. Distance education program developers have paid less attention to the appropriate blend of media, content, learner, and gain; instead defining effectiveness in terms of the number of students served or student satisfaction (Eiserman & Williams, 1987). The Software Publishers Association reported evidence that educational technology's positive effects depend on subject area, student population, and level of access to technology (1998). A quantitative synthesis of those studies will greatly increase understanding of the effectiveness of distance learning on K-12 achievement by revealing the features and combinations of characteristics that make distance education most effective.

Interaction in Distance Education

Because of the high degree of individuality of students and the growth in the numbers of students entering school globally, individualized learning is becoming increasingly important. Highly interactive technology-mediated instruction makes individual attention possible. The most effective form of interaction is natural language. Highly interactive learning systems are intrinsically motivating, and do not need attention-gaining embellishments. Instead, resources can be concentrated on the interactive learning with which all students can learn at a high level (Bork, 1997). For high level learning, feedback must be individualized and immediate to be beneficial (Howard, 1987).

Technology can be the vehicle for encouraging thought and interaction: involving students in conversations with each other, with others, and within their own heads (Dockterman, 1995). Instructional designs that develop strong learner-centered environments include five critical elements for interactive learning with technology, according to Oliver and Reeves (1996):

- collaboration--peer groups work toward shared goals
- generative learning--interpretation and assimilation of information
- contextual engagement--anchored in relevant context
- personal autonomy--increased learner control and individualization
- motivation--intrinsic and self-regulated learning

Using these elements to positively effect achievement and attitude through cooperative learning and interaction, the virtual classroom can facilitate learning equal to any other collaborative learning environment (Abrami, 1996).

Technology can create communities of learners and facilitate interactions necessary for solving real-world problems. Jonassen's situated learning models (1995) emphasize the role of context in learning and socially negotiated meaning. He developed four attributes of learning environments that engage learners and require them to construct meaningful knowledge: context, construction, collaboration, and conversation. He proposes that distance education incorporate methods such as computer-mediated communication, computer-supported collaboration, case-based learning environments, and computer-based cognitive tools.

To further elaborate on interaction in distance education, Moore (1989) specified three types of interaction that are valuable in learning:

- Learner-Content--results in changes in understanding through internal conversation
- Learner-Instructor--contributes to reality testing and feedback
- Learner-Learner--leads to essential development of expertise

Moore asserts that educators need to design programs to ensure maximal effectiveness of each type of interaction, and provide the type most suitable for the teaching tasks and learners in the situation.

Dede's 1990 theory of technology-mediated learning states that effectiveness depends on inclusion of these characteristics: (a) a technological medium that either intervenes between direct human interaction or provides a shared environment that shapes the process of interpersonal communication, (b) spontaneous participant interactions, and (c) technology-based tools and experiences that enhance collective learning and individual accomplishment.

The above characteristics are present in the distance learning delivery systems involving videoconferencing, on-line telecommunications, and combinations of the two. These delivery systems are also those experiencing the most rapid growth in schools now. Moore warns that the main weakness of distance education programs is their commitment to only one type of medium. Attention is needed in evaluating multi-media approaches to interactive distance education.

Students learning with effective use of distance education strategies not only experience educational benefits, but learn career and life skills related to technology, problem-solving, and communication. Teachers will be better equipped to provide quality instruction with the tools in their hands when they know the factors leading to effective instruction with distance learning.

A compilation of factors of effective distance education has been assembled in Appendix A. While such a compilation can work as a useful guide for educators, it remains a gathering of the opinions of experts and a tally of studies. It will not be possible to quantitatively evaluate distance education effectiveness until a comprehensive statistical synthesis such as the proposed study is performed. This assembly of best practices in distance education served as the basis for selecting the variables in the proposed meta-analysis. The studies analyzed were coded for each variable when they were incorporated into the meta-analysis.

Purpose

The intent of this study of interactive distance education systems at K-12 levels is to examine the relationship between classroom use of videoconferencing and on-line distance learning technology and student performance. The goal of the study is to

provide educators with more knowledge concerning the effective use of distance education technology, by quantitatively synthesizing the results of previous investigations into the academic effects of distance education.

The following review of pertinent literature centers on the recent findings on the effectiveness of distance education techniques in K-12 and higher education settings. Interactive videoconferencing and on-line telecommunications are contrasted. The value of meta-analytic techniques for adding to the base of knowledge in instructional technology is outlined. Chapter III then details the process of selecting and analyzing studies for the meta-analysis. The technological tools for handling the data are described.

The meta-analysis involves gathering study data from research conducted on interactive distance education at K-12 levels. The study data are weighted to account for the size of the study sample. The study results were converted to an effect size estimate to allow different measures to be compared. The effect sizes have been averaged or otherwise combined to yield an overall assessment of K-12 interactive distance education effectiveness.

Delimitations

The results of this study apply to K-12 level learners. Generalization is limited to similar groups, and not possible for higher education applications of distance education. The studies included in the analysis focus on either interactive videoconferencing or on-line telecommunications technologies, so the findings do not generalize to other distance education delivery systems such as audio, cable and broadcast television, or CD-ROM. Because the meta-analysis focuses on academic achievement effects, other effects cannot be implied.

Accepted practice in distance education research reviews is to include data from countries worldwide, due to the international scope of distance education. If a gap exists between the United States and other countries with regard to distance education, then the U.S. would be distinguished by using less distance education than others (Moore & Thompson, 1990). In terms of the general education systems of countries using distance education, two 1996 reports from the National Center for Education Statistics (Phelps et al; Matheson et al) compare 14 industrialized nations and the G-7 countries with American states on key education indicators. The general characteristics of ethnic homogeneity, school starting age, average days and minutes of instruction, and teacher preparation were found to be almost identical between the U.S. and Canada. For every demographic, economic and sociological indicator, the U.S. states "closely resembled" other countries (Matheson et al, 1996). Participation in formal education at primary and secondary levels was virtually universal in every state and country. As far as technology use in schools, the US was in the middle of the range for the proportion of students using computers (Phelps et al, 1996). For the reasons described, the proposed meta-analysis is international in scope, encompassing studies of K-12 distance education in the United States and Canada.

Limitations

Studies were considered to be usable in the meta-analysis if they are free from obvious flaws such as small sample size, and if they provide data necessary to compute effect size (Pisapia & Perlman, 1992). The studies must provide data in enough detail to be used for meta-analysis, and must have occurred after microcomputers entered schools in the 1980's, to relate to current technology and classroom practice.

Definitions

Distance education. For the purposes of this study, educational activities conducted in primary and secondary school settings using interactive communications technology for acquisition of knowledge from a source distant in time or place from the classroom.

Delivery system. The technology used in distance education, limited in this study to interactive videoconferencing and on-line telecommunications.

Educational technology. The application of specific hardware, software, and infrastructure employed in delivering instruction.

Effect size. The difference between the means of two groups divided by the standard deviation of the control group.

Effectiveness. Student performance indicated on achievement measures given at the end of the distance education period.

Interactive videoconferencing. A system of communication in which distant participants see and hear each other.

Meta-analysis. A statistical process of combining the results of many quantitative studies for an overall synthesis.

On-line telecommunications. A system of communication in which distant participants send text, sound, or images using computers connected by telephone or high-speed data lines.

Students. Full-time kindergarten through twelfth grade enrollees, for this study.

Traditional instruction. Education methods exclusive of distance education.

CHAPTER II: REVIEW OF LITERATURE

The research on the effectiveness of distance education systems is wide-ranging in terms of the populations and delivery systems studied. Learners from early childhood through adulthood have participated in studies comparing distance learning and other learning systems. Each study concentrates on a different subject matter, with varying results. This review of the literature points out the great scope of studies that have been done in the area, beginning with a look at the state of research in distance education today. The findings on both interactive videoconferencing and on-line telecommunications are outlined. Because of the challenge in measuring the effectiveness of the complex learning occurring with interactive distance education, assessment issues will be explored. The review concludes with a summary of distance education theory and research, and recommendations for future directions in the field. Because a wide range of studies have been completed, but not analyzed and synthesized, the value of the meta-analysis proposed here will become evident, and the role of the meta-analysis will be described.

Distance Learning Delivery Systems

Distance education as it is used in K-12 education operates with dozens of physical delivery systems. The delivery systems range from passive reading of texts, listening to audiotape, and watching videotape. Technically, these systems qualify as distance education because the knowledge is transferred over a distance of space or time

to the learner. However, to differentiate between distance education and traditional instruction for the purposes of this study, the distance education systems studied will be limited to interactive videoconferencing and on-line telecommunications. Not only are these the most common and popular systems being investigated and invested in for schools now, they also best meet Dede's criteria for quality technology mediated learning.

Distance Education Effectiveness

Educators and technology planners in the 1990's see distance education becoming a core educational strategy. Although distance education has existed in some form since the publication of the first printed material, today's emphasis on technology has brought rapid change in the systems used to deliver distance learning instruction. Traditional reviews of distance education literature conducted in the 1980's indicate that learners achieve as well in distance education programs as they do in traditional classroom settings (Moore, 1989). Other studies described by Moore and Thompson (1990) indicate that the instructional format itself has little effect on student achievement as long as the delivery technology is appropriate for the content, and timely teacher-to-student feedback is included. This research involved technology that is now outdated, and was not conducted using quantitative synthesis methods, but it points out the need for educators to have data showing the most appropriate situations for the use of distance learning systems. Good distance teaching practices have been found to be fundamentally identical to good traditional teaching practices, with quality factors being universal across environments and populations (Wilkes & Burnham, 1991). This means not only that

various studies of distance learning may be synthesized reliably, but that the results of such a synthesis ought to generalize to most comparable education situations.

Souder's 1993 study with students in three Master's degree programs showed that achievement on instructor-administered tests tends to be higher for distant students rather than for traditional students. Students enrolled in the distance satellite course scored significantly higher on the course exam than the students taught face-to-face. However, because the groups attended different institutions, age and experience differences could explain the results. The same study revealed no significant difference in attitudes toward course material. The question remains as to whether the trends hold true for elementary and secondary students. Future research should also include a variable that is critical in determining student achievement: the design of instruction.

The Internet will continue to grow as a mechanism for distance education, and the best means of using it must be discovered using empirical data. Telecommunications offers increasing access to educational programs, but does not necessarily enhance the quality of education. Documented effective practices must be used to develop approaches and policies regarding distance education. (Hirumi & Bermudez, 1996).

Distance Learning with Interactive Videoconferencing

Interactive videoconferencing provides real time synchronous interaction between students and instructors or other students. It is a cost-effective means for incorporating speakers, electronic field trips, and subject matter experts into education. Human interaction is important because of the value and benefits students realize from timely feedback, involvement with others, help received, and support during learning. Interactive videoconferencing assures that learners form accurate interpretations and

provides feedback, instructional components difficult to provide with noninteractive video broadcasts (Schaffer & Hannafin, 1986).

Roblyer (1997) states, "The combination of visual context and real-time interactive conversation is highly desirable. Communication is made more effective with the tones and nonverbal cues present in face-to-face interaction." Videoconferencing for distance education leads to an effective and collaborative instructional environment in which distance is no obstacle to learning. When interactivity is limited, student dissatisfaction results, even when achievement remains steady (Oliver & Reeves, 1996).

Studies of the effectiveness of interactive videoconferencing instruction have rendered mixed results. A study by Bauer and Rezabek in 1992 involving 172 graduate students in an educational technology course compared teleconferences with two-way audio, teleconferences with one-way audio, and traditional instruction. Students were randomly assigned to three treatment groups. The teleconferencing groups did not differ significantly in the number of verbal interactions, but the traditional group interacted more than either.

Boling (1996) and Worley (1991), working with adult learners in professional settings have shown that the use of interactive video systems make no significant difference on learners' attitude toward the instruction or content. Addition of techniques such as cooperative grouping or multimedia instruction improved effectiveness and enjoyment. Boling's sample of 115 adults was randomly divided into groups comparing two-way interactive video and audio instruction. Cooperative grouping significantly increased the learning with distance technology. Worley conducted a quasi-experimental study comparing digital video instruction combined with either one-way or two-way

audio. Both systems were effective for learning, with preference for two-way audio. Recognition that adult learners differ greatly from children led to the recommendation from Worley that investigation be conducted in K-12 environments.

Secondary level students have been the focus of numerous studies, with much more variety in the findings. Studies by Hinnant (1994), Martin (1990), and Sisung (1992) indicated that interactive videoconferencing systems are as effective as traditional methods for bringing about achievement in general education, humanities and science. No differences in the attitudes of the students toward the content were suggested. Hinnant evaluated high school achievement with two-way video and audio vs. traditional instruction with no significant difference. Sisung tested two-way video against traditional instruction for 44 high school students, with equivalent results on content tests. Sisung pointed out the need for additional research to verify the reliability and generalizability of these findings. In contrast, the research of Burkman (1994) states that while test achievement of 54 high school students in psychology was not impacted by the use of interactive videoconferencing when compared with face-to-face teaching, attitudes were significantly more positive about learning psychology using interactive television. In 47 western classrooms, students using satellite television plus two-way telephone and computer conferencing learned a year of Spanish in a single semester, although at a statistically lower level than traditional classrooms on standardized tests (Quinn & Williams, 1987). Libler's 1991 work with 85 high school physics students showed a combination of lower achievement on a standardized test, but higher attitude toward content among students learning with interactive video when compared with the norming population. Gray's 1996 non-experimental study with 92 high school students learning

Japanese showed both higher exam achievement and equal or better attitudes than traditional classes after instruction via satellite. The Alabama Star Schools project reports that of 75 high school seniors taking advanced placement courses through one-way video and two-way audio, over 90% would recommend the course by satellite, a strong indicator of positive attitude toward the course (Wilson, 1990). Dede's innovative Collaborative Visualization Project (CoVis, 1993) involved high school students studying weather with videoteleconferencing among students, university researchers, and scientific experts in the field. The project is considered an exemplary example of distance education in which science learning occurred through shared experiences and communication.

Studies of pre-high school children in general education classrooms in 40 schools by Fyock (1994) and Lane (1996) imply that interactive videoconferencing instruction is as effective as traditional methods for achievement and attitude, but the distance system leads to more time devoted to learning the content. Fyock found that grade point average was not impacted by participation in two-way instructional television courses. One of the most comprehensive distance learning studies done with elementary level students is reported by Lane (1996), in which live interactive instructional telecasts were delivered to students in grades 2 through 6 across the United States and Canada from 1992 to 1996. Evaluations were conducted by teacher survey of 7299 students in 1994, and 8235 students in 1995. Improved content knowledge and skills in mathematics and science was directly attributed to the participation in the project. Similar gains were reported for the GALAXY satellite learning network used by 39 American elementary schools. Students enrolled in the GALAXY language arts class used interactive video technology,

and showed higher overall test scores and greater gains in vocabulary than the comparison group in traditional classes (Moore & Kearsley, 1996).

Distance Learning with On-line Telecommunications

In distance education, the primary on-line learning vehicles are electronic mail, distribution list, and the World Wide Web, all of which can be used interactively. In addition, on-line use of interactive video is growing with the introduction of CU-SeeMe™ teleconferencing and similar technology. These communications technologies serve as extensions of traditional classroom instruction, as well as delivery systems for complete courses. On-line methods allow messaging, feedback, targeted communication, and group interaction.

Being a newer technology to reach education, on-line telecommunications has been the subject of fewer studies to this point. Twenty eight teachers participating in a graduate instructional computing course delivered by telecommunications showed no significant difference from a traditional course in their final grades or attitudes toward computers (Cheng, Lehman, & Armstrong, 1991). A study done in several college classes at several curricular areas and levels by Karayan and Crowe (1997) indicated an overall increase in knowledge after use of electronic discussion groups. Participants felt they were 57% more likely to learn course content as a result of involvement in the discussion groups. Oliver and Reeves' 1996 research into the effectiveness of audiographics (computer and modem communication with audioconferencing) revealed positive findings. Students showed attitude and motivation gains and cognitive improvements. Cooperative interaction and collaborative activities were central components in maximizing learning outcomes.

Studies of pre-college students seem to be just as positive about the effects of on-line telecommunications. Allen's 1993 experiment with fifth graders in writing found that participation in a computer-mediated telecommunications network dialog with readers who responded to their work contributed to an increase in the quality of the writing. A national study in 1996 by the Center for Applied Special Technology (CAST) compared 500 elementary school students using on-line communications to those learning with traditional instruction. The students were evaluated before and after a Civil Rights lesson on nine measures of achievement, and the results show a significantly higher score on five of the measures for the on-line group. This study was sponsored by the Scholastic Network, a commercial provider of on-line services for education.

Dede (1996) has reported several K-12 telecommunications projects that highlight the possibilities for enhancing learning through highly interactive distance learning. The Distant Mentor project is described as a leading-edge example of collaborative learning using telecommunications between students learning workplace skills and professional mentors. In Teleapprenticeships, collaboration tools were valuable, and students experienced learning gains through increased access to workplace experts. Classrooms with Electronic Walls joined student groups using wireless networking for real-world data collection.

It is difficult to draw solid conclusions from a sample of studies. A meta-analysis of the completed research would assist in explaining overall effects. Meta-analyses have been performed recently to show trends correlating use of technology in general with improved achievement (Kulik, 1993; Ryan, 1994), but not focused on distance education.

Distance Education Assessment Issues

When implementing distance education, assessment of both the instruction and the students safeguards the quality of the educational experience. Distance education offers special challenges for assessment. The instruction and its goals may be non-traditional and therefore resistant to standardized test instruments. Experienced distance education practitioners report that assessment of distance education is best accomplished with attention to higher order objectives, including synthesis, evaluation, analysis, and complex communication competencies.

Assessment of students in any educational context exists primarily to provide feedback to learners about their progress and success in learning. Generally, student assessment entails comparisons between the prescribed objectives and performance standards and the resulting achievement of students. Higher order objectives should be evaluated with prompt, focused, and constructive feedback (Holmberg, 1989). Student self-assessment should be an emphasis so students develop an internal feedback loop and become independent learners. Self-assessment can be done using study questions, journals, or checklists. Authentic assessment occurs in the context of learning, as students perform learning tasks.

Assessment of the distance learning course or instructional unit leads to understanding of its effectiveness in helping students attain learning objectives. With this understanding, the course can be revised and improved. One approach to course evaluation entails consultation with the students' future employers and teachers in order to relate the course objectives to students' needs in the next phases of their learning. Student attitudes also offer important information about how well a course works.

Questionnaires and interviews are useful for identifying student interest, confusion, and satisfaction in the course. An evaluation of which course elements were most used will point out strengths in the instruction. Finally, an appropriate measure of student learning shows the degree of retention, comprehension or skill attained by learners (Moore & Kearsley, 1996).

New Directions for Distance Education

The conventional role of distance education is to enable traditional classroom teaching to cross distances and time. New technologies make new instructional messages, and therefore, new models of distance education possible. Greater access to information necessitates a literacy of information evaluation and the development of learning experiences designed to foster such skills.

Dede (1996) outlines four new models of distance education in which educators and learners enter highly interactive distributed learning situations. Knowledge webs provide "distributed access to experts, resources, authentic environments, and shared investigations". Virtual communities support learners through contact with others for shared, collaborative learning. Synthetic environments extend the learning experience to virtual worlds shared by many people to simulate authentic environments. Sensory immersion in artificial realities uses visualization tools to stimulate perception of abstract relationships.

The responsibility of the educator is creating experiences in which new ideas lead to "insights in intriguing and challenging situations". Learners are constructing new mental models with meaning for their lives. Each model is a highly interactive preparation for developing future work and learning skills.

Distance Education Theory and Research

At the root of distance education theory is the belief that distance education is different from face-to-face-instruction (Schlosser & Anderson, 1994). A new distance education paradigm begins with the offer to students of an experience as much like a real-world problem-solving situation as possible. As distance education advances, we will see greater transparency of the technology and greater similarity between education with distance technology and without it. We will also witness less dichotomy and a more subtle continuum from distance education to traditional instruction, with a great variety of blends and combinations emerging.

The focus of research in distance education must be on teaching and learning, rather than the technology itself. The content and student performance are paramount. The purpose of distance education is meeting student needs, and the criterion it must meet is a high standard of meaningful learning. Distance education can both accomplish some of the challenging goals of education and present new ones. Educators are charged with accommodating the needs of learners in the most effective way with an eye on cost- and time-effectiveness as well. This role cannot be fulfilled without complete and accurate knowledge of the technological and instructional tools available.

Research on distance education has begun to show the effect of distance learning on student achievement, but the picture is not clear at this point, especially in the K-12 realm. Traditional instruction and distance education can be equally effective, given quality design and delivery. Studies comparing distance education and traditional instruction have resulted in a wide range of conclusions. The research cited here shows every level of achievement attributed to distance education. A key issue is determining

the types of students and educational messages best suited for distance education media. Distance education may be more appropriate at a particular age, subject, or ability level. Teachers need facts about the most effective ways to incorporate distance systems into learning experiences.

Traditionally, reviews and syntheses of education research attempted to combine results of studies to reach general conclusions about the effectiveness of an approach by using the box score or narrative methods. Box score reviews report the proportion of related studies that found the approach to be effective, without regard to sample size, controls, or the magnitude of the result. Narratives, similar to Appendix A, describe studies and draw intuitive conclusions about the findings. Both approaches are susceptible to giving excess weight to anecdotal reports (Pisapia & Perlman, 1992). The meta-analytic process identified by Glass (1977) is a quantitative replacement for such reviews.

Meta-Analysis

Meta-analysis provides a systematic method for accumulating and synthesizing statistical evidence from a variety of studies that address a common research question. A strength of meta-analytic method is the ability to reach quantitative generalizations from a group of related studies. Meta-analysis, as a method of synthesis, integrates findings more rigorously than narrative discussions (Glass, 1977). Meta-analysis allows the transformation of the outcomes of many studies into a quantitative measure. The importance of meta-analysis goes beyond addition of knowledge and increased understanding to a greater utility in public policy decisions (APS, 1994).

That social science researchers, including educators, have recognized the value of

meta-analysis in the last fifteen years, is a trend demonstrated by tracking the number of meta-analyses published from 1975 to 1990, as enumerated in PsycInfo, ERIC, and Social SciSearch. In 1980, the cumulative number was less than 100, and by 1990 had climbed to over 300. The importance of meta-analysis goes beyond addition of

Single studies rarely provide definitive answers on which to base policy. Meta-analysis provides a quantitative synthesis of studies leading to a more precise estimate of the effect of distance education technology on academic achievement. More informed conclusions can then be drawn about effectiveness of the distance education technology systems. Meta-analysis integrates findings from numerous studies in order to reveal patterns of relationships (Hunter & Schmidt, 1990). In the case of distance education with K-12 students, numerous studies exist, so the need may not be for additional data. What is needed is to reach conclusions based on the cumulation of data. These cumulations across all of the available studies can provide guidance for decision-making, lead to theory development, and aid in problem solving. The preceding review of the literature demonstrates that to this point meta-analyses have been done with data on distance education in higher education, but not at the pre-college level.

Issues in Meta-Analysis Method

The logic of meta-analysis is complicated by the fact that numerous studies addressing a research question use various definitions, variables, procedures, methods, samples, and design. Thus, the conclusions of the studies may contradict each other (Wolf, 1986). Glass has delineated some common criticisms of meta-analysis: (1) the difficulty of drawing logical conclusions from dissimilar studies, (2) contamination of meta-analysis results by poor studies, (3) the bias of published studies in favor of

significant findings, and (4) bias rising from inclusion of multiple results from the same study that are logically interdependent (Glass, 1977).

Strategies have been developed for addressing each of the criticisms of meta-analysis. (1) Variables and characteristics of studies can be coded and tested to determine homogeneity and mediating effects. Different meta-analysis processes are used for studies that are homogeneous and for those that are heterogeneous. (2) The coding of studies is used to make comparisons, which allow detection of significant differences between groups of studies. (3) Studies from multiple sources, published and unpublished, must be included in the analysis to avoid bias, and a calculation of Fail Safe N (Wolfe, 1986) will estimate the number of additional studies with nonsignificant results that would be needed to reverse the conclusions of the meta-analysis. (4) When studies present data from multiple measures on the same sample, results can be combined to avoid giving those studies greater weight in the meta-analysis.

Effect Size in Meta-Analysis

Effect size is “the degree to which the phenomenon is present in the population” or “the degree to which the null hypothesis is false” (Wolf, 1986). The effect size used in this study is Cohen's effect size, a pure number in standard deviation units, free of original measurement units used to index size of difference from the null (no effect) condition. It indicates the size of the difference between the groups or treatments compared in an experiment. The aim of the meta-analysis is to determine an average effect size of many studies on the topic.

Meta-analysis has been firmly established in instructional technology over the past two decades as an evaluative tool for computer applications in education. A 1993

overview of meta-analysis in education compiled in American Psychologist listed 12 meta-analyses evaluating the effectiveness of computer-aided and computer-based instruction. The meta-analyses conducted between 1980 and 1991 found positive effects ranging from small to large, based on syntheses of as few as 13 studies up to 199 studies.

This meta-analysis of K-12 interactive distance education could serve the education community by accomplishing several goals. The meta-analysis provides quantitative data concerning the effectiveness of different interactive distance learning systems, and compares their effectiveness for a variety of learner types. A gap in knowledge about the use of distance technology at pre-college levels has been filled. The results of the analysis have the potential to become guiding data for educators who are weighing large and important decisions regarding technological infrastructure for learning. This study can enable schools to more effectively and appropriately allocate limited technology dollars.

CHAPTER III: METHODS

Meta-analysis is a specialized form of statistical analysis used in this study to combine the results of many studies of interactive distance education at the K-12 level. The purpose is to arrive at a comprehensive assessment of the effectiveness of interactive distance education for K-12 learners. This chapter details the specific questions addressed in the study, the main variables, and the overall research design. Critical issues including study coding, effect size computation, and validity are discussed.

Research Questions

To determine whether use of interactive distance education contributes significantly to student academic achievement, the study addresses the following issues in a meta-analysis:

1. What are the effects on K-12 student achievement of interactive distance education use of videoconferencing or on-line telecommunications?
2. What are the features (duration of use, frequency of use, instructional design, delivery system, ability of students, level of students, content area) of the most effective interactive distance education systems?

The study explores the relationships between the independent variables (features) of interactive distance education. The features include duration, frequency, instructional design, delivery system, student ability, grade level, and content area, with the dependent

variable (academic achievement). The variables were identified as important features of distance education in the review of studies. This review appears in Appendix A. The meta-analysis studied the relationships between the dependent variables and the potentially contributing independent variables. The hypothesis was:

> Students using interactive distance education will experience varying levels of academic achievement relative to the control groups, depending partly on the duration and frequency of their use of distance education technology, the design of instruction, the ability and grade level of the student, and the academic content area.
>
> The statistical null hypothesis for meta-analysis states that the average effect size in the population is zero.

Variables

- Independent: Use of distance education, subgrouped by duration, frequency, instructional design, delivery system, student ability type, grade in school, and content area
- Dependent: Student achievement as measured by instruments appropriate to the study analyzed

This study examines the relationship between student academic achievement at the K-12 level and use of the interactive videoconferencing or on-line telecommunications distance education systems. Studies of such impacts were quantitatively synthesized using meta-analytic techniques. Main effects evident in were explored through accumulation of effect sizes.

Research Design

Overview of Research Design

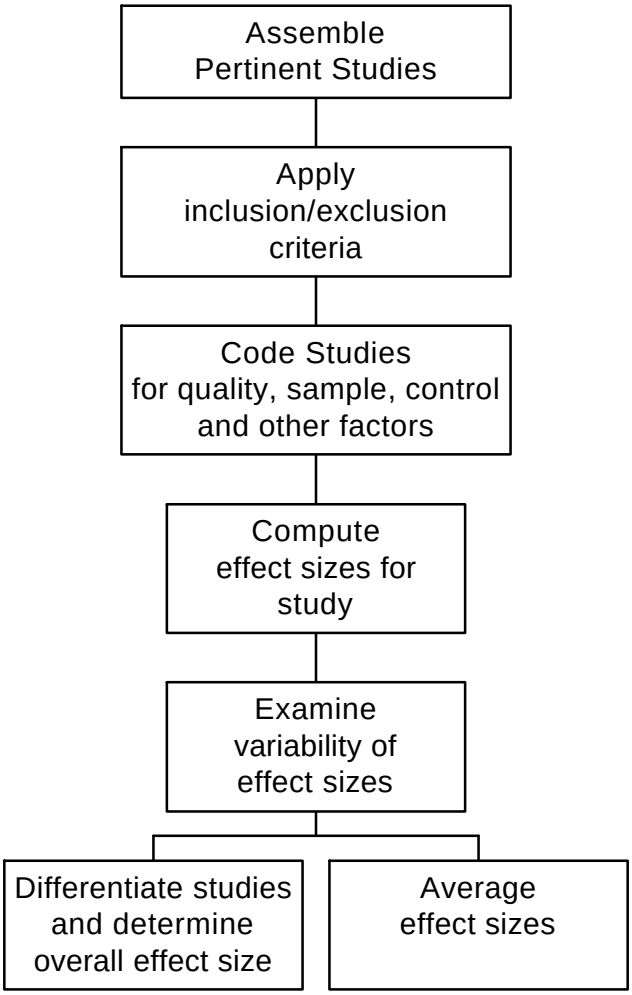

Figure 1. Overview of study design

The steps for conducting the meta-analysis begin with defining the domain of the research. This study investigates relationships between the following variables (features) and student achievement: type of interactive distance learning system, frequency and duration of use of the distance education system, instructional design, school grade and ability levels of learners, academic subject. Such comparisons are important because, until now few studies or reviews have methodically discriminated among types of

learners and other characteristics (Moore & Thompson, 1990). Including a large number of variables clarifies factors that may contribute to the effectiveness of interactive distance education, while reducing sample size available for analysis of particular features.

Study Inclusion Criteria

The criteria for inclusion of studies are established. In this case, studies from published and unpublished sources written in the 1980-1998 time period are included to encompass the period of microcomputer use in education. The studies provide data sufficient for analysis, and are free of major flaws such as significant demographic differences between the groups being compared, studies of less than a week in duration, and studies with insufficient sample size to provide adequate power.

Table 1

Meta-analysis Criteria

Meta-analysis Criteria	
Inclusion Criteria:	Focus on the use of interactive distance education technology for education at K-12 levels, either videoconferencing or on-line telecommunications. Publication date between 1980 and 1998. Experimental or quasi-experimental design providing quantitative outcomes from which effect size can be estimated. Free of flaws previously described.
Exclusion Criteria:	Exclusive focus on attitudes. Less than one week duration. Focus on higher education or adult education. Use of distance education technology exclusive of videoconferencing or online telecommunications.

Data Collection

Studies involving student academic achievement as a result of distance education at the K-12 level were assembled. Quasi-experimental studies were included with experimental studies because true experiments are done in artificial situations, while quasi-experiments usually occur in more realistic conditions. Quasi-experiments, although having lower internal validity, produce more realistic results and increased external validity (Carlberg et al, 1984). The setting for the studies is K-12 learning environments, with preference for studies using random sampling. Both published and unpublished studies are included to avoid publishing bias.

Studies were gathered from computer databases including ERIC, Dissertation Abstracts, requests from national and state distance education projects and the World Wide Web. Searches were conducted in journals of education organizations from the 1980's and 1990's because of the recent development of the distance education delivery systems being examined here. Programs from professional organization meetings were employed to locate other unpublished studies.

Search Process:

1. ERIC database: The ERIC database was searched using the keywords "distance education", "distance learning", "teleconferencing", "satellite", "telecommunications", and "email".
2. Dissertation Abstracts: The same descriptors as were used with ERIC were used to locate dissertations.

3. Journals and proceedings of professional organizations: The same terms were employed in searches of university periodical indexes to locate studies from professional organizations.
4. World Wide Web: The same search terms were used in the World Wide Web search engines Metacrawler and Yahoo.

These initial searches unveiled references for hundreds of documents. Each document was located in ERIC files, on the Web, in journals, by interlibrary loan, or by ordering dissertations. When the studies met all inclusion criteria for this meta-analysis, they were included. The bibliographies of studies that did not meet all inclusion criteria provided references for locating other studies. When studies lacked data for inclusion in this analysis, a direct request was made to the authors or sponsoring organization to send additional information. A total of 59 such requests were sent via post or email. In addition, the technology directors for each state were contacted by email with requests for data.

A preliminary group of 59 studies was selected from all available studies for review to determine their appropriateness for inclusion in the meta-analysis. Of the 59 studies reviewed, most were eliminated. The studies met most of the established inclusion criteria, with exceptions noted below.

- The study referred to, but did not provide data on student achievement: 15
- The study provided incomplete data on student achievement: 11
- The study did not focus exclusively on K-12 learners: 8
- The study provided qualitative data on student performance: 3
- The study focused on attitude rather than achievement: 2

- The study examined achievement as a result of audioconferencing: 1

After searching the World Wide Web, ERIC, other databases, education research journals and conference proceedings, and direct requests for data from distance education programs and state technology directors, a total of 19 studies was selected for inclusion in the meta-analysis. Thirteen studies are dissertations, four came from published journals, and two were available from evaluating agencies' World Wide Web pages.

A review of the APA list of meta-analyses published in 1993 showed that of the 12 audio-visual and computer technology meta-analyses conducted on K-12 learning, the average meta-analysis included 52 studies, with a range of 13 to 199 studies analyzed. The total of 19 studies included in this meta-analysis is low, but within acceptable range for published meta-analyses in educational technology. Several studies were obtained and excluded from the meta-analysis for lack of data, a focus on adult learners, a focus on non-interactive distance education, use of a qualitative approach, or lack of a comparison to a control.

The measure of student performance in the studies was indicated on achievement measures given at the end of the distance education period. Such measures included standardized tests, and teacher/researcher designed instruments. Traditional measures may not be effective in assessing the effectiveness of distance education systems that strengthen higher order skills. Complex skills such as problem solving, motivation, writing, collaboration, and awareness of community are some of the benefits of using distance education (Pisapia & Perlman, 1992). Growth in these areas can only be inferred with the use of common achievement measures. The student performance

measures used in the studies analyzed here are accepted as the best estimates of the effect of interactive distance education technology on student achievement currently available.

Study Coding

Data extracted from the studies is coded according to the features of the study. The study coding is shown in Table 2.

Table 2

Study Coding Table

Coding Category	Options
Publication Characteristics:	
Title	
Authors	
Affiliation	
Year of Study	1980-1998
Source of study	Journal, Database, Dissertation, Web, Other
Technological Characteristics:	
Distance Learning System	Web, Email, 2-way Audio/Video, 1-way Video/2-way Audio, 1-way Audio/Video + Text, Combination
Ecological Characteristics:	
Duration of Exposure	1-3 weeks, 4-7 weeks, 8-11 weeks, 12-15 weeks, 15+ weeks
Frequency of Exposure	Daily, weekly, monthly, less often
Instructional Design	Primary or supplementary instruction
Grade Level of Learners	Primary (K-2), Intermediate (3-5), Middle (6-8), High (9-12), Mix
Learning Environment	Laboratory, School, Home, Other
Student Ability Type	Regular, Advanced, Exceptional, At-risk, ESOL, Other
Academic Content Area	General, Language, Mathematics, Science, Social Studies, Arts, Vocational, Other
Hardware Components	
Type of Computer Interaction	Text, Audio, Video, Combination
Methodological Characteristics	
Student Achievement Measure	Standardized, Teacher-developed, Researcher-developed, Other
Testing Sequence	Pretest-posttest, Posttest only, Repeated, Other
Sample Size	n
Sampling Method	Random selection, Random assignment, Convenience, Other
Controls for Instructor, Historical or Bias Effects	
Research Design	Matching subjects, Matching classes, Cohort control, None
Significance Level:	
Results:	
Standard Deviation	
Group Means	
Other results	t-test, F statistic, Correlation, Other
Effect Size:	
Biased Estimate	
Unbiased Estimate	

The characteristics listed in Table 2 were included in the analysis for the following reasons:

- *Title, author, affiliation*: identification of studies
- *Year of study*: assessment of the effect of changes in interactive media technology, pedagogy, and experience with technology over time
- *Source of study*: estimation of publishing bias
- *Type of interactivity, hardware, and distance learning system*: comparison of the effectiveness of the technology systems and the degree of interactivity
- *Duration and frequency of use*: determination of the optimal exposure, and testing the hypothesis that more use contributes to greater performance
- *Instructional design*: comparison of distance education used as the primary mode of instruction with programs supplementing regular instruction with distance education
- *Grade level of learners*: determination of whether the higher-order communication skills used in distance education contribute to more benefit with a specific age of learners
- *Ability type of learners*: to triangulate findings with other technology that low-achieving and at-risk populations experience significant skill gains
- *Learning environment*: comparison of realistic and artificial situations
- *Academic content area*: determination of whether mathematics and language arts achievement are more strongly influenced than other areas by distance education, as with other learning technologies
- *Methodological features*: comparison of results with study structure

- *Significance, results, effect size estimates*: calculation of the overall effectiveness of interactive distance education

Achievement reliability was not coded because while it is an important feature in evaluating the quality of a study, it was not reported in the vast majority of the studies, and reliability data could not be obtained separately for studies using non-standardized measures.

Analysis of Data

Study coding and data were compiled using a Microsoft Excel 97 spreadsheet created to collect and organize information. An Excel form was created to prompt for all needed features of each study and automatically save the information in a database from which analyses were conducted. Excel was capable of performing most statistical tests needed for this study.

Coding Procedures

Reliability checks were performed on the study coding procedures with subsets of data using percent agreement between the coding results of the coders. The percent agreement procedure provides the average percent agreement on coding samples between independent coders. A sample of five studies was used to compute the percent agreement, and all codes for all studies coded were compared item by item. The coders were the researcher and a distance education professional with a background in educational statistics. Points of disagreement between coders were reexamined to determine whether the coding schemes required revision.

Effect Size

Cohen's effect size provided a common scale for comparison of study outcomes. Outcomes are presented in standard deviation units, describing the difference between achievement with interactive distance education systems and without. Effect size provides a standard metric for judging achievement using interactive distance education technology across studies. Effect sizes were computed using the most appropriate option from the list below, depending on the data available in the study. Method 1 is the preferred computation method. When it was not possible to use Method 1, and more than one alternative was possible, the alternatives were computed and the most conservative estimate was used. When achievement results from multiple measures were reported for the same sample group in a study, Cohen's effect sizes were calculated for each measure, and then averaged.

Table 3

Effect Size Computation

Data Supplied	Effect Size Procedure	Variable
1. Group means, standard deviation	$\frac{\overline{x}_e - \overline{x}_c}{s_c}$	s = standard deviation $\overline{X}$ = group mean score
2. Degrees of freedom, t statistic, and which group mean is higher	$\frac{2t}{\sqrt{N}}$	t = t-test result N = study sample size
3. Sample size, t statistic	$t\sqrt{\left(\frac{1}{n_e} + \frac{1}{n_c}\right)}$	n = sample size t = t-test result
4. Means, Fisher's F, sample size	$\sqrt{\frac{F}{n_e + n_c}}$	F = Fisher's F statistic

The mean and variance of each effect size was next determined, weighted by sample size, using the formulas

1. Biased effect size estimate $$g = \frac{\bar{x}_e - \bar{x}_c}{s_e}$$

2. Correction factor for removing bias

$$J = 1 - \frac{3}{(4m - 1)}$$ where m is degrees of freedom of *s*.

3. Unbiased effect size estimate $$d = J \times g$$

(Hedges, Shymansky, & Woodworth, 1989)

Tests for homogeneity of effect sizes was accomplished by graphing the frequency distribution of effect sizes for the studies synthesized. Outlier studies were considered for grouping into a separate meta-analysis to examine mediating effects

The overall effect size calculation procedures begin with the estimation of between-study variance, used to determine the difference between the observed variance among effect sizes and the within-study sampling variance. The formula for between-study variance:

$$\hat{\delta}^2 = S_d^2 - \frac{\left(S_d^2 + \ldots + S_k^2 \right)}{K}$$

Where S_d^2 is the sampling variance of the studies, S_k^2 is the sampling variance of each study, K is the number of studies (Hedges et al, 1989). The sampling variance must be computed with

$$S_d^2 = \frac{(d_1 - S_1)^2 + \ldots + (d_k - S_k)^2}{K-1}$$

where d_k is the study effect size, S_k is the study standard error.

The variance is used in calculating confidence limits and in combining the effect size estimates in the random effects model. The effect size formula is weighted with both the within-study sampling error variance (standard error) and the variance. The overall effect size is found using:

$$d_+ = \frac{\frac{d_1}{(S_1^2 + \delta^2)} + \ldots + \frac{d_k}{(S_k^2 + \delta^2)}}{\frac{1}{(S_1^2 + \delta^2)} + \ldots + \frac{1}{(S_k^2 + \delta^2)}}$$

The independent effect sizes were combined by weighted averaging to yield an overall effect size estimate. The combined estimate has a smaller standard error than any of its parts (Hedges, Shymansky, & Woodworth, 1989). The combined estimate was found by summing each effect size divided by the square of its standard error, then dividing the sum by the sum of the inverse of the squared standard errors. Formula for sampling variance, which is the square of the standard error:

$$S^2 = \frac{(n_e + n_c)}{n_e n_c} + \frac{d^2}{2m}$$

where n is group sample size, d is the unbiased effect size estimate, m is the degrees of freedom of the control group (Hedges, 1989). The standard error was used in computing the weighted average effect size. Formula for weighted averaging of effect sizes:

$$d_+ = \frac{\frac{d_1}{S_1^2} + \frac{d_2}{S_1^2} + \ldots + \frac{d_k}{S_k^2}}{\frac{1}{S_1^2} + \frac{1}{S_2^2} + \ldots + \frac{1}{S_k^2}}$$

where k is the number of effect sizes being combined.

It was necessary to compute the standard error of the weighted average to determine its significance. The standard error of the random effects weighted average is

$$S_{d+} = \frac{1}{\left(\frac{1}{S_1^2 + \delta^2}\right) + \ldots + \left(\frac{1}{S_k^2 + \delta^2}\right)^{1/2}}$$

For alpha of 0.05, a 95% confidence interval was found by multiplying the standard error by 1.96, then adding and subtracting the result from the overall effect size, d_+. If the confidence interval includes zero, the null hypothesis that effect size in the population is zero cannot be rejected.

Next, the overall standard deviation for the meta-analysis was calculated, using the formula:

$$s = \frac{\sum (d - d_+)^2}{K-1}$$

where K is the number of studies in the meta-analysis.

Heterogeneity of effect sizes was estimated to determine the appropriateness of combining them into an average. Formula for heterogeneity:

$$Q = \left(\frac{d_1 - d_+}{S_1} \right)^2 + \left(\frac{d_2 - d_+}{S_2} \right)^2 + \ldots + \left(\frac{d_k - d_+}{S_k} \right)^2$$

$$Q = Q_1 + Q_2 + \ldots + Q_k$$

where Q is heterogeneity and d_+ is weighted average effect size.

As a rule of thumb, only one study in 19 should have a Q value exceeding 4, and only one in 100 should exceed 5.4. Therefore, when studies were found to be strikingly deviant, they were examined individually to determine the possible reasons, and to decide whether to include them. The heterogeneity test was performed on all studies contributing to the overall effect size.

A formal analysis of heterogeneity (ANOVA) was completed for the effect sizes with effect size as the dependent variable, and the study features as factors. The p-value for the ANOVA was also set at 0.01. This procedure enabled conclusions to be drawn regarding the significance of levels of variables. For example, the ANOVA may reveal that a certain level or type of learner achieves at significantly higher levels using a specific distance education system.

In the case of a significant ANOVA result for published versus unpublished studies, the Fail Safe N (Wolf, 1986) would be computed to determine the number of additional "file drawer" studies with zero effect size that would be needed to reverse a conclusion. The Fail Safe N formula:

$$N_{fs} = \frac{N(d_+ - d_c)}{d_c}$$

where N is the number of studies in the analysis, d_+ is the average effect size for the studies, and d_c is the criterion value for significant effect size selected.

Validity

Issues of validity of results include the problem of deciding which studies appropriately belong in the analysis. External validity is enhanced by coding characteristics of studies and by testing the homogeneity of the results. Internal validity is involved with whether variation in design quality influences the outcome of the analysis, so design quality was coded and examined. More reliable studies have large sample size and better control measures. However, a general rule states that there is seldom more than one-tenth standard deviation difference in average effect size between high quality and low quality experiments (Wolf, 1986). Even so, it was worth looking at such features as experimenter blindness, randomization, sample size, control for error, and type of dependent variable.

Interpreting Results

When interpreting the overall result of the meta-analysis, a confidence interval was constructed to determine whether the average effect size encompasses zero. Other interpretive activities included comparing the findings of this analysis with others in educational technology and distance education, using Cohen's guidelines to evaluate significance of effect size, and determining whether a significant standard deviation of at least 0.25-0.50 improvement can be expected from the use of distance education technology (Wolf, 1986).

In addition to the overall student performance, effect sizes were reported for each variable. Effect size comparisons were made with respect to the following variables:

duration, frequency, instructional design, delivery system, ability level, grade level, and content area. Effect sizes were also compared for the study characteristics date of study, source of study, hardware components, achievement measure, and sample size.

Generalizability

A strength of this study is that it encompasses a broad view of distance education allowing the effectiveness of the technology to be estimated across populations, outcomes and study designs. It was hoped that estimates of effectiveness would enable adaptation of distance education systems for specific improvements in student performance. However, the small number of studies limited such estimates, which may be possible when more studies become available.

The results of the study apply to K-12 level learners. Validity of generalization from these results is limited to similar groups. The extent to which these results will generalize to other population is not known. The studies included in the analysis focus on interactive videoconferencing or on-line telecommunications technologies, so the findings will not generalize validly to other distance learning delivery systems such as audio, cable and broadcast television, or CD-ROM. Because the meta-analysis involves academic achievement effects, other effects cannot be implied.

CHAPTER IV: RESEARCH RESULTS

Introduction

The meta-analysis of the effects of interactive distance education for K-12 academic achievement provided a framework for comparing the features of distance education systems and learners in an attempt to determine the most effective solutions. A sample of K-12 distance education research studies was assembled as described in the Methods section. The features of the studies were coded. Effects for each study were computed and combined, then individual variables were examined.

The following Research Results chapter presents a thorough review of the data collection, coding and computation for the meta-analysis, with the results of each process. The general comparison made here was between the achievement of students learning with distance education systems as the primary or supplementary method of instruction, and the achievement of students learning with traditional methods. With that broad relationship established statistically, more specific comparisons were made between levels of the variables: duration of use, frequency of use, instructional design, distance education technology, student ability, grade level, subject area. Comparisons were also made between the study characteristics: study source, study date, testing sequence, sample size, achievement measure, research design.

The comparisons were made using the most appropriate statistical processes needed to answer the following questions:

1. What is the relationship between K-12 student academic achievement and interactive distance education use of videoconferencing or on-line telecommunications?
2. What is the impact on achievement of the features of interactive distance education systems (duration of use, frequency of use, instructional design, delivery system, student ability, grade level, content area)?

Meta-Analysis Sample

The collection of studies used in the meta-analysis represents a selection of studies available for review that have been performed comparing interactive distance education with traditional education for K-12 academic learning. The sample for the meta-analysis included all studies that met the predetermined inclusion criteria, shown in Table 1.

The selected studies originated from a diverse array of laboratory and agency evaluations, independent research published in scholarly journals, and dissertation studies. Most of the studies were conducted within the past five years, indicating that while technology changes rapidly, this meta-analysis represents an evaluation of recent hardware adoptions and pedagogical approaches. The combined studies include a collective sample of 929 students.

Over two-thirds of the studies focused on students at the high school level who used distance education on a daily basis as the primary delivery system for the subject evaluated. There are more studies done at high school level because distance education is used more at that level to fill a gap for schools that cannot otherwise offer a wide range of educational options. The remaining 33% of the studies examined the effect of distance education on student achievement at grades 3-8. At that level distance education

technology is used less than daily to supplement regular classroom instruction. No studies were located that assessed the learning of primary grades learners. All high school courses were delivered via interactive teleconferencing; all intermediate instruction was based on telecommunications to the exclusion of videoconferencing.

All studies concentrated on regular ability students, except two studies of advanced learners. The subject area most frequently taught using distance education was science, in a third of the studies. Foreign language, language arts, and social studies were the focus of three studies each, followed by mathematics, general education, and computer programming in one study each. No studies were found examining vocational or arts subjects. All studies took place in school/classroom environments.

Table 4 summarizes the features and characteristics of the studies in the meta-analysis.

Study Coding

The features and characteristics of each included study were coded using a coding form based on published educational technology meta-analyses and the important features of distance education outlined in Appendix A. The coders were the author and a local distance education professional with training in education statistics. The full coding form is included in Appendix B. The coding forms for each study were completed independently by the coders. The forms were compared to determine the percent agreement for all items. The average percent agreement between the coders for all studies was 85%, indicating that only 15% of all questions answered for all studies coded were in disagreement. No patterns of disagreement emerged that necessitated changes in the coding process. The points of disagreement were unique for each study. The

researcher re-examined each point of disagreement to determine the most appropriate coding for each study by reviewing the study author's statements. In a third of the cases of coder disagreement, the decision was made in favor of the comparison coder. In the other two-thirds of the cases, this author's coding was found to agree with the study author's statements. The full study coding can be found in Appendix C.

Table 4

Meta-Analysis Study Features

Author	**Year**	**Source**	**System**	**Duration**	**Frequency**	**Grade**	**Subject**
Allen	95	Journal	Email	8-11 wks	Weekly	3-5	Lang.
Blanton	97	Journal	Web	15+ weeks	Weekly	3-5	General
Burkman	94	Dissert	2 way AV	1-3 weeks	Daily	9-12	Science
Burkman	94	Dissert	2 way AV	1-3 weeks	Daily	9-12	Science
Burkman	94	Dissert	2 way AV	1-3 weeks	Daily	9-12	Science
CAST	96	Web site	Email	4-7 weeks	Weekly	3-5	Soc. St.
CAST	96	Web site	Email	4-7 weeks	Weekly	6-8	Soc. St.
Erickson	92	Dissert.	E-mail	15+ weeks	Weekly	3-5	Lang.
Gray	96	Dissert.	2 way AV	15+ weeks	Daily	9-12	Foreign
Hinnant	96	Dissert.	2 way AV	1-3 weeks	Daily	9-12	Comp.
Libler	91	Dissert.	2 way AV	15+ weeks	Daily	9-12	Science
Martin	89	Journal	2 way AV	15+ weeks	Daily	9-12	Science
McBride	90	Dissert.	2 way AV	15+ weeks	Daily	9-12	Math
Riel	90	Journal	Email	1-3 weeks	Weekly	6-8	Lang.
Rudolf	86	Dissert.	2 way AV	8-11 wks.	Daily	9-12	Science
Ryan,	96	Dissert.	2 way AV	15+ weeks	Daily	9-12	Math
Sisung	92	Dissert.	2 way AV	15+ weeks	Daily	9-12	Soc. St.
Smith	90	Dissert.	2 way AV	15+ weeks	Daily	9-12	Foreign
Wick	97	Dissert.	2 way AV	8-11 wks.	Daily	9-12	Foreign

Effect Size Calculation

The achievement data reported in each study contributed to the calculation of effect size for the meta-analysis. Cohen's effect size is a standardized estimate of the difference in achievement between students learning with interactive distance education and students learning with traditional methods. Effect size is expressed in standard deviation units, allowing effects sizes to be compared and combined across various achievement measures. For example, a distance education study with an effect size of 0.30 standard deviations would be a study in which students learning with distance education earned mean achievement scores 0.30 standard deviations above the mean of the control. Based on Cohen, an effect size of 0.30 is small, but may be a significant effect size, depending on sample size. A negative effect size indicates that the students learning with traditional methods achieved at higher levels, on average, than those using distance education did.

For studies in which a group of students was evaluated using multiple achievement measures, effect sizes were found for each measure, and then averaged. The average effect size was used in the overall effect size estimate of the meta-analysis. For studies in which more than one independent group of students was evaluated, an independent effect size were found for each group and used in the meta-analysis separately. While different groups tested in one study were dependent with respect to study features and characteristics, the samples were independent.

Effect sizes were calculated using the most appropriate method shown in Table 3.

The first method was the preferred option when more than one was possible. When Method 1 could not be used, then the most conservative alternate was used to find the biased effect size for each study. A correction factor was applied to each biased effect size found using Method 1 to remove bias by accounting for sample size. Effect sizes for eleven of the studies were estimated using Method 1, four effect sizes were found with Method 4, three used Method 2, and one required Method 3. One study reported its own effect size. The corrected effect sizes for each study are shown in Table 5. The significance of the estimate is based on Cohen's classification, which specifies that an effect size of 0.20 is small, 0.50 is medium, and 0.80 is large.

Approximately 26% of the studies had medium effect sizes, another 26% had large effect sizes, with the remainder having small effect sizes. The largest positive effect size occurred for the study of elementary school students using a multimedia telecommunications system in a supplementary program that was found to greatly improve their standardized mathematics and language scores over students not using the program. The largest negative effect size occurred for high school students learning foreign language via an interactive television system.

Descriptive Analysis

Table 6 provides the descriptive analysis of the unbiased effect size estimates for the studies, obtained using Excel 97. The mean shown in the table is an arithmetic mean, and not the overall meta-analytic effect size for the studies.

Table 5

Unbiased Effect Size Estimates

Author	Subject	Sample	Effect Size	Significance
Allen, G. & Thompson, A.	Language arts	45	0.469	medium
Blanton, William et al	General	26	1.474	large
Burkman, T., Low teacher-motivated	Science	52	0.525	medium
Burkman, T., Medium teacher motivated	Science	52	0.238	small
Burkman, T., High teacher motivated	Science	52	-0.598	medium
CAST, grade 4	Social studies	41	0.154	small
CAST, grade 6	Social studies	25	0.008	small
Erickson, Barbara	Language arts	26	0.253	small
Gray, Barbara	Foreign language	16	-0.433	medium
Hinnant, Edward	Computer science	34	0.149	small
Libler, Rebecca	Science	67	-0.815	large
Martin, E. & Rainey, L.	Science	49	0.856	large
McBride, Ronald	Mathematics	20	1.365	large
Riel, Margaret	Language arts	22	0.574	medium
Rudolf, Sidney	Science	13	0.198	small
Ryan, Walter	Mathematics	277	0.151	small
Sisung, Nancy	Social studies	15	0.19	small
Smith, Robert	Foreign language	54	-0.818	large
Wick, William	Foreign language	43	-1.152	large

Table 6

Descriptive Statistics for Unbiased Effect Sizes

Mean	0.147
Standard Error	0.159
Median	0.19
Mode	#N/A
Standard Deviation	0.693
Sample Variance	0.481
Kurtosis	-0.011
Skewness	0.015
Range	2.626
Minimum	-1.152
Maximum	1.474
Sum	2.788
Count	19
Confidence Level(95.0%)	0.334

The SAS statistical analysis package was used to analyze the frequency distribution of the study effect sizes. The univariate plot procedure identified the interquartile range of the effect sizes to be 0.958 around the mean of 0.1467. Effect sizes falling outside the range bounded by 1.5 interquartile ranges are considered to be outliers. In this case, studies not falling between 0.8652 and -0.5718 are outliers. Six of the studies' effect sizes are outliers, and the studies were examined for possible mediating effects. With the exception of the three foreign language studies, the outlier studies do not have unusual characteristics. The foreign language studies comprised the two negative outliers and three of the five negative effect size results in the database.

In order to examine patterns in the effect sizes of the different levels of the variables in the meta-analysis, Table 7 classifies the included studies by effect size, according to each feature.

Table 7

Study Features Classified by Effect Size

		Number of Studies in the Meta-Analysis with		
Feature	**Level**	**Small d**	**Medium d**	**Large d**
System	Videoconference	5	3	5
	Telecommunication	3	2	1
Duration	15+ weeks	3	1	5
	<15 weeks	5	4	1
Frequency	Daily	5	3	5
	Weekly	3	2	1
Grade	High 9-12	5	3	5
	Intermediate 3-8	3	2	1
Ability	Regular	6	5	6
	Advanced	1	0	1
Subject	Foreign language	0	1	2
	Language arts	1	2	0
	Mathematics	1	0	1
	Science	2	2	2
	Social Studies	3	0	0
	Other	1	0	1
Instructional design	Primary instruction	5	3	5
	Supplementary material	3	2	1
Achievement measure	Standardized	1	0	4
	Non-standardized	7	5	2
Research design	Pretest/posttest	7	3	4
	Posttest only	1	2	2
Sample size	<26	4	2	2
	32+	4	3	4
Date	Pre-1993	3	1	4
	Post-1993	5	4	2
Source	Published	2	2	2
	Unpublished	6	3	4

Student Performance by Study Variable

Student Performance by Type of Distance Education Technology

Studies of distance education by videoconferencing systems composed 68% of the database. Of the videoconferencing group, 38% of the studies had large effect sizes, 23% had medium effect sizes, and 38% had small effect sizes. The average effect size for videoconferencing was -0.016. This is a small negative effect.

Of the studies of telecommunications systems, half had small effect sizes, a third had medium effect sizes, and only one study had a large effect size. The average effect size for telecommunications systems was 0.489, a medium positive effect size. According to this result, the average student learning with telecommunications earned scores 0.489 standard deviations in achievement over the student learning solely with traditional methods.

Student Performance by Duration of Use of Distance Education

Almost half of all studies in the meta-analysis lasted for more than 15 weeks of instruction, generally a semester to a full school year. Of the longer duration studies, 56% had a large effect size, one study had a medium effect size, and one-third had small effect sizes. For the studies lasting from one to eleven weeks, 56% had small effect sizes, 44% had medium, and one had a large effect size.

The average effect size for the long studies was 0.094, a small positive effect size, indicating that slightly improved or unchanged achievement is likely to result from using distance education longer than 15 weeks. The average effect size for shorter studies was

0.186, also a small positive effect size.

Student Performance by Frequency of Use of Distance Education

Over two-thirds of the studies in the database involved students using distance education on a daily basis for instruction. Of those, 38% had a small effect size, 23 % had medium, and 38% had large effect sizes. The average effect size for daily distance education was -0.010, a small negative result.

The third of studies in which students learned using distance education weekly showed one large effect size, two medium, and three small. However, the average effect size was 0.489, a medium positive effect that indicates potential improvement in achievement as a result of supplementing traditional instruction with distance education.

Student Performance by Grade Level

High school (grades 9-12) students used distance education in 68% of the studies, balanced fairly evenly between small, medium and large effect sizes. The average effect size for high school learners was -0.011, a small negative effect size. Intermediate level (grades 3-8) students used distance education in 32% of the studies, with mainly small effect sizes. However the average effect size was 0.489 for these studies, denoting a medium positive effect.

Student Performance by Subject Area

Almost a third of the studies used distance education to teach science. They were equally distributed over small, medium, and large effect sizes, with an average of 0.069, a small positive result. Foreign language, language arts, and social studies each represented 16% of the studies. Foreign language had mainly large effect sizes, and an

average of -0.801, indicating that traditional instruction may be better suited to the task. Social studies had all small effect sizes and the small positive average of 0.117. Language arts studies had mostly medium effect sizes, averaging at the medium positive 0.432, an indication that speaking, reading, and writing have the potential for improvement through distance communication. The two mathematics studies and the two other subjects studies evenly divided between small and large effect sizes. The average effect size for mathematics was 0.758, a large positive effect, while the other subjects, general education and computer science, averaged 0.812, pointing out that technical logical subjects may be strengthened through distance education.

Student Performance by Instructional Design

Students using distance education for the primary course delivery method composed 68% of the studies, balanced fairly evenly between small, medium and large effect sizes. The average effect size for primary distance education learners was -0.011, a small negative effect size. Students using distance education for supplementary instruction made up 32% of the studies, with mainly small effect sizes. However the average effect size was 0.489 for these studies, denoting a medium positive effect.

Student Performance by Year

With all studies published since 1986 and only two studies prior to 1990, this meta-analysis represents distance education accomplished with recently developed hardware and pedagogy. Almost half of the studies occurred before 1993 when school network infrastructure and fast video connections were less widespread. Those studies showed half with large effect sizes, 38% with small, and 13 % with medium effect sizes.

The small positive effect size was 0.225. The studies performed after 1993 had 45% small effect sizes, 36 % medium, and 18 % large, averaging at 0.090.

Student Performance by Achievement Measure

Standardized tests were used as the achievement measure in 26% of the studies, for a wide range of subject area. All but one study showed a large effect size. The average effect size was 0.279, a small positive result. Non-standardized measures accounted for 74% of the studies. The measures included instruments developed by researchers, publishers, and teachers, as well as final course grades. The effect sizes were small for half of the studies, medium for 36%, and large for 14%. The average effect size was 0.099, a small positive outcome. The studies using standardized measures resulted in twice as much improvement in achievement as the studies using non-standardized achievement measures.

Standard Error of Effect Size Estimates

The sampling standard error of an effect size estimate is the standard deviation of the estimated effect size around the true effect size in the population of students from which the study population was selected. Sampling standard error measures the sampling variation of the estimated effect size, but does not reflect non-sampling variations which would occur if the study used a different population of students or changes in treatment (Hedges et al, 1989). Individual effect sizes may not be significant, but when properly combined, the effect can become statistically significant.

Table 8 shows the estimated unbiased effect size for each study with its sampling standard error (S). The sampling standard errors provide weights for optimally

combining effect sizes across studies.

Table 8

Sampling Standard Error

Study Author	Estimated Effect Size (d)	Standard Error (S)
Allen, G. & Thompson, A.	0.469	0.212
Blanton, William et al	1.474	0.313
Burkman, Thomas	0.525	0.198
Burkman, Thomas	0.238	0.194
Burkman, Thomas	-0.598	0.198
CAST	0.154	0.277
CAST	0.008	0.305
Erickson, Barbara	0.253	0.361
Gray, Barbara	-0.433	0.277
Hinnant, Edward	0.149	0.214
Libler, Rebecca	-0.815	0.13
Martin, Elaine & Rainey, Larry	0.856	0.202
McBride, Ronald	1.365	0.351
Riel, Margaret	0.574	0.303
Rudolf, Sidney	0.198	0.365
Ryan, Walter	0.151	0.084
Sisung, Nancy	0.19	0.318
Smith, Robert	-0.818	0.179
Wick, William	-1.152	0.251

Overall Effect Size

One of the goals of the meta-analysis is obtaining an overall average of the effect size of the studies. Several methods have been developed for researching an average effect size. Glass (1976), the original developer of meta-analysis, performed simple mathematical averaging, using the formula:

$$d_+ = \frac{\Sigma d}{K}$$

where K= number of studies in the meta-analysis. When using Glass' approach, the mean effect size for this meta-analysis is 0.147, considered to be a small positive effect size.

Recently, Hedges et al (1989) reported a "statistically optimal" method for combining effect sizes using a weighted average, taking into account the sampling variance of each study. When effect sizes of studies differ from each other by several standard errors, there may be differences in the characteristics of the studies. Heterogeneity analysis is used to study such variation. An index of heterogeneity, Q, is computed for each effect size, using:

$$Q = \left[\frac{d_1 - d_+}{s_1}\right]^2 + ... + \left[\frac{d_k - d_+}{s_k}\right]^2$$

$$Q = Q_1 + ... + Q_k$$

Table 9 shows the heterogeneity for each study.

Only one study in 19 should have a Q value in excess of 4, and only 1/100 should exceed 5.3. Seven studies in the meta-analysis have Q values above 5.3, indicating that they are "strikingly deviant." Additionally, the Q total of 170 exceeds 99% on a chi-square table, indicating that the studies are significantly heterogeneous. To investigate the heterogeneity issue formally, analysis of variance of effect sizes is used.

Table 9

Heterogeneity Statistics

Study Author	Estimated Effect Size (d)	Standard Error (S)	Heterogeneity (Q)
Allen, G. & Thompson, A.	0.469	0.212	5.12
Blanton, William et al	1.474	0.313	21.90
Burkman, Thomas	0.525	0.198	6.79
Burkman, Thomas	0.238	0.194	1.39
Burkman, Thomas	-0.598	0.198	9.370
CAST	0.154	0.277	0.274
CAST	0.008	0.305	0.00001
Erickson, Barbara	0.253	0.361	0.456
Gray, Barbara	-0.433	0.277	2.55
Hinnant, Edward	0.149	0.214	0.427
Libler, Rebecca	-0.815	0.13	40.18
Martin, Elaine & Rainey, Larry	0.856	0.202	17.58
McBride, Ronald	1.365	0.351	14.92
Riel, Margaret	0.574	0.303	3.48
Rudolf, Sidney	0.198	0.365	0.268
Ryan, Walter	0.151	0.084	2.85
Sisung, Nancy	0.19	0.318	0.324
Smith, Robert	-0.818	0.179	21.35
Wick, William	-1.152	0.251	21.39

Analysis of Variance (ANOVA) tests were conducted, using the statistical analysis tool package within Excel 97, for each study feature. The ANOVA results are presented in Tables 10-19. An ANOVA was not conducted for the variable student ability level because of the impracticality of comparing 17 studies of regular students to only two studies of advanced students. An alpha level of 0.01 has been suggested as the criterion for significance for meta-analysis because multiple analyses are performed.

Table 10

ANOVA for Duration of Use of Distance Education System

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
<15 weeks	11	2.041	0.18555	0.44479
15 weeks+	8	0.749	0.09363	0.59565

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03913	1	0.03913	0.0772	0.78448	4.45132
Within Groups	8.61746	17	0.50691			
Total	8.65659	18				

The effect sizes of 15 weeks or more of distance education use are not significantly different from programs in which distance education is used less than 15 weeks.

Table 11

ANOVA for Frequency of Use of Distance Education System

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Daily Use	13	-0.134	-0.0103	0.52003
Weekly Use	6	2.932	0.48867	0.27543

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.02211	1	1.02211	2.28104	0.14933	4.45132
Within Groups	7.61751	17	0.44809			
Total	8.63962	18				

The effect sizes of daily use distance education are not significantly different from programs in which distance education is used weekly.

Table 12

ANOVA for Design of Distance Education Instruction

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Primary Instruction	13	-0.144	-0.0111	0.52104
Supplementary Instruction	6	2.932	0.48867	0.27543

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.02526	1	1.02526	2.28445	0.14904	4.45132
Within Groups	7.62962	17	0.4488			
Total	8.65488	18				

The effect sizes for studies in which distance education is the primary instructional delivery system are not significantly different from those in which distance education supplements regular instruction.

Table 13

ANOVA for Delivery System of Distance Education

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Videoconferencing	13	-0.144	-0.0111	0.52104
Telecommunications	6	2.932	0.48867	0.27543

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.02526	1	1.02526	2.28445	0.14904	4.45132
Within Groups	7.62962	17	0.4488			
Total	8.65488	18				

The effect sizes for studies using audiovisual videoconferencing distance education are not significantly different from those using on-line telecommunications distance education systems.

.

Table 14

ANOVA for Student Grade Level

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
High School: 9-12	13	-0.144	-0.0111	0.52104
Intermediate: 3-8	6	2.932	0.48867	0.27543

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.02526	1	1.02526	2.28445	0.14904	4.45132
Within Groups	7.62962	17	0.4488			
Total	8.65488	18				

The effect sizes of studies of high school students are not significantly different from those with intermediate students.

Table 15

ANOVA for Subject Area

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Language	3	1.296	0.432	0.02679
Foreign Language	3	-2.403	-0.801	0.12946
Mathematics	2	1.516	0.758	0.7369
Science	6	0.413	0.06883	0.41739
Social Studies	3	0.352	0.11733	0.00929
Other: General, Computer Science	2	1.623	0.8115	0.87781

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.60885	5	0.92177	2.97146	0.05272	3.02543
Within Groups	4.0327	13	0.31021			
Total	8.64155	18				

The effect sizes of studies of various subject areas are not significantly different from each other, although they approach significance at the 0.05 level, mainly because of the strong negative effect of foreign language studies.

Table 16

ANOVA for Research Design

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Pretest-Posttest	14	4.129	0.29493	0.45947
Posttest Only	5	-1.341	-0.2682	0.37836

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.16831	1	1.16831	2.65293	0.12175	4.45132
Within Groups	7.48657	17	0.44039			
Total	8.65488	18				

The effect sizes of studies using a Pretest-Posttest design are not significantly different from those using a Posttest Only design.

Table 17

ANOVA for Study Date

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Pre 1993	8	1.803	0.22538	0.57025
Post 1993	11	0.985	0.08955	0.45777

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.08545	1	0.08545	0.16952	0.68569	4.45132
Within Groups	8.56943	17	0.50408			
Total	8.65488	18				

The effect sizes of studies completed prior to 1993 are not significantly different from those completed after 1993.

Table 18

ANOVA for Study Source

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Unpublished	13	-0.747	-0.0575	0.46187
Published	6	3.537	0.5895	0.27917

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.7183	1	1.7183	4.21011	0.05592	4.45132
Within Groups	6.9383	17	0.40814			
Total	8.65659	18				

The effect sizes of studies from published sources are not significantly different from those from unpublished sources.

Table 19

ANOVA for Achievement Measure

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Standardized Test	5	1.396	0.2792	1.2539
Non-Standardized	14	1.392	0.09943	0.27079

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.11907	1	0.11907	0.23713	0.6325	4.45132
Within Groups	8.53582	17	0.50211			
Total	8.65488	18				

The effect sizes of studies using standardized measures are not significantly different from those using non-standardized measures of student achievement.

Table 20

ANOVA for Sample Size

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Fewer than 26	8	3.629	0.45363	0.43515
More than 32	11	-0.832	-0.0756	0.42981

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.29739	1	1.29739	3.00314	0.1012	4.45132
Within Groups	7.34417	17	0.43201			
Total	8.64155	18				

The effect sizes of the studies using groups with samples below 26 are not significantly different from those using groups with samples over 32.

Interactions between the various features and characteristics of the distance education studies are worth investigating with ANOVAs of interaction effects. Such investigations could be used to illuminate significant relationships between factors of the most effective distance education systems. However, due to the limited number of studies in this meta-analysis ANOVA tests are unlikely to detect interaction effects. The addition of more studies would enable those important comparisons.

Each ANOVA above shows no significant difference between levels of the variables at the customary alpha level of 0.05 or the suggested meta-analysis alpha level of 0.01. Each ANOVA was repeated with the omission of the foreign language studies, because those studies all had medium to large negative effect sizes, two of which were outliers, and those studies differed greatly from the rest. The modified ANOVAs resulted in non-significant findings in each case. The alpha values for the modified ANOVAs are presented in Table 21.

Table 21

Modified ANOVA Results

Study Feature or Characteristic	ANOVA Alpha Value
Duration of Use of Distance Education	0.965
Frequency of Use of Distance Education	0.407
Instructional Design	0.406
Technology Delivery System	0.406
Student Grade Level	0.406
Content Area	0.437
Research Design	0.261
Study Date	0.776
Study Source	0.171
Achievement Measure	0.387
Sample Size	0.129

The heterogeneity in the studies is unexplained. The optimal method for combining effect size estimates with unexplained heterogeneity is the random effects model (Hedges et al, 1989).

Random effects procedures treat between-study variations in effect sizes as random. The procedures begin with the estimation of between-study variance, used to determine the difference between the observed variance among effect sizes and the within-study sampling variance. The sample variance for the 19 studies in the meta-analysis is 0.481, verified by Excel 97 at 0.481. The between-study variance was found

to be 0.413. This variance is used in calculating confidence limits and in combining the effect size estimates in the random effects model. The effect size formula is weighted with both the within-study sampling error variance (standard error) and the variance.

The overall effect size for the 19 studies is 0.147, considered a small positive result. The standard error of the effects weighted average is 0.159. This result is a small positive effect size. At an alpha level of 0.05, the 95% confidence limits are constructed by multiplying the square root of the variance, 0.413, by 1.96, then adding and subtracting from the effect size, d_+ (Cooper & Hedges, 1994). In this case, the confidence limits are -1.113 and 1.407. Because the interval encompasses zero, the null hypothesis that the population effect size is zero cannot be rejected. Interactive distance learning techniques cannot be considered to be more or less effective than traditional instruction.

Because of the near-significant result of the ANOVA for subject area and the cluster of outliers, a second overall effect size was estimated without the foreign language studies. The random effects effect size estimate for the meta-analysis is 0.344, discounting foreign language studies. The effect size improves after accounting for these discrepant studies in post hoc analysis, although the confidence interval of -0.686 to 1.374 still encompasses zero.

The overall standard deviation for the random effects effect size estimate was found. The result for the 19 studies is a standard deviation for effect size of 0.480. Because publication bias was not found to be significant in the ANOVA of published and unpublished studies, the Fail Safe N for publication bias was not needed. The effect size of the 12 APA meta-analyses of audio-visual or computer instruction with K-12 learners ranged from 0.26 to 1.05. In light of those moderate to large published results, the effect

size found in this meta-analysis is small.

Discussion of Findings

The majority of the studies in the meta-analysis had small effect sizes, not significant statistically. Seventy-four percent had positive effect sizes. Although the weighted mean effect size is small, it is positive, especially when the outlying foreign language studies are eliminated. The effect size, using data from 929 students, indicates that interactive distance education, while neither preferable to nor worse than traditional instruction with a teacher present, can be expected not to hinder learning. Additionally, when distance education is necessary in order to provide needed educational options to students, it can be as effective as traditional instruction.

Table 22 shows the average effect sizes for subgroups of the variables and features of interest in the study.

Table 22

Effect Sizes for Variables and Study Features

Variable	**Level**	**# of Studies**	**% of Total**	**Average Effect Size**
Delivery System	Telecommunications	6	32	0.488
	Videoconferencing	13	68	-0.011
Duration	Over 15 weeks	8	42	0.094
	Less than 15 weeks	11	58	0.186
Frequency	Daily	13	68	-0.010
	Weekly	6	32	0.489
Instructional Design	Primary	13	68	-0.011
	Supplementary	6	32	0.489
Grade Level	9-12	13	68	-0.011
	3-8	6	32	0.489
Content Area	Science	6	32	0.069
	Social Studies	3	16	0.117
	Language Arts	3	16	0.432
	Foreign Language	3	16	-0.801
	Mathematics	2	11	0.758
	Other	2	11	0.811
Year	Pre-1993	8	42	0.225
	Post-1993	11	58	0.090
Achievement Measure	Standardized	5	26	0.279
	Non-Standardized	14	74	0.099
Test Sequence	Pretest-Posttest	14	74	0.295
	Posttest Only	5	26	-0.268
Sample Size	Fewer than 26	8	42	0.454
	Over 32	11	58	-0.076
Study Source	Published	6	32	0.590
	Unpublished	13	68	-0.057

Summary

The meta-analysis presented here examined a sample of studies that met established inclusion criteria, including data from 929 learners. The analysis encompassed a broad view of K-12 interactive distance education by focusing on the range of subject areas, grade levels, and applications of distance education in use today. The questions of the overall effect on K-12 academic achievement of interactive distance education, and of the features of effective distance education systems were addressed through the use of random effects effect size estimation and analysis of variance. The study design permitted review of a wide sample of research done on academic achievement of students learning with distance education.

The overall effect size for interactive distance education on K-12 learning was the small positive 0.147, accounting for sampling error and variance. The 95% confidence interval for the random effects weighted effect size was -1.113 to 1.407. In comparing levels of the variables delivery system, grade level, ability level, content area, instructional design, duration, and frequency of use, and the study features of date, source of study, achievement measure, testing sequence, and sample size, no significant differences were found. In a post hoc analysis after eliminating the outlier foreign language studies, an effect size of 0.344 was calculated, with a confidence interval of -0.686 to 1.374.

CHAPTER V: DISCUSSION OF RESULTS

Introduction

Although many thousands of students at K-12 levels are learning a variety of subjects using interactive distance education technology, few quantitative analyses have been conducted to demonstrate the effectiveness of such technology for academic achievement. Compared to other educational technologies, relatively few research studies have been documented evaluating K-12 distance education programs. Very few quantitative studies are available that include enough data for meta-analysis.

The meta-analysis presented here represents an effort at collecting a sample of the available quantitative evaluations of K-12 interactive distance education in order to assess its overall effectiveness. The discussion of results will review the focal questions of the meta-analysis, the data collection and analysis processes, and the findings of the analysis. The implications and recommendations for education practice will follow.

Summary of Study

The main concern of the meta-analysis was estimating to the extent possible the relationship between the use of interactive distance education strategies of videoconferencing or telecommunications and academic achievement in grades K-12. The effectiveness estimate takes the form of the overall weighted average effect size result reached after quantitatively combining the individual effect sizes of the sample of

experimental and quasi-experimental studies assembled in the database.

After investigating the relationship in past research between the use of interactive distance education and K-12 academic achievement, the sample studies were analyzed to determine whether specific variables and features of individual studies were related to their educational effectiveness as estimated by weighted average effect size. The variables that emerged from the literature as important to consider were the duration and frequency of use of distance education, instructional design, technology system used, the ability level and grade level of the learners, and the subject area. The study characteristics under investigation for their role included sample size, learning environment, source of study, date, type of achievement measure, and testing sequence.

A group of 59 potentially useful studies was collected from the pool of hundreds found using keyword searches and over 50 direct requests for information from researchers. Forty studies were eliminated on the grounds of lack of quantitative achievement data, incomplete data, inclusion of students beyond K-12, focus on attitude, or the study of distance education technology other than videoconferencing or on-line telecommunications. A sample of 19 studies met the established inclusion criteria for the meta-analysis. Each study focused on academic achievement of K-12 learners, each included data necessary for effect size estimation, and each was an experimental or quasi-experimental study conducted after 1980. The selected studies represent an array of research completed between 1986 and 1997 from published and unpublished sources. The 929 student participants ranged from grades 3 to 12, both regular and advanced learners of diverse content areas. Learning occurred using several permutations of videoconferencing and telecommunications systems in school environments, over periods

of one to 15 weeks or more. Several different experimental designs, achievement measures, and testing sequences were used in evaluating learning, with a range of results. The study features were coded for the meta-analysis variables and features by independent coders, who had 85% overall agreement on the total set of codes for all studies coded.

Student evaluation data provided the raw material for effect size calculations for each study. The effect sizes ranged from 1.474 to -1.152, indicating that in some studies, learners experienced very large achievement gains using distance education, while in other studies, learners using traditional instruction significantly outperformed distance learners. The 19 study effect sizes were checked statistically for homogeneity and heterogeneity. Analysis of variance was employed to formally examine heterogeneity for each study variable and feature. ANOVA tests revealed no significant difference in effect for each variable and feature, even after accounting for the outlying foreign language studies. Due to the small number of studies qualifying for the database, ANOVAs for interaction effects among the features and characteristics could not be performed. When the effect sizes were found to be significantly heterogeneous, they were combined using the random effects model, suited for heterogeneous data with unexplained variance. The overall effect size was 0.147, a small positive effect in favor of distance education. After the elimination of the foreign language studies, which had effect sizes in the outlier range, the overall effect size rose to 0.344. The confidence intervals for both effect sizes included zero, so in each case the null hypothesis could not be rejected, indicating that interactive distance education cannot be expected to differ in effectiveness for achievement from traditional instruction.

Discussion

As a result of the statistical processes applied in the meta-analysis, the overall effectiveness of interactive distance education has been estimated as it is used for K-12 learning. Interactive distance education was found to have an average effect size of 0.147, translating to a gain of 0.147 standard deviations on average for a student at the 50^{th} percentile learning with distance education over traditional methods. No significant differences were detected between grade levels, subject areas, ability levels, distance education technology, duration and frequency of use of distance education, or instructional design in relation to learning. However, the three foreign language studies made a close approach to significance with strong negative effect sizes.

Consequently, distance education can be expected to result in achievement at least comparable to traditional instruction in most academic circumstances. Educators planning implementations of distance education programs should expect no difference in academic performance as a result of the use of distance education. More importantly, when implemented with the same care as effective face-to-face instruction, distance education programs can be used to complement, enhance and expand education options for students, at least at intermediate, middle, and upper grades levels.

Although meta-analysis is a demanding statistical process, it is useful for examining complex relationships within an area of study. Meta-analytic technique, however, is only effective with a large database. Using a limited base of studies, it became impossible to draw meaningful conclusions about interactions among variables.

Implications

In a time when standards-based education has taken on a greater real-world, situated focus, it has become more important for educators to provide students with authentic connections to a learning environment beyond the school boundaries. Interactive distance education is a vehicle for extending the reach of student influence into the community, as well as a means of including the family and community in a learning conversation. In light of the findings of this meta-analysis, supplementing traditional instruction with distance education can enable more reality-based learning, with possible achievement gains. The benefits of such educational enhancement in terms of attitude and interpersonal workplace skills are unknown at the present time.

Under pressure to present learners with greater opportunities at lower cost, educational leaders may find that offering courses to secondary learners via interactive distance education effectively enlarges the course catalog and students' worldview at the same time. On a cautionary note, distance education for K-12 is much newer and less proven than traditional instruction. The fact that only 19 studies were found to be suitable for this analysis is a testimony to that fact. Therefore, students and teachers have fewer quality materials and less experience on which to draw when using distance education. It can be argued that as the use of interactive distance education grows and expertise develops, academic gains can be expected to increase.

Because this meta-analysis covers a diverse range of education conditions, the results described here will not be replicated in all learning environments. As more study is completed in this domain, educators will be better suited to pair their specific education problems and needs to the optimal distance education solution.

Recommendations

As new interactive distance education studies of K-12 learning become available, meta-analysis should be repeated using a larger sample. As data from the growing number of virtual high schools is collected, a more comprehensive meta-analysis could clarify understanding of the effectiveness of distance education for K-12 learners. A future meta-analysis will allow more specific identification of the conditions that improve the effectiveness of distance education by testing interactions among system features and education needs. In this sample of studies, videoconferencing was the system in use in high school distance education programs, while lower grades used telecommunications. However, new high school programs, notably the virtual high schools, are relying more heavily on telecommunications. This growth and accompanying change in systems offers tremendous potential for data collection that could vastly strengthen the pool of data existing today.

In the area of foreign language instruction, great potential exists theoretically for linking students with native speakers and writers, but the results of the studies reviewed here indicate that distance education in foreign language should be studied closely. The three foreign language studies in this meta-analysis reported that students learning with distance education systems performed demonstrably lower than students learning in traditional classrooms. While foreign language options are needed in high schools, distance education courses for foreign language instruction should be evaluated very carefully.

Because interactive distance education is especially well-suited for learning complex communication and problem solving skills, future study of distance education

effectiveness should make use of new outcome measures designed to more precisely gauge higher-order thinking. As learners improve these critical skills using distance education, it is likely that they will undergo a change in their attitudes toward learning. Another valuable meta-analysis would be one that evaluates the effect of interactive distance education on learners' attitude toward learning. Teachers' skills and attitudes are important considerations in any education situation, and would be valuable variables to include in future examinations of interactive distance education.

The areas of learning styles and locus of control are fertile ground for a closer look with regard to distance education. Answers to questions about whether intrinsically or extrinsically motivated students are more successful in distance education would help educators in providing the most effective options for learners. One group of studies included in this meta-analysis examined the effect of students' level of motivation by their instructor on the students' achievement in distance education classes (Burkman, 1994). Students who depended more on the teacher to motivate their learning achieved better in traditional environments than they did in distance classes. More study in this area with a greater range of age levels and subject areas is needed.

Cost-benefit analysis should be used to evaluate the practicality of adding courses to high schools that have limitations on their course offerings. Adding a distance education component to the menu of options would serve to equalize opportunity among some undeserved populations. An additional benefit of the use of distance education courses for small and rural schools is that the individual communities of learners can remain physically intact, preserving community identity rather than closing or consolidating small schools.

An aid to future meta-analyzers would be inclusion of complete quantitative data in reports of distance education studies. The specific data needed includes group sizes, average pre- and post-measure scores, standard deviations, and other statistical results such as *t*, *F*, and *z* results. Although requests for additional data were made directly to researchers, no useful information was forwarded to the author. If such data had been reported in the studies reviewed here or if researchers had responded to requests for information, an additional 30 studies could have been added to the database, enabling more detailed investigation of the features of effective distance education systems.

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APPENDICES

APPENDIX A

Distance Education Guidelines for K-12 Educators

The following guidelines have been identified through research and by experienced distance education professionals to contribute to effective distance education. They apply to K-12 levels as well as to adult learning, but do not represent an exhaustive list. Many of the guidelines characterize good education practice, for distance or face-to-face situations.

Virtual Learning Communities

Students who enter into distance education become members of virtual learning communities. Teachers can enhance those communities in the following ways:

- share interactivity and control of activities among participants
- achieve a balance between virtual and direct interaction, meaning interaction with both distant and local participants
- plan opportunities for interaction among participants

(Dede, 1996; Ludlow, 1994)

Instructional Objectives

As a part of content learning, distance education is most effective when joined with higher order goals. To reach those goals teachers can:

- help students to transform archival information into personal knowledge
- assist learners as they move from accessing information through assimilation to appropriation
- create ways for learners to make sense of massive information sources
- give students experiences that lead to knowledge construction

(Dede, 1996)

Instructional Design

Extensive preplanning and preparation are necessary for successful distance education. When planning for distance education, the experiences, materials and assessments should incorporate the following recommendations:

APPENDIX A (Continued)

Experiences:

- conduct needs assessments examining new types of literacy required in today's workplace
- structure the learning based on earlier learning and prior knowledge
- center the learning on problems or questions of importance to the students
- present problems requiring a repertoire of knowledge, judgment, and skills
- develop environments that engage learners and require them to construct the most meaningful knowledge for them
- use a real-world setting as the context for learning
- encourage construction of knowledge through articulation and reflection by providing opportunities for communication and introspection
- ensure the effectiveness of three types of interaction: learner-content, learner-learner, learner-instructor
- provide the type of interaction most suitable to the tasks of the content and the development of the learners, such as manipulation of concrete materials
- use speech as the communication medium because it is the most natural and powerful language for interaction, especially for complex learning
- set up true collaborative tasks requiring resources that no single individual possesses
- include tasks similar to those used to solve real-world problems
- plan for conversation in which learners negotiate plans for solving situated problems
- combine visual contact and real-time interactive conversation among participants

Materials

- use materials in a conversational style with invitations to exchange views and become emotionally involved
- provide access to authentic resources, including materials and references used in realistic situations
- incorporate visuals and graphics to positively impact success

Assessment

- design feedback for the type of knowledge demanded:
    - declarative knowledge--elaboration and organization of information
    - pattern recognition--classification of examples and nonexamples
    - action sequence--application of procedures
- combine assessment with learning for a seamless activity
- use assessment to determine what learning should occur next

(Abrami & Bures, 1996; Bork, 1997; Holmberg, 1985; Howard, 1987; Jonassen, 1995; Ludlow, 1994; Moore, 1989; Moore & Kearsley, 1996; Moore & Thompson, 1990; Roblyer, 1997; Schlosser & Anderson, 1994)

APPENDIX A (Continued)

Instructor Preparation

Effective distance educators plan for success by developing a repertoire of behaviors to enhance the transaction:

- establish learning outcomes
- develop competency in using equipment and effective techniques
- become proficient in the subject matter
- acquire habits of clarity and organization
- collaborate with technical support staff
- facilitate of guest experts at a distance, and thoughtfully integrate new participants in the learning
- be prompt at starting prearranged connections
- adopt a natural style of delivery, slow speech, and clear enunciation of carefully selected words
- communicate spontaneously, not from a script
- provide a friendly atmosphere of respect
- use silence appropriately

(Moore & Thompson, 1995; Oliver & Reeves, 1996; Thach & Murphy, 1995)

Instructional Strategies

Specific strategies used during instruction result in quality distance education:

- shift from content provider to facilitator
- engage students in evaluating the relevance and selection of learning goals and objectives
- structure flexible student groups and schedules so students can take the time they need for an activity
- maximize the overall amount and type of learner interaction
- help students develop strategies to handle active involvement in group activities
- keep communication constantly open to students for questions and exchanges with other participants
- accommodate multidirectional communication among all participants
- refer to participants by name
- ensure that students become competent using the technology
- frequently assign students to solve problems or evaluate material
- encourage reflective thought when confronting new information
- use visuals effectively
- frequently change pace or stimuli
- increase learner control and individualize instruction
- motivate with challenge, curiosity, and fantasy
- summarize concepts
- provide immediate, consistent, and informative feedback

- incorporate performance assessment

(Abrami & Bures, 1996; Holmberg, 1985; Kearsley, 1996; Ludlow, 1994; Moore & Thompson, 1990; Oliver & Reeves, 1996; Willis, 1994)

Technology and Media

Consider the following criteria for selecting the technology and media best suited for the distance learning situation:

Media Selection:

- recognize that a multi-media program is likely to be more effective than one which relies on a single medium
- identify the media attributes required by the instructional objectives, such as sound, motion, etc.
- select media that will engage student motivation, recall earlier learning, provide new learning stimuli, activate responses, give speedy feedback, and encourage practice
- select based on content, involvement, and the learning outcomes desired
- maximize active learning and face-to-face communication
- identify student and environmental characteristics which suggest or preclude certain media
- take into account cost, labor involved in operation, level of interactivity, available infrastructure, equipment compatibility, and users' skills
- be familiar with copyright provisions of commercial media

Maximizing Technology

- ask what the technology can do to better enable students to learn more effectively
- adapt media and sequencing to student needs and the requirements of the content
- maximize use of visual methods and materials
- compare the characteristics of media available
    - audioconferencing is suited for discussion of abstract concepts
    - audiographic teleconferencing is useful for abstract and concrete learning experiences
    - videoteleconferencing allows satisfying natural conversation
    - computer conferencing allows transmission of text or graphics

(Holmberg, 1985; Lambert, 1996; Ludlow, 1994; Moore & Kearsley, 1996; Moore & Thompson, 1990; Schlosser & Anderson, 1994; Willis, 1994)

APPENDIX A (Continued)

Distance Education Techniques

The various media have their own advantages and require unique skills for maximum effect:

Teletechniques:

- break down barriers of distance and generate rapport with videoconferencing
- encourage interaction with enthusiasm, discussion, and role play
- shorten segments, vary the voice, and use visual aids to enhance interest and appeal
- provide verbal and written feedback to increase motivation

Teleconferencing Skills:

- provide structure and socio-emotional support
- establish a democratic atmosphere
- create a sense of shared space
- model appropriate behavior
- set appropriate pace
- step in to clarify points or repair sessions with problems

Computer Conferencing Facilitation:

- share participant information
- encourage learners to share on-line projects and responses
- reply to messages daily
- use positive and helpful tones in responses
- schedule on-line activities at regular intervals
- encourage electronic collaboration on problems and projects

(Moore & Kearsley, 1996; Moore & Thompson, 1990)

APPENDIX B

Study Coding Form
Meta-Analysis Coding

STUDY TITLE:_____

I. Qualifying the study:
For each study, answer the following questions.

1. Does the study focus on academic achievement resulting from the use of interactive distance education at K-12 level?
2. Does the study have an experimental or quasi-experimental design?
3. Was the study completed between 1980 and 1998?
4. Is the study free of major flaws such as:
   - significant demographic differences between the groups being compared?
   - less than 1 week duration?
   - insufficient sample size to provide adequate power?

If the answer to each of the above questions is yes, the study qualifies for inclusion in the meta-analysis.

II. Coding the study:
Please provide the following information about the study. If the requested information is not available in the study documentation, leave the item blank. Some questions require you to choose from a set of options. Please choose the best option.

A. Publication Features
1. Title of the study
2. Authors
3. Affiliation of the authors
4. Year the study was completed
5. Source of the study(Choose)
   Journal Web Database such as ERIC Dissertation Other

B. Technological Features
1. Distance learning system used (Choose)
   Web Email 2-way audio and video 1-way video with 2-way audio
   1-way audio and video with text Combination

APPENDIX B continued

C. Ecological Features

1. Duration of learners' exposure to the distance education technology (Choose)
   1-3 weeks 4-7 weeks 8-11 weeks 12-15 weeks 15+ weeks
2. Frequency of learners' exposure to distance education technology (Choose)
   Daily Weekly Monthly Less often
3. Grade level of learners (Choose)
   Primary K-2 Intermediate 3-5 Middle 6-8 High 9-12 Mix
4. Learning environment (Choose)
   Laboratory School/Classroom Home Other
5. Student ability type (Choose)
   Regular Advanced Exceptional/Special At-risk
   English as a Second Language Mix Other
6. Academic content area (Choose)
   General Language arts/reading Mathematics Science
   Social studies Arts Vocational Foreign language Other
7. Hardware components of the distance education system (List)
8. Type of computer interaction used by learners (Choose)
   Text Audio Video Combination

D. Methodological Features

1. Student achievement measure used for assessment (Choose)
   Standardized test Teacher-developed test
   Researcher-developed test Other
2. Testing sequence (Choose)
   Pretest-Posttest Posttest only Repeated posttests Other
3. Sample size of groups (List the size of each group)
4. Sampling method (Choose)
   Random selection Random assignment Convenience Other
5. Controls for instructor, historical, bias or other effects (List)
6. Research design (Choose)
   Matching subjects Matching classes Cohort control None

E. Results

1. Significance levels for findings (List)
2. Group means for measure (List)
3. Standard deviations (List)
4. Other results, such as t-tests, F statistics, correlations, other (List)

Based on the information provided in the study, do you believe that this study is appropriate to include in a meta-analysis of the effectiveness of interactive distance education for K-12 learning?

Do you believe that there are other features of the studies that should be considered in the meta-analysis?

APPENDIX C

Study Coding Summary

	Study 1	Study 2	Study 3
Title	Analysis of the Effect of Networking on Computer-Assisted Collaborative Writing in a Fifth-Grade Classroom	Effects of Participation in the Fifth Dimension on Far Transfer	An Analysis of the Relationship of Achievement, Attitude, of Students in an Interactive Television Course
Authors	Allen, G. & Thompson, A.	Blanton, William et al	Burkman, Thomas
Affiliation	Iowa State U.	Appalachian State U.	Western Michigan U.
Year	95	97	94
Source	J. of Educational Computing Research, 12(1) 65-75	J. of Educational Computing Research, 16(4) 371-396	Dissertation
System	Email	Web	2-way audio & video
Duration	8-11 weeks	15+ weeks	1-3 weeks
Frequency	Weekly	Weekly	Daily
Grade	Intermed3-5	Intermed3-5	High9-12
Ability	Regular	Regular	Regular
Subject	Language	General	Science
Hardware	Computer/modem	Computer, network	ITV, microphone, fax
Achievement Measure	Researcher-developed test	Standardized test	Publisher-developed test
Test Sequence	Pretest-Posttest	Pretest-Posttest	Pretest-Posttest
Sample Size	45	26	52
Sampling Method	Random Assignment	Other: voluntary	Convenience
Design	Experimental	Experimental	Quasi-experimental
Unbiased ES est.	0.469	1.474	0.525
ES significance	medium	large	medium

APPENDIX C Continued

Study 4	Study 5	Study 6	Study 7
An Analysis of the Relationship of Achievement, Attitude, of Students in an Interactive Television Course	An Analysis of the Relationship of Achievement, Attitude, of Students in an Interactive Television Course	The Role of Online Communications in Schools: A National Study	The Role of Online Communications in Schools: A National Study
Burkman, Thomas	Burkman, Thomas	CAST	CAST
Western Michigan U.	Western Michigan U.	Center for Applied Special Technology	Center for Applied Special Technology
94	94	96	96
Dissertation	Dissertation	www.cast.org	www.cast.org
2-way audio & video	2-way audio & video	Email	Email
1-3 weeks	1-3 weeks	4-7 weeks	4-7 weeks
Daily	Daily	Weekly	Weekly
High9-12	High9-12	Intermed3-5	Middle6-8
Regular	Regular	Regular	Regular
Science	Science	Social Studies	Social Studies
ITV, microphone, fax	ITV, microphone, fax	Computer/modem	Computer/modem
Publisher-developed test	Publisher-developed test	Researcher-developed test	Researcher-developed test
Pretest-Posttest	Pretest-Posttest	Pretest-Posttest	Pretest-Posttest
52	52	41	25
Convenience	Convenience	Selected classes	Selected classes
Quasi-experimental	Quasi-experimental	Experimental	Experimental
0.238	-0.598	0.154	0.008
small	medium	small	small

APPENDIX C Continued

Study 8	Study 9	Study 10	Study 11
Quality and Fluency of Fourth Grade Students' Compositions Written With and Without Telecommunications Treatment	Student Achievement and Temperament Types in Traditional and Distance Learning Environments	Distance Learning using Fiber Optics: A Study of Student Achievement and Student Perception of Delivery System Quality	A Study of the Effectiveness of Interactive Television as the Primary Mode of Instruction in High School Physics
Erickson, Barbara	Gray, Barbara	Hinnant, Edward	Libler, Rebecca
U. of Houston	Wayne State U.	Mississippi State U.	Ball State U.
92	96	94	91
Dissertation	Dissertation	Dissertation	Dissertation
Email	1-way video & 2-way audio	2-way audio, video & data	1-way video & 2-way audio/text
15+ weeks	15+ weeks	1-3 weeks	15+ weeks
Weekly	Daily	Daily	Daily
Intermed3-5	High9-12	High9-12	High9-12
Regular	Regular	Regular	Regular
Language	Foreign Language	Computer science	Science
Computer/modem	Satellite TV, telephone	Computer network, compressed video receiver	ITV, microphone
Researcher-developed test	Teacher-developed test	Teacher-developed test	Standardized test
Pretest-Posttest	Posttest only	Pretest-Posttest	Posttest only
26	16	34	67
Parent choice	Convenience	Voluntary	Convenience
Quasi-experimental	Quasi-experimental	Quasi-experimental	Quasi-experimental
0.253	-0.433	0.149	-0.815
small	medium	small	large

APPENDIX C Continued

Study 12	Study 13	Study 14	Study 15
Student Achievement and Attitude in a Satellite-Delivered High School Science Course	Telelearning: An Evaluative Study of a Computer-Based, Interactive Audio and Graphics Long-Distance Learning System for Secondary Education	Computer-Mediated Communication: Tool for Reconnecting Kids with Society	A Study of the Effectiveness of an Audiographic Teleconferencing System in a Remotely Delivered High School Physics Program
Martin, Elaine & Rainey, Larry	McBride, Ronald	Riel, Margaret	Rudolf, Sidney
	Georgia State U.	AT&T Learning Network	U. of Utah
89	90	90	86
American J. of Distance Education 7(1),	Dissertation	Interactive Learning Environments 1(4), 255-263	Dissertation
2-way audio, 1-way video	2-way audio & text	Email	2-way audio & text
15+ weeks	15+ weeks	1-3 weeks	8-11 weeks
Daily	Daily	Weekly	Daily
High9-12	High9-12	Middle6-8	High9-12
Advanced	Regular	Regular	Regular
Science	Mathematics	Language	Science
ITV, telephone	Computer/modem, microphone	Computer/modem	Microphone, computer
Teacher-developed test	Standardized test	Researcher-developed test	Researcher-developed test
Pretest-Posttest	Pretest-Posttest	Posttest only	Pretest-Posttest
49	20	22	13
Other:selected class	Other: school choice	Convenience	Convenience
Quasi-experimental	Quasi-experimental	Quasi-experimental	Experimental
0.856	1.365	0.574	0.198
large	large	medium	small

APPENDIX C Continued

Study 16	Study 17	Study 18	Study 19
The Distance Education Delivery of Senior High Advanced Mathematics Courses in the Province of Newfoundland and Labrador	The Effects of Two Modes of Instructional Delivery: Two-Way Interactive Television and Traditional Classroom on Students in Humanities	Effectiveness of the Interactive Satellite Method in the Teaching of First-Year German	An Analysis of the Effectiveness of Distance Learning at Remote Sites Versus On-Site Locations in High School Foreign Language Programs
Ryan, Walter	Sisung, Nancy	Smith, Robert	Wick, William
Ohio U.	U. of Michigan	U. of Mississippi	U. of Minnesota
96	92	90	97
Dissertation	Dissertation	Dissertation	Dissertation
2-way audio & text	2-way audio & video	1-way video & 2-way audio/text	2-way audio & video
15+ weeks	15+ weeks	15+ weeks	8-11 weeks
Daily	Daily	Daily	Daily
High9-12	High9-12	High9-12	High9-12
Advanced	Regular	Regular	Regular
Mathematics	Social Studies	Foreign Language	Foreign Language
Microphone, telewriter, fax	ITV, microphone, phone, fax	Satellite	ITV, microphone
Final course grade	Standardized test	Standardized test	Teacher-developed test
Posttest only	Pretest-Posttest	Posttest only	Pretest-Posttest
277	15	54	43
Stratified Random Selection	Convenience	Convenience	Convenience
Experimental	Quasi-experimental	Experimental	Quasi-experimental
0.151	0.19	-0.818	-1.152
small	small	large	large

VITA

Catherine Cavanaugh received a Bachelor of Arts degree in Elementary Education from the University of the Virgin Islands in 1984 and a Master of Arts degree in Science Education from the University of Central Florida in 1988. She began her teaching career in 1982 in St. Croix. She taught grades 6-12 science in the Virgin Islands and in Orlando and Naples, Florida from 1982 until 1996. In 1996, she took the position of coordinator of the Whitaker Center for Math, Science, and Technology in Naples.

As coordinator, Catherine developed and taught graduate courses for teachers offered through the University of South Florida and Florida Gulf Coast University. In 1998, she worked at the Florida Center for Instructional Technology at USF. She is co-author of a book for science teachers, as well as numerous articles, papers, and presentations on science and technology education topics.