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THE EFFECTS OF FREQUENCY OF TECHNOLOGY USE ON HIGH SCHOOL STUDENTS' MATHEMATICS AND SCIENCE ACHIEVEMENT

A Dissertation Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Education

by

Michael John King

May 1998

UMI Number: 9828323

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King, Michael John "The Effects of Frequency of Technology Use on High School Students' Mathematics and Science Achievement." Unpublished Doctor of Education Dissertation, University of Houston, May, 1998.

Abstract

Meta-analyses of research studies have demonstrated that computer-based education (CBE), in general, significantly increases student achievement scores when compared to traditional (non-computer) instruction (Bangert-Drowns, Kulik, & Kulik, 1985; Kulik & Kulik, 1987; Niemiec & Walberg, 1987). Similarly, a meta-analysis of calculator-use studies has shown that, on average, calculator-based instruction significantly increases student achievement levels when compared with traditional (non-calculator) classroom instruction (Hembree & Dessart, 1986). The use of computer-based instruction (CBI) in precollege education has the potential of significantly improving learning in mathematics and science classrooms (Kulik & Bangert-Drowns, 1983-84).

Purpose of the Study

This study investigated whether the frequency of technology (calculator, computer) use among a nationally representative, random, sample of U.S. public and private high school seniors significantly ($p < .001$) impacts achievement in mathematics and science. Two types of technology (calculator, computer) and two subject areas (mathematics, science) were analyzed in four separate pairs (calculator/mathematics, calculator/science, computer/mathematics, computer/science), in order to better

understand the relative influence of each type of technology use on each area of learning.

Need for the Study

Although many reviews of educational research have indicated that technology use has a significant positive impact on students' academic achievement, most of these studies were conducted a decade or more ago. During that period, mainframe computers, not PCs, were the norm, and calculators were much less sophisticated than more recent versions. The teaching strategies and software packages for implementing classroom technology have also changed dramatically since the 1970s. In addition, there have been few large-scale, national studies conducted on the subject of technology use and secondary school education in mathematics and science. For these reasons, there is a need for more up-to-date research on this important educational issue.

Significance of the Study

Across this country, vast sums of educational dollars are being spent on classroom technology, including both equipment purchase and teacher training. Are those large expenditures being used wisely? Is the use of hi-tech equipment in the classroom a cost-efficient way of increasing students' achievement in mathematics and science? Niemiec and Walberg (1992) maintain that technology use in the classroom may be the most cost-effective intervention for improving our nation's education system. If so, at what frequency of use is it most helpful? Are increased frequencies of computer use and calculator use equally effective in raising mathematics and science exam scores? Is there a point of diminishing returns, where increased use of classroom technology is associated with little or no improvement in academic performance? This study seeks to answer some of these pressing questions.

Methods

Four null hypotheses were investigated: (a) there is no significant ($p < .001$) difference in mathematics achievement regarding the frequency of calculator use in mathematics class, (b) there is no significant ($p < .001$) difference in science achievement regarding the frequency of calculator use in science class, (c) there is no significant $p < .001$) difference in mathematics achievement regarding the frequency of computer use in mathematics class, and (d) there is no significant ($p < .001$) difference in science achievement regarding the frequency of computer use in science class.

Student survey data from NELS:88 (Ingels et al., 1994) were analyzed in order to determine how the frequency of technology (calculator, computer) use among more than 10,000 randomly-selected high school seniors impacts test performance on cognitive exams in mathematics and science. NELS:88 (National Education Longitudinal Study of 1988) is the first nationally-representative longitudinal study of eighth-grade students in U.S. public and private schools. A series of four ANCOVAs were employed in order to determine the significant ($p < .001$) impact of technology (calculator, computer) use on high school seniors' mathematics and science achievement, after statistically controlling for: (a) sophomore exam scores, and (b) socio-economic status.

Instruments

In the Spring term of 1992, NELS:88 high school seniors, completed survey questionnaires concerning their frequency of technology (calculator, computer) use in their current or most recent mathematics and science classes. The response choices were: (a) never/rarely, (b) 1-2 times per month, (c) 1-2 times per week, (d) almost each day, and (e) every day. These data comprised the four independent variables: (a) frequency of calculator use in mathematics class, (b) frequency of calculator use in science class, (c) frequency of computer use in mathematics class, and (d) frequency of computer use in science class.

In the Spring term of 1990, NELS:88 high school sophomores completed cognitive tests in mathematics and science (pretest). Two years later, in the Spring term of 1992, that same panel of participants (then seniors) was again administered cognitive exams in mathematics and science (posttest). In the present study, the sophomore scores (mathematics, science) constituted pretest covariates, while the senior scores (mathematics, science) were employed as posttest dependent variables.

The second of two covariates used in the current study's four data analyses was the socio-economic status (SES) variable. NELS:88 researchers combined five different social and economic factors in arriving at a composite that best reflected each student's SES. The SES variable included: (a) total annual household income, (b) father's occupation, (c) mother's occupation, (d) father's educational level of attainment, and (e) mother's educational level of attainment.

Results

Each of the four null hypotheses is rejected. The frequency of calculator use, after controlling for sophomore exam scores and SES, had a significant ($p < .001$) impact on seniors' achievement in both mathematics and science. Likewise, the frequency of computer use, after including the two covariates (sophomore exam scores, SES), showed a significant ($p < .001$) difference regarding seniors' achievement in both mathematics and science.

Students who, in their mathematics class, used calculators either every day or almost each day scored significantly ($p < .001$) higher on the mathematics cognitive exam than did those students who never or rarely used calculators. Mathematics students who employed calculators every day attained significantly ($p < .001$) greater test scores than students who used calculators 1-2 times per month. Those students in mathematics class who used calculators every day achieved significantly $p < .001$) higher mathematics exam scores than did the students who used calculators 1-2 times each week.

The science students who used calculators at any one of the following three frequencies: (a) every day, (b) almost each day, or (c) 1-2 times per week, scored significantly ($p < .001$) higher on their senior cognitive science exam than did those science students who never or rarely used calculators in their science class. Employment of calculators by science students at any one of the following three rates: (a) every day, (b) almost each day, or (c) once or twice each week, showed significantly ($p < .001$) higher science exam scores when compared to students who used calculators once or twice a month in their science class.

Mathematics students who never or rarely used computers achieved significantly

($p < .001$) greater test scores when compared with students who employed computers almost each day in their mathematics class. Students who used computers 1-2 times per month in their mathematics class scored significantly ($p < .001$) higher on the cognitive mathematics exam than did those students who used computers almost every day. Science students who never or rarely employed computers in their science class achieved significantly ($p < .001$) higher science test scores than did those students who used computers in science class at the rate of once to twice per week.

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CHAPTER I

Introduction

Educational technology (e.g., calculator, computer, videodisc, & CD-ROM) is the scientific tool for learning in today's classroom. Innovative uses of this technology will probably transform both teaching and learning processes (Olive, 1992). Classroom technology is viewed by many researchers as an important catalyst for improving the education of all students (Owens & Waxman, 1995). A major challenge for today's educators is preparing high school graduates for the constant technological changes of daily life (Hartoonian, 1992). In addition, classroom technology has the potential of revolutionizing K-12 learning and instruction in our nation's schools (Maddox, Johnson, & Willis, 1997).

The primary goal of Project 2061, one of several educational reports from the scientific community, calls for every high school graduate to be scientifically literate (American Association for the Advancement of Science, 1992). The Project defines science as including these four areas of study, (a) physical science, (b) natural science, (c) mathematics, and (d) chemistry. Because of our rapidly changing world, every American must have an understanding of the basics of science and scientific endeavors (American Association for the Advancement of Science, 1992).

The quality of our nation's schools has a direct impact on each high school graduate's mastery of technology and science (Hartoonian, 1992). In order to keep pace with other institutions (e.g., business, industry, & government) in our society, public and private school educators should rely less on the teaching practices of the 1800s (e.g., chalkboard, drill, lecture, rote memorization, & textbook) and concentrate more on incorporating the numerous breakthrough technologies into our classrooms (Mecklenburger, 1990). Such knowledge-building electronic tools can be beneficial resources for transforming the current classroom environment into one which will prepare our students for the next century (Scardamalia & Bereiter, 1992).

Students graduating from high school must be mathematically literate in order to function effectively in today's society; including having calculator and computer skills (National Council of Teachers of Mathematics, 1993). Pre-college education in our nation has the responsibility of providing every student with an understanding and appreciation for the sciences in order to keep pace with the rapid and complex technological and scientific changes of modern citizenship (National Research Council, 1996). If the U.S. is to be first in the world in science and mathematics in the 21st century, technology must be a fundamental component in our nation's education system (National Science Foundation, 1995).

Purpose of the Study

This study was conducted in order to find whether the frequency of technology (calculator, computer) use among a nationally representative, random, sample of U.S. public and private high school seniors significantly ($p < .001$) impacts achievement in mathematics and science. Two technologies (calculator and computer) and two subject areas (mathematics and science) were analyzed in four separate pairs, (a) calculator/mathematics, (b) calculator/science, (c) computer/mathematics, and (d) computer/science, in order to better understand the relative influence of each type of technology use on each area of learning.

Need for the Study

Although many reviews of educational research have indicated that technology use has a significant positive impact on students' academic achievement, most of these studies were conducted a decade or more ago. During that period, mainframe computers, not PCs, were the norm, and calculators were much less sophisticated than more recent versions. The teaching strategies and software packages for implementing classroom technology have also changed dramatically since the 1970s. In addition, there have been few large-scale national studies conducted on the subject of technology use and secondary school education in mathematics and science. For these reasons, there is a need for more up-to-date research on this important educational issue.

Significance of the Study

Across this country, vast sums of educational dollars are being spent on classroom technology, including both equipment purchase and teacher training. Are those dollars being used wisely? Is the use of hi-tech equipment in the classroom a cost-efficient way of increasing students' achievement in mathematics and science? Niemiec and Walberg (1992) maintain that technology use in the classroom may be the most cost-effective intervention for improving our nation's education system. If so, at what frequency of use is it most helpful in increasing the achievement levels of mathematics and science? Are increased frequencies of computer use and calculator use equally effective in their influence on mathematics and science exam scores? Is there a point of diminishing returns reached, where the increased use of classroom technology is associated with little or no improvement in academic performance? This study attempts to answer some of these pressing questions.

Classroom teachers and school administrators are frequently required to make important decisions about resource allocations of technology and staff development in the schools they serve. Classroom technology advances at such a rapid pace, that expensive new equipment can become old in three or four years. Does the increase in academic improvement justify that amount of capital outlay? Is it more prudent that a sizeable portion of that funding for equipment and teacher training be invested in other, possibly more beneficial, areas of public and private high school education? Research using more current information concerning these educational issues would be of benefit to today's educators and policymakers.

Null Hypotheses

The present study investigated the following four null hypotheses:

Null Hypothesis 1. There is no significant ($p < .001$) difference in mathematics achievement regarding the frequency of calculator use in mathematics class.

Null Hypothesis 2. There is no significant ($p < .001$) difference in science achievement regarding the frequency of calculator use in science class.

Null Hypothesis 3. There is no significant ($p < .001$) difference in mathematics achievement regarding the frequency of computer use in mathematics class.

Null Hypothesis 4. There is no significant ($p < .001$) difference in science achievement regarding the frequency of computer use in science class.

Definition of Terms

The current study analyzed several NELS:88 student variables. Those CD-ROM data entries are defined below:

F22XMC. Senior students' mathematics centile (1-99) scores.

F22XSC. Senior students' science centile (1-99) scores.

F2SES1C. Socio-economic status (SES) centile (1-99) composite. Combination of five NELS:88 variables: (a) total annual household income, (b) father's occupation, (c) mother's occupation, (d) father's educational level of attainment, and (e) mother's educational level of attainment.

F2F1PNFL. Survey panel 'flag' identifies those high school students who were included in both the second (1990) and third (1992) waves of the longitudinal study.

F2F1PNWT. Panel weighting factor (2.3129-6780.0735) used for analyses that include data from both the second (1990) and third (1992) waves. Adjusts for over-sampling of certain population sectors, (a) private school students, (b) Hispanic students, (c) Asian/Pacific Islander students, and (d) American Indian/Alaskan Native students, as well as compensating for survey item non-response. Enables a more accurate generalization of research findings to the nation's public and private high school senior population in the Spring term of 1992.

F2S19BF. Frequency of calculator use in mathematics class. The question was, "In your current or most recent mathematics class, how often do/did you use calculators?" Five selection choices were provided: (a) never/rarely, (b) 1-2 times per month, (c) 1-2 times per week, (d) almost each day, and (e) every day.

F2S15BD. Frequency of calculator use in science class. The question was, "In your current or most recent science class, how often do/did you use calculators?" Five selection choices were provided: (a) never/rarely, (b) 1-2 times per month, (c) 1-2 times per week, (d) almost each day, and (e) every day.

F2S19BG. Frequency of computer use in mathematics class. The question was, "In your current or most recent mathematics class, how often do/did you use computers?" Five selection choices were provided: (a) never/rarely, (b) 1-2 times per month, (c) 1-2 times per week, (d) almost each day, and (e) every day.

F2S15BI. Frequency of computer use in science class. The question was, "In your current or most recent science class, how often do/did you use computers for collecting and/or analyzing data?" Five selection choices were provided: (a) never/rarely, (b) 1-2 times per month, (c) 1-2 times per week, (d) almost each day, and (e) every day.

F12XMTH. Sophomore students' mathematics IRT (item response theory) Theta exam scores. A continuous variable (24.87-72.90) that allows for comparison of mathematics scores across population groups and time.

F12XSTH. Sophomore students' science IRT (item response theory) Theta exam scores. A continuous variable (25.18-74.92) that allows for comparison of science scores across population groups and time.

ID. Individual student identification number. Confidential student number which identifies each student in a data set. Any data analysis of NELS:88, with the student as the unit of analysis, employs this distinct reference.

G12CTRL1. Classification of student's school type as reported by the school: (a) public school, (b) Catholic school, (c) private school of another religion, (d) private non-religious school, or (e) non-ascertained private school.

F2S12A. Description of student's high school program type: (a) general high school, (b) college preparatory, (c) technology education, (d) agricultural education, (e) business occupations, (f) marketing/distributive education, (g) health occupations, (h) home economic occupations, (i) consumer education, (j) technology occupations, (k) trade occupations, (l) other education, (m) special education, (n) 'I don't know', or (o) alternative education.

F2RACE1. Description of student's ethnic background: (a) Asian/Pacific Islander, (b) Hispanic, (c) Black, not Hispanic, (d) white, not Hispanic, or (e) American Indian/Alaskan Native.

G12REGON. Description of student's U.S. Census region: (a) Northeast, (b) Midwest, (c) South, or (d) West.

F2SEX. Description of student's sex, (a) male, or (b) female.

G12URBN3. Description of the urbanicity of student's school: (a) urban, (b) suburban, or (c) rural/outside a metropolitan statistical area (MSA). Classification determined according to the Federal Information Processing Standards as designed by the U.S. Census.

Following are the four data sets analyzed in the present study:

CalcMath. Frequency of calculator use in mathematics class (N = 11,058).

CalcScie. Frequency of calculator use in science class (N = 10,529).

CompMath. Frequency of computer use in mathematics class (N = 11,039).

CompScie. Frequency of computer use in science class (N = 10,535).

CHAPTER II

Review of Research

Meta-analyses of research studies have demonstrated that computer-based education (CBE), in general, significantly increases student achievement scores when compared to traditional (non-computer) instruction (Bangert-Drowns, Kulik, & Kulik, 1985; Kulik & Kulik, 1987; Niemiec & Walberg, 1987). Similarly, a meta-analysis of calculator-use studies has shown that, on average, calculator-based instruction significantly increases student achievement levels when compared with traditional (non-calculator) classroom instruction (Hembree & Dessart, 1986). The use of computer-based instruction (CBI) in precollege education has the potential of significantly improving learning in mathematics and science classrooms (Kulik & Bangert-Drowns, 1983-84). Following, are some of the major meta-analyses and syntheses relating to the use of technology and academic achievement in the classroom.

Review of Meta-Analyses and Syntheses

Niemiec and Walberg (1987) conducted a meta-analysis which integrated approximately 250 separate studies, conducted from 1969 to 1986, dealing with computer-assisted instruction (CAI). With regard to achievement gain, 81.9% of the individual studies making up the meta-analysis revealed that the CAI students attained significantly higher scores as compared to the non-CAI students. The meta-analysis included multiple subject areas and educational levels and found that experimental classes using technology, in general, scored significantly higher than the traditional (non-technology) classes on achievement tests, with the overall, moderate effect size being .42. An effect size of this amount places the average technology student at approximately the 66th percentile of the non-technology control group distribution (i.e., the 50th percentile).

Samson, Niemiec, Weinstein, and Walberg (1986) found a moderate effect size of .32 in their synthesis of research that examined only secondary school students. They analyzed 42 individual studies that looked at students from the seventh grade to the twelfth grade, comparing computer-based instruction (CBI) with non-computer classes. The technology classes, typically, scored significantly higher on achievement exams when compared to the control classes. The effect size of their study places the average CBI student at about the 63rd percentile of the control (non-computer) group distribution.

Bangert-Drowns, Kulik, and Kulik (1985) also examined only secondary school students (grades 10-12), using research data from 42 individual studies. The 42 separate studies had an effect-size range of -.46 to 1.44. Approximately 70% of the independent studies examined mathematics and science courses. Their meta-analysis showed the classes using computer-based education (CBE), in general, scored significantly higher on achievement than did the non-computer control groups, with a small effect size of .29. This effect size places the average CBE student at about the 61st percentile of the non-technology control group distribution.

The impact of computer programming on cognitive performance was examined in a meta-analysis by Liao and Bright (1991) of students across several grade levels (K-college). The nine individual studies which investigated only high school students had an effect-size range of .051 to .595. The meta-analysis data from those nine research studies concerning high school students showed a negligible effect size of .05 (approximately the 52nd percentile) for the programming classes as compared to traditional (non-programming) classes. This finding was very low when compared with a moderate effect size of .41 (approximately the 66th percentile) for the kindergarten-through-college students in the entire 65 studies (an effect-size range of -.59 to 1.58) reviewed by meta-analysis.

The effect of calculator use on academic achievement (the only study under review dealing strictly with calculator use and achievement) in mathematics classrooms was conducted by Hembree and Dessart (1986) in a synthesis of 79 independent research reports dealing with grades K-12. A range of effect sizes for the 79 separate studies was recorded as -1.065 to 1.966.

Each of the 79 individual calculator-use studies compared achievement (i.e., basic operational skills) outcome with regard to two groups of students: (a) calculator-enhanced mathematics instruction (technology classes), and (b) traditional mathematics instruction (non-technology classes). Meta-analysis results (for all but the fourth grade) indicated a small effect size of .14 (approximately the 56th percentile), whereby the technology (calculator) students, on average, scored significantly higher on mathematics achievement exams than did the traditional (non-calculator) students. Students in the fourth-grade calculator classes, typically, scored significantly lower on the mathematics test as compared to the non-technology students; with a small, negative effect size of -.15 (approximately the 44th percentile).

Niemiec and Walberg (1985) conducted a synthesis of 48 independent research studies which investigated elementary school students and the impact of computer use on their achievement scores. The researchers collapsed the various grade levels (K-8) into three categories: (a) primary (K-3), (b) intermediate (4-6), and (c) upper (7-8) in order to get a more clear understanding of the results. Primary grade levels revealed a large effect size of .81 (approximately the 79th percentile), while the intermediate grade category showed a small effect size of .27 (approximately the 61st percentile). The upper grades showed a moderate effect size of .32 (approximately the 63rd percentile). In each of the three grade categories, the computer-using classes, usually, scored significantly higher on exams than did the traditional (non-computer) classes.

A meta-analysis by Burns and Bozeman (1981) integrated 16 secondary education studies, 11 dealing with computer drill and practice programs, and 5 examining computer tutorial programs. Students in the drill and practice experimental groups, typically, scored significantly higher on achievement than did the control (non-technology) groups, attaining a small effect size of .24 (approximately the 60th percentile). In the computer tutorial studies, the benefit was more than twice that of the drill and practice students. A moderate effect size of .52 (approximately the 70th percentile) was noted, indicating that the computer users, in general, scored significantly higher on achievement tests when compared to the non-technology students.

The effect of computer-assisted instruction (CAI) for exceptional high school students was reviewed via meta-analysis by examining two different grade categories. Four studies provided data concerning eleventh and twelfth graders, resulting in a moderate effect size of .53 (approximately the 70th percentile). CAI classes, usually, scored significantly higher on performance than did the conventional (non-CAI) groups. Multi-grade high school classes comprised the second category of 15 separate studies for review. Those findings indicated that CAI classes, generally, showed a significant increase in achievement scores when compared to the non-technology control groups, with a moderate effect size of .54 (approximately the 71st percentile) (Schmidt, Weinstein, Niemiec, & Walberg, 1985-86).

A research synthesis by Liao (1992) examined 31 independent studies, with a total of 207 comparisons, to determine the effect of computer-assisted instruction (CAI) on cognitive outcomes. The studies analyzed were published from 1968 to 1989, and there were no restrictions as to grade level or classroom subject. The effect sizes of the 31 separate studies showed a range of -.91 to 3.31. Results from the meta-analysis showed that, generally, the CAI groups scored significantly higher on cognitive evaluation than non-CAI groups. The technology classes showed an overall, moderate effect size of .48; meaning that the average student in the CAI class scored approximately 18%iles higher (about the 68th percentile) than the average non-CAI student.

A meta-analysis of 40 independent studies involving elementary school students (K-6) was conducted by Ryan (1991). She reviewed primary research findings which compared the integration of microcomputers into classroom instruction with traditional (non-technology) classroom instruction. Effect sizes for the 40 separate studies ranged from -.482 to 1.226. The meta-analysis results showed that the computer-enhanced classes achieved a moderate effect size of .31 (approximately the 62nd percentile) on achievement tests.

Kulik, Bangert, and Williams (1983), using meta-analysis, reviewed 32 studies of high school students (grades 9-12) involving computer-based teaching and conventional instruction. An effect-size range of -.75 to 1.75 was reported for the 32 separate studies. In the meta-analysis, instructional matter consisted mainly of mathematics and science classes, with approximately 20% involving other subject areas. A moderate effect size of .34 (approximately the 63rd percentile) was found, indicating that computer-based students, typically, attained significantly higher achievement scores when compared with the non-technology students.

A meta-analysis by Fletcher-Flinn and Gravatt (1995) examined 120 independent studies, published between 1987 and 1992, which investigated the impact of computer assisted instruction (CAI) on student learning. The experimental groups received the CAI treatment, while the control groups received traditional (non-technology) instruction. With regard to all grade levels and content areas, results showed that students in the CAI classes (i.e., the experimental groups), typically, scored significantly higher on cognitive examinations than did the non-CAI students (i.e., the control groups); with a small effect size of .24 (approximately the 60th percentile). This degree of effect means the average computer-using student out-scored approximately 60% of the students who did not use computers.

That same meta-analysis reported results for the 20 individual CAI studies which investigated only secondary students (grades 7-12), and their achievement gains in several different content areas. Again, the purpose was to learn the impact that CAI has on academic gain when compared with traditional instruction. Findings revealed that the computer-using classes (i.e., the experimental groups), in general, scored significantly higher on academic tests than did the non-computer (i.e., control) classes; indicating a small effect size of .20 (approximately the 58th percentile of the control group distribution).

The foregoing studies which dealt with technology (calculators and computers) and academic achievement can be further summarized according to three categories: (a) elementary grades, (b) secondary grades, and (c) all grades. [For calculation purposes, the contradictory fourth grade effect size (-.15) in the calculator study by Hembree and Dessart (1986) was treated as an outlier, and not included.] The overall effect size from the meta-analyses concerning technology (calculator, computer) use by elementary-grade students was .39 (approximately the 65th percentile). A mean effect size of .30 (approximately the 62nd percentile) was recorded from the research studies dealing with technology (calculator, computer) use among secondary-grade students. Regarding all grades, students' use of calculators and computers in the classroom showed an overall effect size of .34 (about the 63rd percentile). The grand mean from all three categories of technology (calculator, computer) use was an effect size of .34 (about the 63rd percentile).

With regard to findings which dealt strictly with calculator use in mathematics classrooms, as mentioned previously, there was only one meta-analysis (Hembree & Dessart, 1986) that addressed that research issue. Their study looked at the impact of calculator technology on students' (K-12) mathematics achievement. If the contradictory result dealing with fourth grade classes (i.e., an effect size of -.15) is treated as an outlier, and thus excluded, the overall study indicated a small effect size of .14 (approximately the 56th percentile).

Secondary Data Base Studies

The secondary data base (NELS:88) used in the current study has recently been applied as the data source in three research projects which have also examined technology use in the classroom. Owens and Waxman (1995-96) used the eighth-grade cohort data to find if school setting (urban, suburban, rural) has a significant impact on level of technology use in mathematics classrooms. Approximately 3,800 eighth-grade mathematics teachers provided survey information dealing with how often technology (calculators and computers) was used in their classrooms. Results showed the suburban-school teachers used calculators significantly more often than those instructors working in rural- and urban-school settings. Educators teaching in rural settings were significantly less likely to employ calculators and computers in their classrooms as compared to teachers in suburban- and urban-school settings.

A second study using NELS:88 as its data source was conducted by those same researchers (Owens & Waxman, 1995) to examine technology (calculator, computer) use among tenth-grade students in mathematics and science. Approximately 15,000 sophomore-year high school students provided self-report information as to how frequently they used calculators in mathematics class and computers in both mathematics and science classes. Analysis was also applied to see whether school setting (urban, suburban, rural) significantly impacted the level of technology use. Results showed that students, overall, only rarely employed computers in either subject area. Students in rural schools used computers in their science class significantly less often than did students in the other two school settings. Those students in rural-type schools used both types of technology (calculators, computer) in mathematics at a significantly higher rate than did students in urban- and suburban-school settings.

NELS:88 data were used a third time by Owens and Waxman (1998) with the objective of finding whether sex- and ethnic-related differences have a significant impact on the use of classroom technology among approximately 15,000 tenth grade students. Their study concentrated on the second wave (1990) of NELS:88, and examined computer use in science class, and both computer use and calculator use in mathematics class.

Their findings showed that male students used computers at a significantly greater rate than did females students in both mathematics and science classes. Female students were significantly more likely to employ calculators in mathematics as compared to male students. African American students used computers in science at a significantly higher frequency as compared to Hispanic and white students. African American students, also, employed computers in mathematics significantly more often than did their Hispanic and white classmates. With regard to calculators in mathematics courses, white students used that technology at a significantly increased rate as compared with Hispanic and African American tenth-graders. In addition, the Hispanic students in the study employed calculators in mathematics at a significantly higher frequency when compared with their African American cohorts.

Attitudinal Studies

When computer-based instruction (CBI) is employed as an adjunct to (not a replacement for) the classroom teacher, student attitudes toward technology become significantly more positive (Hasselbring, 1984; Kulik & Bangert-Drowns, 1983-84). Kulik, Bangert, and Williams (1983) conducted a meta-analysis of four studies which looked at student attitude toward computers. The control groups were taught using traditional (non-CBI) instruction, while the experimental groups employed computers for a portion of the class sessions. CBI classes, generally, had a significantly more positive attitude concerning classroom technology than did the control (non-CBI) groups. The large effect size was reported as .61 (approximately the 73rd percentile).

A more recent meta-analysis investigated the same research question, finding a much smaller overall result. Kulik and Kulik (1987) integrated the findings from 17 independent research studies. Again, it was found that students in computer-based instruction (CBI) classrooms, on average, attained significantly more positive attitudes toward computers when compared with students who received traditional (non-technology) instruction. The moderate effect size, only about one-half the magnitude of the findings mentioned in the previous paragraph, was recorded as .33 (approximately the 63rd percentile).

With regard to calculator use and students' attitudes towards mathematics, Hembree and Dessart (1986), conducted a meta-analysis of 79 separate studies which dealt with grades K-12. The experimental groups of students incorporated calculator use into their mathematics curriculum, while students in the control groups did not employ any calculators. Findings revealed that the technology (calculator) students had, on average, a significantly more positive attitude towards mathematics as compared to the non-technology students, with a small effect size of .19 (approximately the 57th percentile). In addition, the students who employed calculators in their mathematics classes, typically, showed significantly higher levels of self-concept in mathematics as compared with their non-calculator cohorts, with a moderate effect size of .31 (approximately the 62nd percentile). After analyzing the two groups of classes (calculator vs. non-calculator), results showed a non-significant effect size with regard to students' anxiety levels towards mathematics.

The impact of the level of technology (calculator, computer) use on students' motivation, anxiety, and classroom learning environment in mathematics was examined by Waxman and Huang (1996-97). Random samples of approximately 4,000 sixth- and eighth-grade students in a multi-ethnic school district showed significant attitudinal differences with regard to the frequency (i.e., infrequent use, slight use, or moderate use) of technology use. In sixth grade mathematics classes, those students who used technology at a slight rate revealed significantly higher levels of involvement, satisfaction, and achievement motivation when compared to students using technology at either a moderate or infrequent rate. Eighth grade mathematics students who employed classroom technology at a slight frequency showed significantly greater levels of: (a) student affiliation, (b) parental involvement, and (c) achievement motivation than did the other two frequency groups. In addition, eighth grade students who used technology at a moderate rate had significantly higher levels of satisfaction and significantly lower levels of mathematics anxiety as compared to the other two frequency groups.

Marcoulides (1988) studied the relationship between the computer anxiety levels of college students at a large urban university and their computer aptitudes. The participants were volunteer students in a course on computer information systems. Findings indicated a high, negative correlation of -.71; where increased levels of computer anxiety among the students were associated with lower levels of computer aptitude. The author suggested that using student support groups, consisting of graduate students, might help in lowering the computer anxiety levels of under-graduates.

Socio-economic Status and Achievement

Fleming and Malone (1983) performed a meta-analysis of six studies to discover the correlation between socio-economic status (SES) and science achievement among high school students (grades 10-12). The science courses included: (a) general science, (b) life science, and (c) physical science. SES was defined in the studies as: (a) father's income, (b) average school district income, (c) average income of the area where the students lived, or (d) some composite of the three. [NELS:88 uses a much different combination of factors in assigning a value for SES.] Mean correlation findings showed a positive, moderate correlation of .30, indicating that as SES increases, there is a statistical tendency for science performance scores to also improve. Stated another way, approximately 9% of the variation in science achievement scores can be accounted for by the variation in SES.

The relationship between academic achievement and SES in 27 separate studies was investigated by White (1982) using meta-analysis. Overall, the studies involved a variety of grade levels and courses, with the individual student as the unit of analysis. SES was defined as a combination of three components: (a) total household income, (b) parents' education levels, and (c) parents' occupations. [NELS:88 uses the same composite of factors to define SES.] The mean correlation between SES and academic performance was found to be a positive, moderate relationship of .32. Statistically speaking, therefore, as a student's SES drops, that same student's achievement score tends to also fall. The results suggest that about 10% of the variation in achievement scores can be explained by the SES variation.

Descriptive Studies

Becker (1991a) conducted a survey study of approximately 1,400 U.S. elementary schools, middle schools, and high schools in an attempt to determine the degree and method of computer use in America's schools. During the 1980s, the number of classroom computers (for all three grade divisions) increased from about 50,000 to about 2,400,000; for an approximate fifty-fold increase. The second half of that decade showed a yearly increase of computer terminals (for all three grade categories) of approximately 300,000 to 400,000. During the late 1980s, a majority of mathematics and science educators viewed computers in the classroom as an avenue for improving students' basic skills in mathematics and science, and for analyzing data and solving problems. High school computer time in the classroom amounted to about 8% in mathematics, and about 5% in science. Forty-two percent of high school mathematics teachers and 36% of high school science teachers in the study used computers during at least one class session, indicating that computer use in mathematics and science occurs in a minority of classrooms.

Ross (1991) conducted a national survey of secondary level, social studies teachers in order to find the degree of computer integration in their classrooms. Those teachers in the study, in general, reported small levels of implementation of computers in their social studies classes. When asked whether they had used computers in their social studies classes during the preceding year, 29% said they had. With regard to frequency of computer use, about 40% of the teachers who used computers in their classrooms reported a rate of once every two weeks, while approximately 60% of the teachers using computers said their frequency of use was once each month or less. The three most often mentioned barriers to greater computer implementation were the teachers': (a) lack of computer knowledge, (b) lack of computer experience, and (c) lack of applications software understanding. Overall findings indicated limited levels of use of computer technology by teachers in their social studies classrooms.

Becker (1991b) investigated, by survey research, the usage of computers by teachers in their mathematics and science classes and found that, although computer use had increased substantially during the late 1980s, the level of use was essentially sporadic rather than systematic. For those classes where some computer use was evident, approximately 40% of mathematics teachers and about 20% of science teachers employed this technology throughout the school year. Those teachers who used computers in their classes, most often mentioned two main instructional reasons for using them: (a) the mastery of basic facts and skills, and (b) motivating students' interest in the subject material. Most frequently, the type of computer software employed was of the drill & practice type.

Picciano (1991) examined the level of use and the method of use of computers in two public school areas: (a) New York City, and (b) northern Westchester County (a suburban area in Northeastern U.S.). The typical public school student in New York City was from a minority, urban working-class family; while the typical northern Westchester

County student was from a white, middle- or upper-class suburban family. When overall computer-use figures were examined whereby three-quarters or more of the students used computers during one school year; New York City students showed a 36% frequency, while Westchester County students evidenced a 76% rate; an approximate ratio of 1:2 in favor of the suburban students' increased access to computers. When only high school comparisons were analyzed, close to twice as much computer time was invested in drill & practice at urban high schools (approximately 30%) as compared to drill & practice computer time in suburban high schools (about 17%).

Observational Studies

Many times, technology-use data which are collected from students, teachers, or supervisors are not very accurate; usually indicating exaggerated levels of technology implementation. In order to avoid this limitation which is inherent in much self-report data, researchers have also used ethnographic approaches and systematic classroom observations whereby trained experts are present in the classroom in order to systematically observe the activities and interactions that take place.

Waxman and Huang (1996) conducted an observational study of approximately 2,200 middle-school students who were randomly selected. The study's purpose was to find whether the frequency (i.e., infrequent, slight, or moderate) of computer use and calculator use significantly changed the instructional characteristics in the mathematics classroom. It was found that the degree of technology use significantly impacted classroom instruction.

Their findings showed that classrooms where technology was infrequently employed tended to have significantly more whole-class activity, with much of the time spent on listening to or watching the teacher. Instructional characteristics in moderate-use classes were, typically, less of a whole-class nature; where significantly more class time was used by students working/learning in pairs and medium-sized groups. In classrooms where technology was used moderately, the students usually: (a) spent significantly more time engaged in independent work (i.e., less instructional interaction with the teacher), and (b) spent significantly more class time being on-task; as compared with the lower-frequency classes. In general, the increased use of technology tended to change the classroom environment from a teacher-focused one to a student-focused one.

Waxman and Huang (1995) investigated the amount and method of computer integration in approximately 200 elementary and middle-school classrooms of a large, urban school district, by using an observational research approach. Each instructional level (elementary, middle-school) contained approximately one computer for each classroom. Findings showed that there was no computer integration in the elementary classes. Regarding the middle-school classes, analysis revealed that the average student spent approximately 2% of class time working with computers. Middle-school students used computers for approximately 1% of the class time in each of four activity areas: (a) problem solving, (b) drill & practice, (c) writing, and (d) games. The overall indication was that computer integration into these elementary and middle-school classrooms was either totally absent (elementary) or very slight (middle-school).

Huang and Waxman (1996) used systematic classroom observations of about 1,300 multi-ethnic, middle-school mathematics students to determine the amount of technology (calculator, computer) use, and how that amount of technology use related to differences in, (a) sex, (b) ethnicity, and (c) grade-level. Results showed that mathematics students employed calculators approximately 25% of the time, while they used computers less than 1% of the time; indicating that neither form of these instructional technologies was used during approximately three-quarters of class time. In addition, about one-half of the mathematics students were never observed using calculators. There were no sex-related or ethnicity-related differences noted. Regarding grade-level differences, observations indicated that seventh grade students employed calculators at a significantly higher rate than sixth and eighth grade students. The study showed that general integration of calculators and computers into mathematics classrooms was not present.

Technology Integration Studies

Saye (1998) conducted in-depth interviews of 10 secondary school teachers over a three-year period in order to discover the teacher characteristics that were associated with the comfortable acceptance and systemic integration of classroom technology. Results from this ethnographic approach to education research revealed that most of the technology-using instructors in the case study possessed the following characteristics: (a) high tolerance for the unfamiliar, (b) teachers are also learners, (c) learning is pleasant and lifelong, (d) student-centered instruction, (e) emphasize higher-order thinking, and

(f) open and flexible class environment. This view of learning and teaching was classified by the researcher as a constructivist orientation toward education.

Findings, also, showed that most of the technology-avoiding teachers in the study possessed the following qualities: (a) desire for predictability and control, (b) learning is serious business, (c) time-honored tradition of teacher as center of classroom, (d) focus on covering basic skills, (e) concentrate on lower-level thinking, and (f) structured and quiet learning atmosphere. This type of approach to teaching and learning was categorized in the study as a traditional orientation toward education.

A major conclusion in the study (Saye, 1998) was that technology information and administration approval, by themselves, probably will not be sufficient in achieving the systemic integration of technology into a majority of secondary classrooms. The personal attitudes and views of the technology-avoiding teachers need to be addressed by using teacher-support groups in order to increase their receptivity levels toward uncertainty and change. Understanding the essential needs and beliefs of classroom instructors is central to the successful integration of technology into the classroom. The study's author pointed out that before students can successfully begin, and continue, their rewarding adventure of learning with technology; the teacher, as gatekeeper, must reach an adequate level of individual comfort regarding the risk and uncertainty of change.

Ronen, Langley, and Ganiel (1992) examined the problems experienced in a large scale project which integrated computer simulations into Israeli high school physics classrooms. Thirty-six high school physics teachers received an intensive five-day training session during Summer vacation to prepare them for implementing this new framework into their classrooms. Data from the physics instructors were gathered using: (a) written individual lesson reports, (b) written cumulative assessment reports, (c) classroom observation reports, and (d) personal interviews.

Findings showed that a major problem in the effective integration of this new technology was the large percentage of teachers who possessed high levels of computer anxiety. Most of the students in these teachers' classes were comfortable with using computers and the accompanying software packages, while many of the teachers were not at ease with either the hardware or simulation-type software. The researchers concluded that the introduction of this innovative equipment and different teaching method simply brought too many changes to the familiar habits and routines which most of the teachers had grown accustomed to. Most of the instructors were reluctant to forego their accepted practices and procedures for a new way of doing things.

Those physics teachers who had difficulty accepting and/or adjusting to the new program expressed concern about their lack of: (a) experience and familiarity with the new method of teaching/learning, (b) comfort in adopting another routine/schedule, and (c) personal input into the initial design and overall implementation of the curriculum changes. The study concluded by stating that to effectively harness the computer's educational potential, administrators must understand that the teacher is the key player.

Parish and Arends (1983) conducted personal interviews of teachers, administrators, and change agents in five midwestern school districts which had adopted, and later discontinued, innovative teaching programs. The purpose of their study was to investigate the school culture in order to learn why these new teaching approaches were not still being used. They considered each school a unique territory with its own natural culture and set of norms.

They found that cooperation from school principals was an essential factor in the adoption phase of the new program, but that the principals' continued support was not very important during the implementation phase. It was found that classroom teachers determined not only if the innovation was initially incorporated into their classrooms, but whether it continued to be employed. Every one of the teachers in the study expressed the view that the principal did not have the right to impose any specifics as to how any new program (involving the classroom) was put into action. Teachers stated the belief that the classrooms were theirs, and all classroom innovations must first fit the teacher's personal teaching methods and education philosophies. The researchers recommended that heavy collaboration, input, and involvement from and between classroom teachers are necessary for the successful introduction and continuation of innovative learning programs.

A Point of Difference

One specific point of difference exists between the present study and the studies that have been conducted on this education issue over the past three decades. Former research dealing with classroom instructional technology has almost exclusively used a study approach of technology/no-technology. Typically, the experimental group received some type of technology treatment, while the control group received traditional (non-technology) classroom instruction. This with/without method of research is quite different from the current study which examined five frequencies of technology use. Not one of the five selections answered by each participant in the current study was clearly without technology, since the least of the technology-use amounts was labeled never/rarely.

Summary

Although many reviews of educational research have indicated that technology use has a significant positive impact on students' academic achievement, most of these studies were conducted a decade or more ago. At that time, mainframe computers, not micro-computers, comprised a majority of classroom computers. Many changes have taken place in not only the type of education computer software available, but how it is integrated into the learning process. In addition, there have been few large-scale, national studies conducted on the subject of technology use and secondary school education in mathematics and science. For these reasons, there is a need for more up-to-date research on this important educational issue.

CHAPTER III

Methods

This study was conducted in order to find whether the frequency of technology (calculator, computer) use among a nationally representative, random, sample of U.S. public and private high school seniors significantly ($p < .001$) impacts achievement in mathematics and science. Two technologies (calculators, computers) and two subject areas (mathematics, science) were analyzed in four separate pairs: (a) calculator/mathematics, (b) calculator/science, (c) computer/mathematics, and (d) computer/science, in order to better understand the relative influence of each type of technology use on each area of learning.

Research Design

The goal of this research project was to discover whether the frequency of technology (calculator, computer) use has a significant ($p < .001$) impact on the achievement gains of public and private high school seniors in mathematics and science. Using data from NELS:88, a random, nationally representative, panel of high school sophomores was tested (pretest) during the Spring term of 1990, and then re-tested (posttest) two years later as seniors in the Spring term of 1992. The current study sought to investigate the impact which frequency of technology (calculator, computer) use has on mathematics and science cognitive scores over the final two years of high school.

A causal-comparative statistical design, such as ANOVA (analysis of variance) was the most appropriate for addressing this study's four null hypotheses. Since each sophomore student probably did not begin at the same starting point with regard to mathematics and science academic achievement, a decision was made to use each student's sophomore exam scores in mathematics and science as pretest control variables (i.e., covariates). Preliminary analysis revealed that SES (socio-economic status) was also an appropriate covariate for the current study (see the Data Analysis section).

Because of the need to control these two variables (sophomore exam scores, SES), it became necessary to employ a variation of ANOVA. ANCOVA (analysis of covariance) is very similar to ANOVA, with the major difference being that ANCOVA statistically controls one or more variables. By using ANCOVA to statistically control for these two intervening variables (sophomore test scores, SES), a more clear picture was obtained as to the impact which frequency of technology (calculator, computer) use has on achievement in mathematics and science.

Both ANOVA and ANCOVA have the same basic statistical formula: $\underline{F}$ = [between-group variance / within-group variance], where $\underline{F}$ represents Fisher's ratio (Isaac & Michael, 1995, p. 190). Essentially, this inferential equation exams the relationship between two figures: (a) the between-group variability, and (b) the within-group variability; in answering the research question (according to the alpha level established), "Is the difference statistically significant?" This analysis equation indicates that: (a) as the number representing the variation for between-groups increases, so does the F value , and (b) as the within-group variation decreases, the F ratio also increases.

Participants

Participant data have already been gathered by other researchers who conducted the National Education Longitudinal Study (NELS:88) beginning in 1988. It was funded through the U.S. Department of Education, and conducted by the National Center for Education Statistics (NCES), which is a department of the Office of Educational Research and Improvement (OERI). NELS:88, a secondary data base, used a two-stage stratified, clustered national probability design. It was a longitudinal study, meaning that over a period of years the same cohort sample members were followed in order to discover the critical transitions and experiences that U.S. public and private school students had as they attended school, and began careers and families. A national, random sample of U.S. public and private schools with eighth grade classes (approximately 1,000) made up the first-stage, with students (approximately 25) enrolled in those selected schools randomly selected for the second stratum. The original study sample totaled more than 24,000 eighth-grade students.

To date, four waves have been carried out by NELS:88 researchers. In 1988, eighth graders in U.S. public and private schools were randomly sampled for the original research wave. Two years later, those same students (most in the tenth grade) were again surveyed for the 1990 data set. After two more years (1992), the same panel of original eighth graders (a majority being in their senior year of high school) was examined for the third wave. The fourth wave of the NELS:88 study took place in 1994, when most of the participants in the study panel had graduated from high school, and were working and/or continuing with their education. A fifth NELS:88 wave is currently scheduled for either 1999 or 2000. The current research project concentrated on the third wave (high school seniors), and used the individual student as the unit of analysis; but also incorporated those same students' mathematics and science exam scores from the second wave (sophomore year) as pretest covariates.

Data were collected in each wave from students, and their: (a)parents, (b) teachers, (c) school principals, (d) school records, and (e) grade transcripts. To enable more accurate data analysis of certain under-represented population groups, over-sampling of Asian/Pacific Islander students, American Indian/Alaskan Native students, Hispanic students, and private-school students was implemented by NCES researchers. The base-year (1988) panel of students was twice freshened; once in 1990 (the first follow-up), and again in 1992 (the second follow-up). Freshening adds students who did not have an opportunity of being selected in the base year (e.g., out of the country, seriously ill, or retained in grade). This research approach increased the probability that the sophomore (1990) and the senior (1992) cohort groups would be representative of the larger national public and private school population. Further information regarding NELS:88 in general, and the second and third waves in particular, is available in the student component user's guide (Ingels et al., 1994).

Survey Instruments

During the Spring term of 1992, high school senior cohort members filled out student questionnaires. Four items from that self-reported information dealt with the frequency of technology (calculator, computer) use in each student's class (mathematics, science): (a) frequency of calculator use in mathematics class, (b) frequency of calculator use in science class, (c) frequency of computer use in mathematics class, and (d) frequency of computer use in science class. For each of these four survey items, the response choices were: (a) never/rarely, (b) 1-2 times per month, (c) 1-2 times per week, (d) almost each day, and (e) every day. These four areas of technology use comprised the four independent variables of the present study.

The following seven survey variables were selected as hypothesized covariates during the early stages of the current study: (a) control (public school, Catholic school, private school of another religion, private non-religious school, non-ascertained private school), (b) program type (general high school, college preparatory, technology education, agricultural education, business occupations, marketing/distributive education, health occupations, home economic occupations, consumer education, technology occupations, trade occupations, other education, special education, 'I don't know', alternative education), (c) ethnic background (Asian/Pacific Islander; Hispanic; Black, not Hispanic; white, not Hispanic; American Indian/Alaskan Native), (d) region of country (Northeast, Midwest, South, West), (e) sex, (f) socio-economic status composite (total family income, and parents' occupations, and parents' education levels), (g) urbanicity (urban, suburban, rural). Correlation analyses were performed on these hypothesized covariates in order to determine which ones, if any, were appropriate for inclusion in the current study. That process is explained in more detail in the Data Analysis section.

Cognitive Instruments

NELS:88 high school sophomores (1990) and seniors (1992) completed cognitive tests in mathematics, science, reading, and history. Of interest to the present study are the data from the first two subject areas. Sophomore mathematics and science exam scores were each included as covariates for statistical control; in other words, a pretest of students' performance levels in order to establish benchmarks from which academic achievement could then be measured in their senior year (1992). Mathematics and science exam scores recorded for that same panel of high school seniors (1992) comprised the two dependent variables (i.e., posttests).

Reliability coefficients for the sophomore (1990) cognitive exams were: (a) mathematics, .93, and (b) science, .81. Cognitive exam reliability coefficients for the tests administered to those same students two years later (senior exam scores) were: (a) mathematics, .94, and (b) science, .82 (Rock, Pollack & Quinn, 1995).

Each mathematics achievement test consisted of 40 multiple-choice questions, with a maximum allotted testing time of 30 minutes. The examination content areas included: (a) word problems, (b) graphs, (c) equations, (d) quantitative comparisons, and (e) geometric figures. A simple application of mathematical skill and knowledge was necessary to answer some of the questions posed, while other questions required an advanced level of comprehension and problem-solving ability. A total of five levels of exam difficulty was used, depending on the student's past mathematics exam performance.

Each science achievement test contained a total of 25 multiple-choice questions, with a maximum testing period of 20 minutes. Topics covered on the test included: (a) life science, (b) earth science, (c) physical science, and (d) chemistry. Evaluation emphasis was given to concept attainment rather than retention of isolated science facts. Each student's previous testing performance determined which one of the three difficulty-level exams was administered.

The reason for the multi-level examination design was to try and avoid ceiling and floor effects. Basically, a ceiling effect occurs when the test questions are too easy for the students; and their scores are heavily concentrated at the upper level of the spectrum. In contrast to a ceiling effect, a floor effect occurs when the test material is so difficult that the test-takers frequently guess at the answers. Academic progress is best assessed when test scores indicate an adequate variation (i.e., distribution) in the achievement gains of students.

NELS:88 was designed as a multi-year longitudinal survey, and with the understanding that all students probably do not advance academically at the same rate. Thus, administering a variety of exam-difficulty levels helped to gain a more clear understanding of each student's academic progress in both mathematics and science during their last two years of high school.

Pretest (first covariate) cognitive test data were available for both mathematics and science exam scores using the sophomore IRT (item response theory) Theta variable. Those student assessment figures are of a continuous nature, with a mathematics test range of 24.87-72.90, and a science exam range of 25.18-74.92. Percentile ranks were not provided for the sophomore cohort exams.

For this study, both dependent variables consisted of senior (1992) mathematics and science exam scores. Student achievement results in both subject areas were individually configured into 99 continuous categories, with the first and last percentile each accounting for 1.5% of the total achievement levels, and the remaining 97%iles (2-98) accounting for 1% each. IRT Theta test results were also available for the senior cohort group, but would probably have been more difficult for the reader (consumer) to interpret; thus, the selection of the percentile variable.

Data Analysis

Using SAS (SAS System, 1995) computer software, 14 correlations were calculated in order to determine if the relationship between each of the seven hypothesized covariates (control, program type, ethnic background, region, sex, socio-economic status, urbanicity) and each of the dependent variables (senior mathematics score, senior science score) was within the appropriate range for inclusion in the study. For a variable to be included as a covariate in an ANCOVA analysis, a moderate correlation (approximately $\underline{r}$ = .3-.6) is normally required. If the correlation is less than .3, the hypothesized covariate's impact on the dependent variable is generally too weak to need controlling. A correlation greater than .6 usually indicates there is too strong of an association between the hypothesized covariate and the dependent variable, indicating both may be measuring similar characteristics.

All of the following six hypothesized covariates: (a) control, (b) program type, (c) ethnic background, (d) region, (e) sex, and (f) urbanicity had correlations with each of the two dependent variables at a level of $\underline{r} < .21$, indicating a weak relationship for each comparison. Those six variables were not included in the present study. The seventh hypothesized covariate (socio-economic status) indicated a $\underline{r} = .42$ with the senior mathematics score, and a $\underline{r} = .38$ with the senior science score. Because of that moderate relationship, SES was included as the second covariate in the present study.

A series of four ANCOVAs (analyses of covariance) was conducted in order to analyze the data. The advantage of ANCOVA is its ability to control for extraneous variables (i.e., covariates). A limitation of ANCOVA is that although it will show a significant difference (if any), along with its direction, it will not reveal the magnitude of that significant difference. Employment of effect-size calculations (as was done in the current study) may partially compensate for that disadvantage. Another disadvantage of using ANCOVA is that as the number of covariates increases, the characteristics of the dependent variable come into question. Each additional covariate removes a piece of the outcome variable, to the point where the identity of what the study is measuring may be less certain. That should not be a major problem in the present study, since only two covariates were employed.

The current study used two NELS:88 variables as covariates. The first control variable (sophomore exam scores) and the second control variable (socio-economic status) were statistically controlled in order to better isolate the impact of technology (calculator, computer) use on senior mathematics and science achievement levels.

Each of the four ANCOVA analyses included a total of 7 NELS:88 data variables: (a) dependent variable (senior exam score), (b) independent variable (frequency of technology use), (c) first covariate (sophomore exam score), (d) second covariate (socio-economic status), (e) panel weight, (f) panel flag, and (g) student ID. Using the electronic codebook (ECB) programming software which is included with the NELS:88 CD-ROM, a SAS (Statistical Analysis System, 1995) set of computer instructions was compiled. That instruction program was then entered into SAS in order to transfer the raw data from the CD-ROM to a temporary SAS work file.

Before any statistical analyses could be performed on the raw data, computer instructions had to be entered so that only those participants who were a part of this study were included. Four sets of data were compiled: (a) frequency of calculator use in mathematics class ($\underline{N} = 11{,}058$), (b) frequency of calculator use in science class ($\underline{N} = 10{,}529$), (c) frequency of computer use in mathematics class ($\underline{N} = 11{,}039$), and (d) frequency of computer use in science class ($\underline{N} = 10{,}535$). Because of the large sample sizes ($\underline{N} > 10{,}000$), an alpha level of $\underline{p} < .001$ was used to test for statistical differences in the present study.

Each of the four data sets (calculator/mathematics, calculator/science, computer/mathematics, computer/science) was first examined for main effects via

ANCOVA. When a significant ($p < .001$) difference in adjusted mean scores was located, an analysis was then conducted in order to find whether there were significant ($p < .001$) interactions between frequency of technology use and: (a) sex, (b) ethnicity, and (c) sex and ethnicity. The reason for that investigation was because significant main effects are highly questionable when there are significant interactions present.

With regard to investigating for possible significant ($p < .001$) interactions of calculator use in mathematics classes and: (a) sex, (b) ethnicity, and (c) sex and ethnicity; the following, respective, probability values were recorded: (a) $p = .1200$, (b) $p = .0096$, and (c) $p = .0022$. Analysis of possible significant ($p < .001$) interactions of calculator use in science classrooms and: (a) sex, (b) ethnicity, and (c) sex and ethnicity; revealed the following, respective, probability results: (a) $p = .0851$, (b) $p = .0338$, and (c) $p = .0028$. After examining for possible significant ($p < .001$) interactions of computer use in mathematics classes and: (a) sex, (b) ethnicity, and (c) sex and ethnicity; the following, respective, probability numbers were noted: (a) $p = .8868$, (b) $p = .0092$, and (c) $p = .0695$. When possible significant ($p < .001$) interactions were analyzed between computer use in science classrooms and: (a) sex, (b) ethnicity, and (c) sex and ethnicity; the following, respective, probability values were found: (a) $p = .4429$, (b) $p = .1919$, and (c) $p = .0143$.

The foregoing findings indicated that there were no significant ($p < .001$) interaction effects in any of the four data sets with regard to frequency of technology use and: (a) sex, (b) ethnicity, and (c) sex and ethnicity. Given the absence of any significant ($p < .001$) interaction effects, all data analyses in the current study focused on main-effect findings.

Regarding main-effect findings, when a significant ($p < .001$) difference was found; post hoc, pairwise comparison tests were conducted in order to find where the difference or differences were located. Following any finding of significant ($p < .001$) difference among the post hoc, pairwise comparisons, an effect size was then calculated. An effect size indicates the particular location in the control group distribution where the average experimental student is positioned, thus, aiding in a better understanding of the practical (rather than simply statistical) importance of the group comparison.

A benefit of calculating effect sizes in a data analysis is being able to standardize the mean differences between the experimental and control groups. In addition, those calculations enable the researcher/consumer to better understand a study's findings by converting the effect sizes to a more familiar percentile comparison. In order to calculate the percentile comparison for a certain effect size, that effect size is multiplied by 34; and then the resultant figure is added to (in the case of a positive effect size) or subtracted from (in the case of a negative effect size) 50 (the mean percentile) (Niemiec & Walberg, 1985). As an illustration, if a study examined a technology-using (experimental) group as compared to a traditional (control) group, and a large effect size of 1.00 resulted, the average student in the experimental group would be positioned at approximately the 84th percentile of the control group distribution [(1.00 x 34) + 50].

To further explain, if an experimental group of students out-scored a control group of students by a small effect size of .10; that finding indicates that the average (i.e., the 50th percentile of the experimental group's distribution) student in the experimental group scored higher on the exam than did 54% of the students in the control group. Assuming this amount of difference in performance continued over a period of years, there would be a compounding effect in favor of the higher-scoring experimental groups as compared to the control groups.

In the present study, the formula used for calculating effect size was: ES = [(experimental group's adjusted mean score - control group's adjusted mean score) / (standard deviation of control group's adjusted mean score)] (Glass, McGaw, & Smith, 1981, p. 102). Using hypothetical data, the following example illustrates how an effect size would be determined, if using the same formula. An experimental group evidenced an adjusted mean score of 80, while the control group revealed an adjusted mean score of 70. The standard deviation for the adjusted mean score of the control group was 20. The calculation would show a moderate effect size of .50 [(80 - 70) / 20]. In percentile terms, this indicates that the average student in the experimental group is positioned at approximately the 69th percentile of the control group distribution (i.e., the 50th percentile).

A note of clarification: usually (as in this case) the standard error (SE), not the standard deviation (SD), is reported with each adjusted mean by the computer software package. Since the calculation of effect size requires the standard deviation for the control group's adjusted mean, a simple conversion was performed in the present study.

The formula used for that adjustment was: SD = [(SE) x (square root of n)] (Berk, 1994, p. 165).

Since the current study had no true control group, the decision was made to consider the group which employed the technology at the higher rate (i.e., the higher-frequency group) as the experimental group for calculating effect size comparisons. Likewise, the group that used classroom technology at the lower frequency (i.e., the lower-frequency group) was designated as the control group. This approach was maintained for all effect size computations in the current study. Effect sizes were calculated only for those post hoc, pairwise results which showed a significant ($p < .001$) level of difference.

Those participants in the NELS:88 sophomore (1990) and senior (1992) cohort longitudinal panel who did not meet the parameters of this study (e.g., missing, multiple response, early graduate, drop-out, out of country, legitimate skip, etc.) were excluded. In addition, those high school seniors who provided answers to the questions regarding frequency of technology (calculator, computer) use must have had that particular subject (i.e., mathematics or science) within the previous two years of school.

Limitations

Whenever a study is based on secondary data, as this study was, the researcher (whether the original architect or a later researcher) must accept the design and implementation as previously carried out. It is too late to change any of the data collection processes, or to add/alter survey questions.

A serious drawback in the present study involved the absence of data in NELS:88 with regard to how the classroom technology was being put to use. Simply knowing that a calculator or computer was used by a student in a science class is useful information, but gives no indication as to the way in which that electronic equipment was used. Some of the many methods of technology use in a classroom environment might include: (a) remedial, (b) enrichment, (c) seat-work, (d) exploration, (e) drill, (f) practice, or (g) discovery; with varying possible effects on achievement outcomes.

Another question that was not addressed by NELS:88 survey data: For what length of time was the technology item used during the particular class session in which there was use? Data were only available as to the frequency of class periods in which technology (calculators and computers) was used, not the duration of use. Thus, a student who used a calculator for a brief time during one class period per week received the same magnitude of frequency as another student who used a calculator for almost one entire class session per week.

In addition, there was the drawback of not knowing the type of equipment that was employed by the students in mathematics and science classrooms. The term, computer, probably encompassed a wide variety of different machines, some state-of-the-art for that time, while others quite dated and less useful. Software and hardware configurations were most likely not totally compatible, and may have limited the student's access to certain innovative learning materials. Similarly, the descriptor, calculator, may have referred to different types of hardware (e.g., graphing, scientific, or programmable calculators) with various performance functions and capabilities.

Dependent variables (senior posttest scores) and prettest covariates (sophomore exam scores) all relied on multiple-choice questions to determine each student's academic achievement. In the current study, assessment of performance was entirely determined by that type of testing instrument; one which might tend to evaluate only low-level thinking skills. Increases in the frequency of technology use may not foster high performance for that particular type of academic assessment. Increased use of calculators and computers may mostly benefit higher-order cognitive skills, which might not have been accurately reflected by that type of pencil and paper exam.

All student survey questionnaire data were self-reported, and they relied on participant truthfulness and memory for accuracy. Of particular concern, is the precision of a student's recollection concerning the level of technology use in a class which may have ended many months before. The four survey items which dealt with frequency of technology (calculator, computer) use, the central focus of this study, only required that the responding student either: (a) was taking, or (b) had taken that course (mathematics, science) within the previous two years. Many participants had to rely on distant recall in order to accurately respond to the four survey questions.

With reference to the limitation of memory recall, a sizeable percentage of the participants in this study were not enrolled in mathematics or science when the senior questionnaire was completed. Approximately 35% of the students were not taking any type of mathematics class, while approximately 46% of the study sample were not enrolled in a science class. That indicates that close to 40% of this study's participants were recalling events which had occurred within a previous temporal period of: (a) as recently as the previous term (Fall of 1991), or (b) as distant as the Fall term of 1990 (possibly, for some, the Spring of 1990 - see the following paragraph).

There may have been some confusion regarding the requirement of subject (mathematics, science) enrollment within the previous two years. Whether the NELS:88 researchers intended for that to mean calendar-years or school-years was not explained. Some seniors in their Spring term of 1992 may have included the Spring term of 1990 as a part of the time-frame (calendar-year definition), while others might have considered only their last two high school years as juniors and seniors (school-year definition).

An education research study containing thousands of participants, as this one did, will likely include some students who have traveled different avenues and progressed at varying rates, especially when the research data are compiled over a period of two years. For example, in the current study approximately 100 students were out-of-grade, meaning they were a part of the current study, but were not registered as twelfth-graders. Three of the many possible reasons might involve: (a) grade retention, (b) lack of academic progress due to a prolonged illness, or (c) dropped out of school and later re-enrolled at the original grade level. NELS:88 researchers were mainly concerned with the longitudinal aspect of the study, rather than creating pure categories, such as including only high school seniors in the third-wave.

For each of the four ANCOVA analysis data sets, there are different participant totals. The reason for that variation is because some students enrolled in one of the two subject areas (mathematics, science) during their last two years of high school, but not the second subject. Although the differences between the four data samples are relatively small (approximately 5%), it may be of consideration when making impact comparisons between the four sets of data.

The foregoing limitations, although detractions, do not suggest that the NELS:88 data are inadequate in helping educators to better understand technology's effect on academic achievement. NELS:88, a secondary data base, provided significant benefits to the present study: (a) random sampling, (b) national representation, (c) public and private schools combined, (d) large sample size, (e) longitudinal design, (f) professionally administered, and (g) twice freshened. As long as both researcher and research consumer realize the current study's imperfections, this research project can provide assistance to the education community.

CHAPTER IV

Results

This study was conducted in order to find whether the frequency of technology (calculator, computer) use among a nationally representative, random, sample of U.S. public and private high school seniors significantly ($p < .001$) impacts achievement in mathematics and science. Two technologies (calculators, computers) and two subject areas (mathematics, science) were analyzed in four separate pairs: (a) calculator/mathematics, (b) calculator/science, (c) computer/mathematics, and (d) computer/science, in order to better understand the relative influence of each type of technology use on each area of learning.

Null Hypotheses

This study addressed the following four null hypotheses:

Null Hypothesis 1. There is no significant ($p < .001$) difference in mathematics achievement regarding the frequency of calculator use in mathematics class.

Null Hypothesis 2. There is no significant ($p < .001$) difference in science achievement regarding the frequency of calculator use in science class.

Null Hypothesis 3. There is no significant ($p < .001$) difference in mathematics achievement regarding the frequency of computer use in mathematics class.

Null Hypothesis 4. There is no significant ($p < .001$) difference in science achievement regarding the frequency of computer use in science class.

Each of the foregoing null hypotheses is rejected. The frequency of calculator use, after controlling for sophomore exam scores and SES, showed a significant ($p < .001$) impact on seniors' achievement in both mathematics and science. Likewise, the frequency of computer use, after including the two covariates (sophomore exam scores, SES), showed a significant ($p < .001$) effect regarding seniors' achievement in both mathematics and science. After conducting analyses regarding interaction effects between frequency of technology use and: (a) sex, and (b) ethnicity, and (c) sex and ethnicity; the results indicated there were no significant ($p < .001$) interactions present.

Results Obtained for Null Hypothesis 1

Null hypothesis 1 is rejected (F (4, 11,053) = 565.26, $p < .001$). After controlling for the two covariates (sophomore exam score and SES), frequency of calculator use in mathematics class had a significant ($p < .001$) impact on senior mathematics test scores. With regard to the interaction effects of frequency of calculator use in mathematics class and: (a) sex, (b) ethnicity, and (c) sex and ethnicity; there were no significant ($p < .001$) interactions. Post hoc analyses revealed that four pairwise comparisons showed significant differences at the alpha level of $p < .001$ (see Table 1 & Figure 1).

Students who, in their mathematics class, used calculators either every day or almost each day scored significantly ($p < .001$) higher than those students who never or rarely used calculators. Mathematics students who employed calculators every day attained significantly ($p < .001$) greater test scores than students using calculators 1-2 times per month. Those students in mathematics class who used calculators every day achieved significantly ($p < .001$) higher exam scores than the students who used calculators 1-2 times each week. There were no other significant ($p < .001$) differences found in senior mathematics test scores with regard to the frequency of calculator use in high school mathematics class.

Effect sizes were calculated for the four significant ($p < .001$) post hoc findings by using the formula: ES = [(experimental group's adjusted mean score - control group's adjusted mean score) / standard deviation of control group's adjusted mean score] (see Table 2). For computation purposes, the group which used calculators in mathematics class at a higher frequency (higher-frequency group) was entered into the equation as the experimental group, while the lower-frequency group (mathematics students who used calculators at a lower rate) was recorded as the control group.

A small effect size of .13 was determined when the adjusted mean score of the higher-frequency group (i.e., students using calculators almost each day in mathematics class) was compared to the adjusted mean score of the lower-frequency group (i.e., students who never or rarely used calculators in mathematics class). This effect size indicates that, in reference to the mathematics test, the average student who used calculators almost daily is positioned at approximately the 55th percentile of the lower-frequency (never/rarely) control group distribution (i.e., the 50th percentile).

Calculation of the effect size for comparing the higher-frequency group (daily calculator use) with the lower-frequency group (never/rarely using calculators) showed a small effect size of .20. This result suggests that the typical student in the group that used calculators each day in mathematics class scored approximately 8%iles higher (about the 58th percentile of the control group distribution) on the mathematics exam than did the average lower-frequency student.

A third effect size (a small effect of .13) was calculated in order to compare the adjusted mean of the higher-frequency group (daily calculator use) with the lower-frequency group (1-2 times each month). An average student employing a calculator every day in mathematics class out-performed the typical student who used a calculator once or twice each month by approximately 5%iles. The indication being that the average control student is at the 50th percentile, while the average experimental student is found at about the 55th percentile of the control group distribution.

A comparison of the adjusted means of two frequency groups: (a) daily calculator use by mathematics students, and (b) calculator use of one to two times per week by mathematics students, showed a small effect size of .15. The typical higher-frequency student (calculator use every day in mathematics class) achieved approximately 6%iles higher (about the 56th percentile of the control group distribution) on the mathematics cognitive exam when compared with the average student who used calculators once or twice a week.

The current data set, which is concerned with the frequency of calculator use in high school mathematics classes, is one of four data sets (calculator/mathematics, calculator/science, computer/mathematics, computer/science) in the present study. Four effect sizes were calculated for frequency of calculator use in high school mathematics classes: (a) .13, (b) .20, (c) .13, and (d) .15; for an average effect size of .15. This overall finding suggests that the typical mathematics student who uses calculators at an elevated frequency out-scores the average mathematics student who employs calculators at a lesser rate by about 6%iles.

Table 1

Analysis of Covariance for Frequency of Calculator Use on Mathematics Achievement Using Pretest Score and SES as Covariates

Analysis of Covariance

Source	Sum of Squares	df	Mean Square	F
Frequency	42549722.45	4	10637430.64	565.26*
Pretest	1016527497.17	1	1016527497.17	54016.62*
SES	2407051.82	1	2407051.89	127.91*
Error	207966443.30	11051	18818.82	

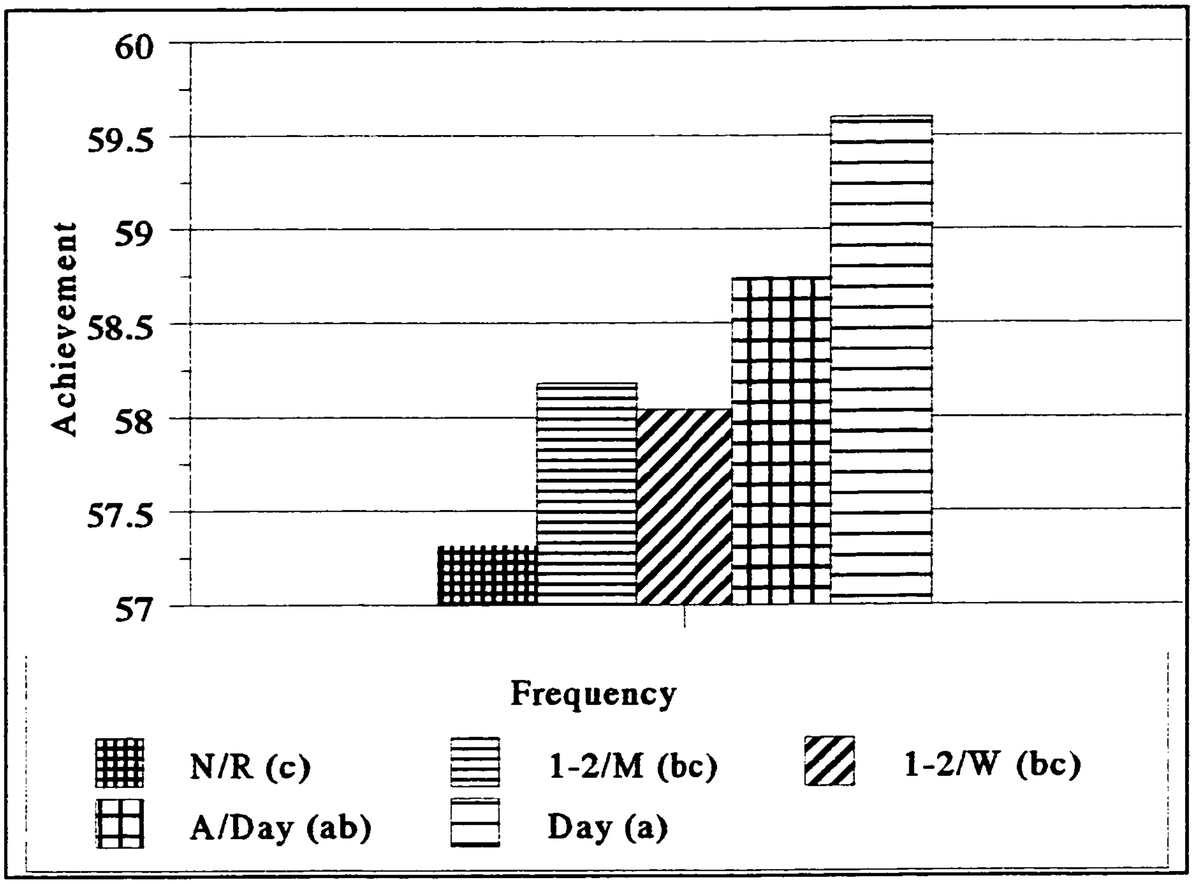
Means

		Pretest		Posttest		
Frequency	n	Mean	SD	Mean	SD	Adjusted Mean
N/R	1378	48.27	9.02	45.83	26.70	57.32 (c)
1-2/M	829	50.21	8.93	51.87	26.61	58.18 (bc)
1-2/W	1588	51.59	9.27	55.60	27.49	58.04 (bc)
A/Day	3685	52.81	9.06	59.53	26.52	58.74 (ab)
Day	4178	52.94	8.94	60.79	26.28	59.60 (a)
Total	11058	51.93	9.17	57.19	27.06	

Note. No significant ($p < .001$) interaction effects for technology use and: sex, ethnicity, and sex & ethnicity. Adjusted means with the same letter are not significantly different at $p < .001$. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day. * $p < .001$.

Figure 1

Adjusted Means for Frequency of Calculator Use on Mathematics Achievement Using Pretest Score and SES as Covariates



Note. Frequency groups with the same letter are not significantly different at $p < .001$. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day. Scale relationship represents 3%iles.

Table 2

Effect Sizes for Frequency of Calculator Use on Mathematics Achievement

		Adjusted Means		
		Posttest		
Frequency	n	Mean	SD	Effect Size
A/Day	3685	58.74		.13
N/R	1378	57.32	11.25	
Day	4178	59.60		.20
N/R	1378	57.32	11.25	
Day	4178	59.60		.13
1-2/M	829	58.18	11.15	
Day	4178	59.60		.15
1-2/W	1588	58.04	10.72	

Note. Only significant ($p < .001$) post hoc comparisons are included in table. Group with higher frequency of technology use treated as experimental group. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day.

Results Obtained for Null Hypothesis 2

Null hypothesis 2 is rejected (F (4, 10,524) = 554.41, $p < .001$). After controlling for the two covariates (sophomore exam score and SES), frequency of calculator use in science class had a significant ($p < .001$) impact on senior science test scores. Concerning the interaction effects of frequency of calculator use in science class and: (a) sex, (b) ethnicity, and (c) sex and ethnicity; there were no significant ($p < .001$) interactions. Post hoc analyses revealed that six pairwise comparisons showed significant differences at the alpha level of $p < .001$ (see Table 3 & Figure 2).

The science students who employed calculators at any one of the following three frequencies: (a) every day, (b) almost each day, or (c) 1-2 times per week, scored significantly ($p < .001$) higher on their senior cognitive science exam than did those science students who never or rarely used calculators in their science class. Employment of calculators by science students at any one of the following three rates: (a) every day, (b) almost each day, or (c) once or twice each week, showed significantly ($p < .001$) higher exam scores when compared to students who used calculators once or twice a month in their science class. Post hoc, pairwise comparisons indicated no other significant ($p < .001$) differences.

Effect sizes were calculated for the six significant ($p < .001$) post hoc findings by using the formula: ES = [(experimental group's adjusted mean score - control group's adjusted mean score) / standard deviation of control group's adjusted mean score] (see Table 4). For computation purposes, the group which used calculators in science class at a higher frequency (higher-frequency group) was entered into the equation as the experimental group, while the lower-frequency group (science students who used calculators in science class at a lower rate) was recorded as the control group.

A small effect size of .16 was discovered when the adjusted mean score of the higher-frequency group (i.e., students using calculators once or twice each week in science class) was compared to the adjusted mean score of the lower-frequency group (i.e., students who never or rarely used calculators in science class). This level of effect indicates that, when tested over science material, the average student who used calculators at the rate of 1-2 times per week is positioned at approximately the 56th percentile of the lower-frequency (never/rarely) control group distribution (i.e., the 50th percentile).

In order to compare the average student who used calculators in science at a frequency of almost every day with the average student who never or rarely employed calculators in science class, an effect size was computed. Results revealed a small effect size of .18, where the typical higher-frequency student (almost each day) scored at approximately the 57th percentile of the control group (science students who never or rarely used calculators) distribution on the science exam.

Another small effect size (.22) was found when daily calculator-users in science class were compared with students who never or rarely used calculators in science. The typical higher-frequency (daily use) student out-scored the average, lower-frequency student by approximately 9%iles (59th percentile vs. 50th percentile of the control group distribution) on science achievement.

Students who employed calculators in science class at the rate of one or two times each week were designated as the higher-frequency group. The lower-frequency group was composed of those students who used calculators in science at the rate of once or twice per month. An effect size comparing these two levels of calculator use indicated a small effect of .13. This means that the average higher-frequency student is located at approximately the 55th percentile of the lower-frequency control group distribution with regard to science achievement scores.

The fifth effect size calculation for this set of data (calculator/science) showed another small effect of .15. The higher-frequency group consisted of those students who used calculators in science class almost every day, while the lower-frequency group was comprised of students who employed calculators in science at the rate of one or two times each month. The typical student in the higher-frequency group scored at approximately the 56th percentile of the control group's distribution regarding science test achievement.

The sixth, and final, effect size for this set of data (calculator/science) indicated a small effect size of .18. The higher-frequency group was made up of science students who used calculators each day. Students how used calculators in science class at the frequency of 1-2 times a month comprised the lower-frequency group. With reference to science achievement scores, the average science student who used calculators each day out-scored the typical science student who used calculators one or two times a month by about 7%iles (57th percentile vs. 50th percentile of the control group distribution).

This set of data, which deals with the frequency of calculator use in high school science classrooms, is one of four data sets (calculator/mathematics, calculator/science, computer/mathematics, computer/science) in the present study. A total of six effect sizes were revealed concerning frequency of calculator use in high school science courses: (a) .16, (b) .18, (c) .22, (d) .13, (e) .15, and (f) .18; for an average effect size of .17. This mean effect size indicates that the average science student who uses calculators at an increased frequency scores approximately 7%iles higher when compared with the typical science student who employs calculators at a lower rate.

Table 3

Analysis of Covariance for Frequency of Calculator Use on Science Achievement Using Pretest Score and SES as Covariates

Analysis of Covariance

Source	Sum of Squares	df	Mean Square	F
Frequency	96478809.38	4	24119702.34	554.41*
Pretest	707097600.75	1	707097600.75	16253.05*
SES	6117344.45	1	6117344.45	140.61*
Error	1267459086.89	10522	43505.54	

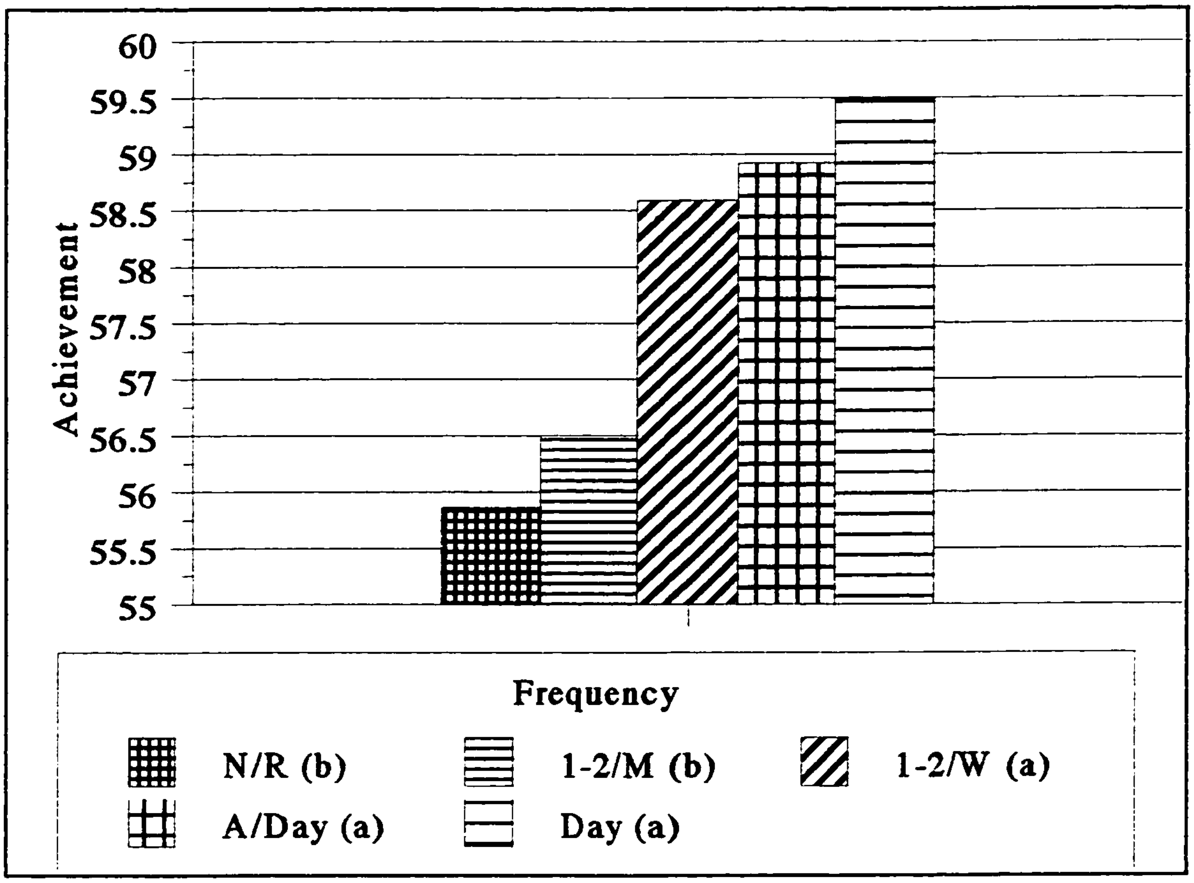
Means

		Pretest		Posttest		
Frequency	n	Mean	SD	Mean	SD	Adjusted Mean
N/R	3408	48.44	9.38	47.20	27.06	55.86 (b)
1-2/M	1155	51.08	9.50	53.96	27.08	56.50 (b)
1-2/W	1941	52.26	9.27	58.68	26.63	58.59 (a)
A/Day	2573	54.71	9.47	64.45	25.95	58.92 (a)
Day	1452	55.25	9.52	66.31	26.31	59.49 (a)
Total	10529	51.80	9.80	56.61	27.70	

Note. No significant ($p < .001$) interaction effects for technology use and: sex, ethnicity, and sex & ethnicity. Adjusted means with the same letter are not significantly different at $p < .001$. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day. * $p < .001$.

Figure 2

Adjusted Means for Frequency of Calculator Use on Science Achievement Using Pretest Score and SES as Covariates



Note. Frequency groups with the same letter are not significantly different at p < .001. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day. Scale relationship represents 5%iles.

Table 4

Effect Sizes for Frequency of Calculator Use on Science Achievement

		Adjusted Means		
		Posttest		
Frequency	n	Mean	SD	Effect Size
1-2/W	1941	58.59		.16
N/R	3408	55.86	16.75	
A/Day	2573	58.92		.18
N/R	3408	55.86	16.75	
Day	1452	59.49		.22
N/R	3408	55.86	16.75	
1-2/W	1941	58.59		.13
1-2/M	1155	56.50	16.63	
A/Day	2573	58.92		.15
1-2/M	1155	56.50	16.63	
Day	1452	59.49		.18
1-2/M	1155	56.50	16.63	

Note. Only significant ($p < .001$) post hoc comparisons are included in table. Group with higher frequency of technology use treated as experimental group. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day.

Results Obtained for Null Hypothesis 3

Null hypothesis 3 is rejected (F (4, 11,034) = 255.96, $p < .001$). After controlling for the two covariates (sophomore exam score and SES), frequency of computer use in mathematics class had a significant ($p < .001$) impact on senior mathematics test scores. With regard to the interaction effects of frequency of computer use in mathematics class and: (a) sex, (b) ethnicity, and (c) sex and ethnicty; there were no significant ($p < .001$) interactions. Post hoc analyses revealed that two pairwise comparisons showed significant differences at the alpha level of $p < .001$ (see Table 5 & Figure 3).

Mathematics students who never or rarely used computers achieved significantly ($p < .001$) greater test scores when compared with students who employed computers almost each day in their mathematics class. Students using computers 1-2 times per month in their mathematics class scored significantly ($p < .001$) higher on cognitive mathematics exams than did those students who used computers almost every day. No other post hoc, pairwise comparisons were significant ($p < .001$).

Effect sizes were calculated for the two significant ($p < .001$) post hoc findings by using the formula: ES = [(experimental group's adjusted mean score - control group's adjusted mean score) / standard deviation of control group's adjusted mean score] (see Table 6). For computation purposes, the group which used computers in mathematics class at a higher frequency (higher-frequency group) was entered into the equation as the experimental group, while the lower-frequency group (mathematics students who employed computers at a lower rate) was recorded as the control group.

The first of two effect sizes computed from this data set (computer/mathematics) dealt with two groups: (a) the higher-frequency group (mathematics students who employed computers almost every day), and (b) the lower-frequency group (students in mathematics class who never or rarely used computers). A small, negative, effect size was found (-.22). This result indicates that the average mathematics student who used computers almost every day scored about 9%iles lower (i.e., at approximately the 41st percentile of the control group distribution) on a cognitive mathematics exam than did the typical mathematics student who never or rarely employed computers.

With regard to the second significant post hoc finding, an effect size was calculated between the higher-frequency group of mathematics students and the lower-frequency group. Students how used computers in mathematics almost each day comprised the higher-frequency group, while students how employed computers in mathematics class at the rate of 1-2 times each month made up the lower-frequency group. A small, negative, effect size of -.24 resulted. The indication is that the typical mathematics student who used computers almost each day scored approximately 10%iles lower (i.e., at about the 40th percentile of the control group distribution) on a mathematics test than did the average mathematics student who used computers once or twice per month.

The current set of data, which deals with the frequency of computer use among high school mathematics students, is one of four data sets (calculator/mathematics, calculator/science, computer/mathematics, computer/science) in the present study.

Analyses showed a total of two effect sizes dealing with the frequency of computer use in high school mathematics classrooms: (a) -.22, and (b) -.24; for an average effect size of -.23. This average effect size indicates that the typical mathematics student who employs computers at an increased rate scores approximately 10%iles lower as compared to the average mathematics student who uses computers at a lower frequency.

Table 5

Analysis of Covariance for Frequency of Computer Use on Mathematics Achievement Using Pretest Score and SES as Covariates

Analysis of Covariance

Source	Sum of Squares	df	Mean Square	F
Frequency	19350598.54	4	4837649.67	255.96*
Pretest	1035420101.89	1	1035420101.89	54784.07*
SES	2615405.11	1	2615405.11	138.38*
Error	208505021.82	11032	18900.04	

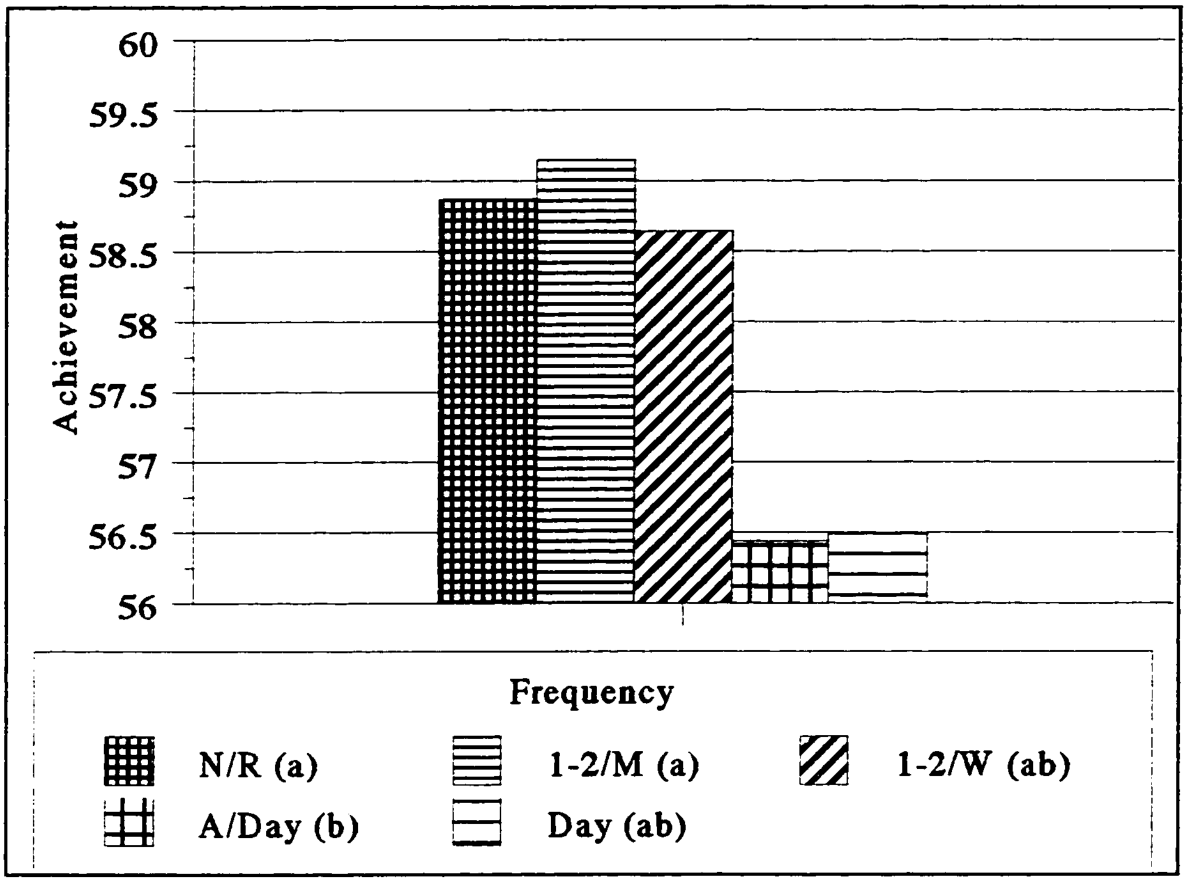
Means

		Pretest		Posttest		
Frequency	n	Mean	SD	Mean	SD	Adjusted Mean
N/R	8555	51.86	9.02	57.06	26.67	58.87 (a)
1-2/M	1438	54.03	9.08	63.28	26.87	59.15 (a)
1-2/W	581	51.16	9.69	54.89	28.07	58.64 (ab)
A/Day	274	49.31	9.74	47.93	27.65	56.44 (b)
Day	191	46.83	9.85	41.33	29.63	56.49 (ab)
Total	11039	51.95	9.16	57.24	27.05	

Note. No significant ($p < .001$) interaction effects for technology use and: sex, ethnicity, and sex & ethnicity. Adjusted means with the same letter are not significantly different at $p < .001$. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day. * $p < .001$.

Figure 3

Adjusted Means for Frequency of Computer Use on Mathematics Achievement Using Pretest Score and SES as Covariates



Note. Frequency groups with the same letter are not significantly different at $p < .001$. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day. Scale relationship represents 4%iles.

Table 6

Effect Sizes for Frequency of Computer Use on Mathematics Achievement

Adjusted Means				
		Posttest		
Frequency	n	Mean	SD	Effect Size
A/Day	274	56.44		-.22
N/R	8555	58.87	10.94	
A/Day	274	56.44		-.24
1-2/M	1438	59.15	11.23	

Note. Only significant ($p < .001$) post hoc comparisons are included in table. Group with higher frequency of technology use treated as experimental group. N/R = never/rarely; 1-2/M = 1-2 times per month; A/Day = almost each day.

Results Obtained for Null Hypothesis 4

Null hypothesis 4 is rejected (F (4, 10,530) = 49.24, $p < .001$). After controlling for the two covariates (sophomore exam score and SES), frequency of computer use in science class had a significant ($p < .001$) impact on senior science test scores. Concerning the interaction effects of frequency of computer use in science class and: (a) sex, (b) ethnicity, and (c) sex and ethnicity; there were no significant ($p < .001$) interactions. Post hoc analyses revealed that one pairwise comparison showed a significant difference at the alpha level of $p < .001$ (see Table 7 & Figure 4).

Science students who never or rarely employed computers in their science class achieved significantly ($p < .001$) higher test scores than those students who used computers in science class at the rate of once to twice per week. Post hoc, pairwise analyses indicated there were no other significant ($p < .001$) differences regarding frequency of computer use in science class and science academic achievement.

An effect size was calculated for the significant ($p < .001$) post hoc finding by using the formula: ES = [(experimental group's adjusted mean score - control group's adjusted mean score) / standard deviation of control group's adjusted mean score] (see Table 8). For computation purposes, the group which used computers in science class at a higher frequency (higher-frequency group) was entered into the equation as the experimental group, while the lower-frequency group (mathematics students who employed computers at a lower rate) was recorded as the control group.

This set of data (computer/science) was used to analyze two groups: (a) the higher-frequency group (science students who used computers one to two times per week), and (b) the lower-frequency group (those students in science class who never or rarely used computers). Results showed a small, negative effect size of -.16. The indication is that the typical science student who employed computers once or twice each week scored approximately 6%iles lower (approximately the 44th percentile of the control group distribution) on the science achievement test than did the average science student who never or rarely used computers.

This data set, which deals with the frequency of computer use by high school science students, is one of four data sets (calculator/mathematics, calculator/science, computer/mathematics, computer/science) in the current study. Analysis indicated an effect size of -.16 regarding the frequency of computer use in high school science classes. The indication from this effect size is that the typical science student who uses computers at a higher frequency scores approximately 6%iles lower when compared to the average science student who employs computers at a lesser rate.

Table 7

Analysis of Covariance for Frequency of Computer Use on Science Achievement Using Pretest Score and SES as Covariates

Analysis of Covariance

Source	Sum of Squares	*df*	Mean Square	*F*
Frequency	8616530.14	4	2154132.54	49.24*
Pretest	790756658.86	1	790756658.86	18074.54*
SES	7241876.14	1	7241876.14	165.53*
Error	460597309.03	10528	43749.74	

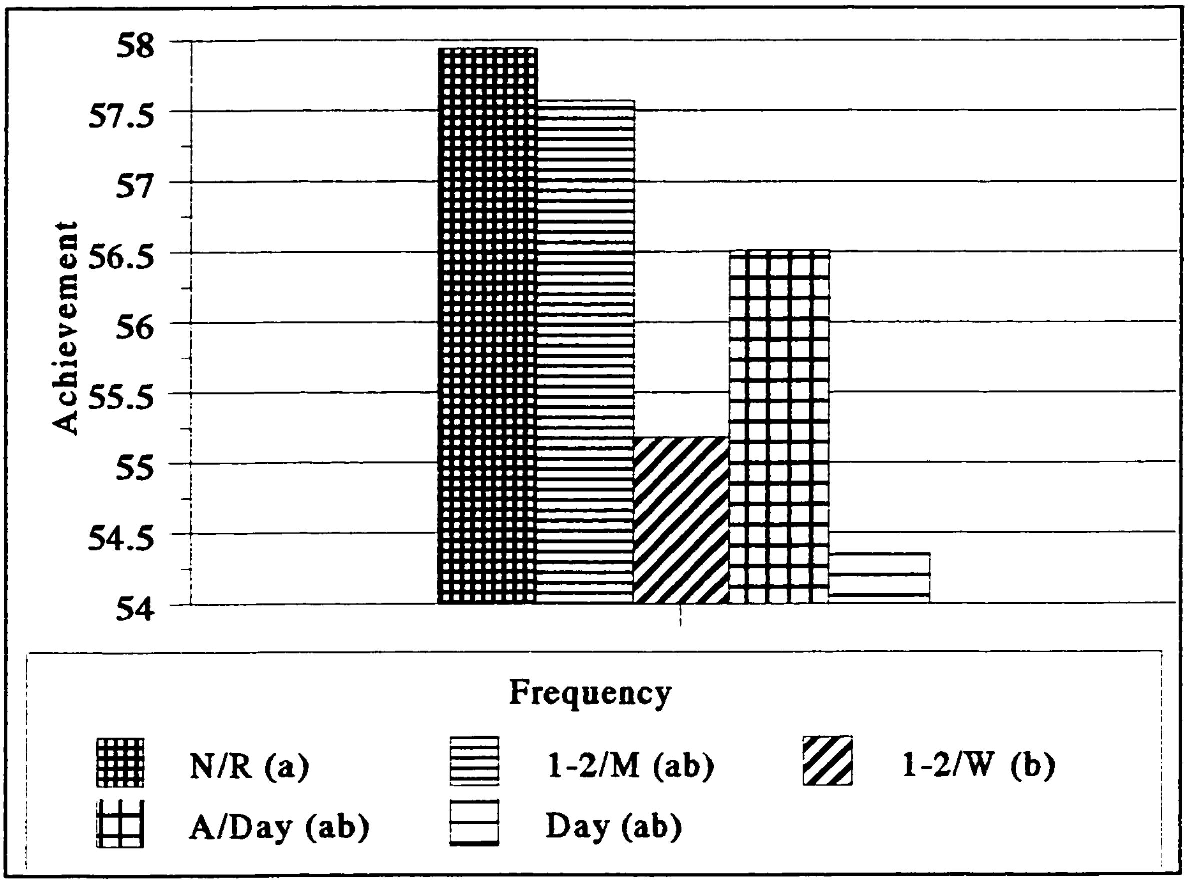
Means

		Pretest		Posttest		
Frequency	*n*	Mean	*SD*	Mean	*SD*	Adjusted Mean
N/R	8010	51.62	9.59	56.43	27.19	57.94 (a)
1-2/M	1523	53.58	10.23	60.66	27.92	57.57 (ab)
1-2/W	648	51.47	10.39	53.69	29.91	55.18 (b)
A/Day	252	49.91	10.33	51.29	31.60	56.51 (ab)
Day	102	47.39	10.59	43.41	30.00	54.35 (ab)
Total	10535	51.81	9.80	56.62	27.70	

Note. No significant ($p < .001$) interaction effects for technology use and: sex, ethnicity, and sex & ethnicity. Adjusted means with the same letter are not significantly different at $p < .001$. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day. * $p < .001$.

Figure 4

Adjusted Means for Frequency of Computer Use on Science Achievement Using Pretest Score and SES as Covariates



Note. Frequency groups with the same letter are not significantly different at $p < .001$. N/R = never/rarely; 1-2/M = 1-2 times per month; 1-2/W = 1-2 times per week; A/Day = almost each day; Day = every day. Scale relationship represents 4%iles.

Table 8

Effect Size for Frequency of Computer Use on Science Achievement

		Adjusted Means		
		Posttest		
Frequency	n	Mean	SD	Effect Size
1-2/W	648	55.18		-.16
N/R	8010	57.94	16.73	

Note. The only significant ($p < .001$) post hoc comparison is included in table. Group with higher frequency of technology use treated as experimental group. N/R = never/rarely; 1-2/W = 1-2 times per week.

CHAPTER V

Discussion

This study was conducted in order to find whether the frequency of technology (calculator, computer) use among a nationally representative, random, sample of U.S. public and private high school seniors significantly ($p < .001$) impacts achievement in mathematics and science. Two technologies (calculators, computers) and two subject areas (mathematics, science) were analyzed in four separate pairs: (a) calculator/mathematics, (b) calculator/science, (c) computer/mathematics, and (d) computer/science, in order to better understand the relative influence of each type of technology use on each area of learning.

Summary of Results

This study began by proposing four null hypotheses dealing with the frequency of calculator use and computer use, and its impact on the academic gains of public and private high school seniors in mathematics and science. The current study's findings indicate that it is proper to reject all four of those null hypotheses. The frequency of technology (calculator, computer) use in mathematics and science classrooms among more than 10,000 public and private high school students in our nation between the years of 1990 and 1992 did have a significant ($p < .001$) impact on achievement gain in those two content areas.

Each consumer of education research should keep in mind that there is a huge difference between study results that indicate a (statistically) significant difference, and findings which have a practical (i.e., meaningful) significance for education. Even when an education research project finds a statistical significance, that same finding may or may not have a practical significance for the teaching community. This point is especially important when the study (as this one did) examines a sample population of thousands of students. As the participant sample size increases (i.e., becomes more robust), the opportunity for very small differences between experimental and control groups to become (statistically) significant, grows considerably. That is one of the reasons effect-size calculations are so helpful in determining whether research findings indicate a practical significance for educators.

The frequency of calculator use by high school students in mathematics classrooms between the years of 1990 and 1992 had a significant ($p < .001$) impact on mathematics test scores. Referring to higher mathematics achievement, four significant ($p < .001$) post hoc comparisons were found; all favored the increased use of calculators in mathematics class. Each of the effect sizes of the four significant ($p < .001$) post hoc, pairwise comparisons in the current study were within a range of .13 to .20 (mean of .15), indicating a small degree of effect.

The results of the present study (effect sizes of .13, .20, .13, & .15) concerning frequency of calculator use and mathematics academic gain are in close proximity to a prior meta-analysis research finding which dealt with calculator use and mathematics achievement (effect size of .14). When the mean effect size (.15) for the four significant ($p < .001$) post hoc calculations in the current data set (calculator/mathematics) is compared with the prior study's (Hembree & Dessart, 1986) meta-analysis effect size (.14), the previous and present findings in this particular area of education are almost identical.

In the calculator/mathematics data set, the largest effect size (.20) indicated an achievement advantage for the higher-frequency group of approximately 8%iles when compared with the performance of the lower-frequency group. Although each of these small effect sizes (.13, .20, .13, & .15) in the calculator/mathematics data set favored the higher-frequency groups (those students who used calculators in mathematics class at an increased rate), their meaningful significance for educators is small.

There was a significant ($p < .001$) difference in science achievement scores with regard to the frequency of calculator use in science class among high school students between the years of 1990 and 1992. Data analyses revealed six significant ($p < .001$) post hoc findings. Regarding increased academic scores in science class, each of those six significant ($p < .001$) results favored those students who employed calculators in their science class at a greater rate than did their classmates.

Each of the resultant effect sizes from the calculator/science set of data fell within the range of .13 to .22 (mean of .17), showing a small degree of effect. Although the calculator-use study (Hembree & Dessart, 1986) listed in the Review of Research dealt exclusively with calculator use and mathematics achievement (effect size of .14), the findings from the current data set (calculator/science) are quite similar to those previous results. The largest effect-size result for this set of data (calculator/science) was .22. To put that into perspective, the average science student who used calculators at a greater frequency out-scored the typical science student who used calculators at a lesser rate by approximately 9%iles. Even though the higher-frequency groups (students who used calculators at an increased frequency) attained greater levels of academic achievement on the science test; the practical significance for educators is small.

The frequency of computer use by high school students between the years of 1990 and 1992 in mathematics classrooms had a significant ($p < .001$) impact on mathematics test scores. With reference to higher mathematics achievement scores, two significant ($p < .001$) post hoc comparisons resulted, and both favored the decreased use of computers in mathematics class. Those two effect sizes were: (a) -.22 (a small, negative effect), and (b) -.24 (also, a small, negative effect); for an average effect size of -.23 (approximately the 40th percentile of the control group distribution). Stated in an alternative fashion, this mean effect size (-.23) indicates that an average mathematics student who employs computers at an increased frequency scores approximately 10%iles lower on a mathematics achievement test, as compared to a typical mathematics student who uses computers at a lower frequency. The magnitude of these findings (mean of -.23) is somewhat lower than prior research (average effect size of .30) dealing with secondary students' academic achievement and computer use.

The mean effect size (-.23) of these results (computer use in mathematics) was slightly greater in magnitude than the average effect-size findings in the present study with reference to calculator use in either mathematics (.15) or science (.17) classrooms. More importantly, while the results dealing with the two null hypotheses concerning calculator use in mathematics and science classes showed an academic advantage (albeit small) in favor of the higher-frequency groups, this data set (computer/mathematics) points to an academic advantage (also, small) for those students who use computers in mathematics class at a lower frequency. Even though increased computer use in mathematics class indicates a negative impact on mathematics achievement, the practical significance for educators is small.

The frequency of computer use among public and private high school students in science class between the years of 1990 and 1992 had a significant ($p < .001$) impact on science test scores. One significant ($p < .001$) post hoc, pairwise comparison revealed a small, negative effect size of -.16 (approximately the 44th percentile of the control group distribution). With regard to elevated science achievement among these high school students, this study's findings favored the decreased use of computers in science class. The effect size of this finding (-.16) is considerably smaller in magnitude when compared with prior research (average effect size of .30) dealing with secondary students' academic achievement and computer use.

This finding (-.16), regarding computer use in science classrooms, is very similar to the magnitude of what has been found in the current study with regard to the effect-size impact that the frequency of calculator use has on mathematics (mean of .15) and science (mean of .17) achievement levels. There is one importance distinction; increased calculator use was found to be associated with increased achievement in mathematics and science, while increased computer use in science was associated with lower academic gain. Although these results indicate that increased use of computers in science is associated with a decrease in science achievement scores, the practical significance for educators is small.

Implications for Literature

Numerous previous meta-analyses dealing with classroom technology have painted a positive picture regarding the achievement benefits to be gained from: (a) the classroom use of computers across multiple subjects (a grand mean effect size of .34), and (b) to a much lesser degree (according to one meta-analysis), the classroom use of calculators in mathematics classes (an effect size of .14). Almost every one of those former research projects entailed a technology/no technology format; unlike the present study which looked at five frequencies of technology use.

Overall, prior studies which examined the impact of classroom computer use on academic gain have shown moderate effect-sizes ranging from approximately .30 to .40; all pointing favorably toward the employment of computers in the classroom. Those results translate to an achievement advantage for computer users of approximately 12-15%iles in the control group distribution, as compared to students who do not employ computers. To restate that in another fashion, according to previous research findings, the average student who uses computers out-performs 62-65% of the students who do not use computers.

With reference to the one meta-analysis (79 separate studies) in the present study's Review of Research which examined calculator use in mathematics, its small effect size of .14 pointed to an academic gain of about 6%iles for students who use calculators in mathematics class as compared to those who do not. The present study's findings concerning the impact of frequency of calculator use in both mathematics (mean effect size of .15; about a 6%ile advantage) and science (mean effect size of .17; about a 7%ile advantage) on achievement gain are very similar to prior research results dealing with mathematics achievement and calculator use (effect size of .14; about a 6%ile advantage). The current study's results concerning computer use and academic achievement, however, are in sharp contrast to previous research findings.

In the current study, the strongest effect size (computer/mathematics) was -.24, which showed that the higher-frequency computer-users in mathematics lost about 10%iles when compared to the lower-frequency group. Previous research results which have evaluated classroom technology and achievement gains have shown results which are slightly greater. In the current study's Review of Research on technology use and achievement, four averages were computed (.39, .30, .34, and .34) according to the respective instructional levels addressed: (a) elementary grades, (b) secondary grades, (c) all grades, and (d) an overall grand mean. When a comparison is made between previous technology-use findings and the present study's grand mean effect size (an approximate magnitude of .17), that gap widens considerably to a ratio of about 2:1

(previous findings/present findings). The overall, technology-use effect-size findings for the current study are considerably smaller (approximately one-half as large) in comparison to prior syntheses results.

Not only were the present study's results considerably smaller in magnitude when compared to prior research results with regard to classroom technology, they were of an opposite direction regarding the use of computers in mathematics and science classes. Although prior syntheses of individual studies dealing with computer use and academic gain have varied in effect-size strength, their direction was always positive; thus, pointing to the benefit of employing computers for attaining increased achievement. In the current study, however, the increased use of computers in mathematics and science classrooms (unlike the increased use of calculators) pointed toward a loss of academic gain. All three effect-size findings (-.22, -.24, and -.16) which addressed the frequency of computer use in mathematics and science classrooms indicated a loss of 6-10%iles in the control group distribution by students who used computers in those two content areas at the higher rate.

If one examines only the area of calculator use in mathematics courses, the gap between prior research and the current study almost disappears. One K-12 meta-analysis (Hembree & Dessart, 1986), as listed in this study's Review of Research, dealt strictly with how calculator-enhanced mathematics classes impacted achievement gain. As previously detailed, if the contradictory effect size (-.15) for the fourth grade classes in their study is excluded as an outlier, the overall effect size becomes .14 (about the 56th percentile). In the present study, the mean effect size for frequency of calculator use in mathematics classes is .15 (also, about the 56th percentile). The indication being that previous research results are very similar to the present study's findings, when the area of education research deals exclusively with calculator use and mathematics achievement.

Unlike the vast majority of prior research which studied how academic achievement was impacted by: (a) classroom technology vs. (b) classroom non-technology, the current study investigated how the frequency of use of classroom technology impacts academic achievement. For that reason, it is somewhat difficult to make accurate comparisons between the current study's findings and previous research results. In the present study, there is no non-technology group.

Providing adequate explanations for the substantial variation between earlier computer-use research results and the present study's findings regarding the frequency of computer use is problematic. Only a small percentage of the computer-use studies in the Review of Research section of the current study were conducted after the mid-1980s. A sizeable portion of previous research on computers and achievement was carried out prior to 1980. Since those earlier periods of research, there has been steady progress in the areas of: (a) performance capabilities of personal computers, and (b) sophistication of software instructional programs. Educators have also witnessed dramatic improvement in the teaching strategies used to make computers a basic part of the classroom curriculum. Perhaps these major changes can account for some of the contradictions noted in the present study.

Since the late 1970s, a major effort by education policymakers has been underway, with the goal of bringing an equitable number and quality of computers into this nation's urban classrooms. Prior to this effort, most inner-city schools, as compared with their suburban and rural counterparts, contained few computers; and much of the computer equipment which was in the urban classrooms was either not working or terribly out-dated. If, as some research indicates, a high proportion of urban schools tend to be classified as low-achieving schools; this large infusion of new computer equipment may help explain the contradiction between this study and prior studies.

Continuing with this possible explanation, the large influx of computers would have, almost certainly, resulted in a dramatic increase in the frequency with which students employed classroom computers. If most of the urban students were low achievers, their academic gains may have been less than students in non-urban settings. This difference between school settings might explain why the present study, in sharp contrast to many previous meta-analyses findings, indicated a decrease in achievement from the higher use of computers

The large infusion of computers into our urban schools may, again, help explain the contradictory findings; but for a different reason, one dealing directly with the urban teachers' comfort with the innovative technology. Non-urban teachers had, in general, been using more computers in their classrooms for a longer period of time than most urban instructors had been. When the new, and basically unfamiliar, computer systems became available for the urban teachers to use; many of those urban school teachers may have misused them, especially when compared to the computer use by their more-experienced non-urban associates.

It seems probable that the urban teachers would have had higher levels of computer anxiety and less computer knowledge and experience, as compared to those teaching in suburban and rural settings. While the urban teachers were playing catch-up to their counterparts in learning how to best use their new instructional equipment, the academic gain of many urban students may have been lower than students in suburban and rural schools. This could help explain the contradiction between prior research and the current study in the area of computer use.

In the last 20-30 years, there has been tremendous improvement in educational computer software. Along with advances in computer software, the systemic integration of classroom computing (although still low) has improved at a moderate rate. Teaching methods that incorporate classroom computers have become more sophisticated; unlike early approaches which tended to think of computers as fancy, neat, add-ons. These advancements might explain some of the differences between the present results and prior findings concerning computer use and achievement.

Where early attempts at capitalizing on the benefits of classroom computers usually amounted to the peripheral use of the expensive electronic gadgets, more recent approaches have employed computers as an integral part of the classroom environment. Instead of using computers mostly for drill and practice exercises, which tend to have their greatest impact on elevating lower-level cognitive skills; more recent computer applications have incorporated enrichment, discovery, and exploration activities which tend to foster higher-order thinking skills.

The multiple-choice exams used by NELS:88 to assess academic performance (the only achievement measure employed in the current study) may not properly tap the reservoir of upper-level cognition associated with more recent computer instructional technology. The ongoing evolution of computer technology could explain a portion of the contradiction between former and current findings with regard to achievement gains and computer use.

Classroom technology advances at such a rapid pace that what was once accepted as state of the art can quickly become obsolete. Previous syntheses of individual research studies are, now, quite dated. Since that time, the technology equipment and the teaching strategies for applying it in the classroom have changed dramatically. In fact, the information upon which the present study relied is between six and eight years old. Because of constant changes in classroom technology, some educators might not be surprised that the present study's results are quite different from the findings of prior research. Contradictory findings regarding computers and achievement gain, such as those found in the present study (as compared to previous results) tend to reinforce the attitude of many who work in education: "The more current our research of classroom technology is, the more valuable it becomes to educators and policymakers alike."

Another possible explanation for the contradictory results with regard to computers and achievement in the present study, when compared with prior research findings, is that the increased frequency of computer use in mathematics and science classrooms may be trying to electronically replace the classroom teacher. By going beyond using classroom computers as an important learning tool, and making it the primary focus, many students could be missing out on some of the skills and abilities of their classroom teachers. The pendulum may have swung too far in favor of excessive computer use in mathematics and science classrooms, thereby, limiting the beneficial impact of the classroom teacher.

The present study's findings regarding the increased frequency of calculator use in mathematics (mean of .15) and science (mean of .17) classes are quite similar to prior research findings regarding the use of calculators in mathematics classrooms (.14). Almost all previous research considered whether mathematics students were in either a calculator-using class or a non calculator-using class; representing an on/off scenario.

An analogy can be made by considering a calculator-technology pipeline. Prior research looked at whether that conduit was either totally open or totally closed. The current study examined five increasing frequencies of calculator use in mathematics class, reflecting neither an on or off classroom environment; but rather an increased frequency of calculator use. Using the pipeline example, it's a matter of having the classroom calculator-valve open to a certain degree, or open to a greater degree. Whether one relies on the overall findings of prior research or the results from the current study, the indication is that both approaches (on/off, or incremental increases) are associated with increased academic outcomes that are very similar in strength.

With regard to computer-use findings in mathematics and science, the present study revealed effect sizes (mean of about -.20) which were somewhat smaller in magnitude when compared to previous research findings (grand mean of about .34). The major contradiction, however, between present results and prior results was that while prior findings, in general, were academically favorable toward computer use; in the current study, the increased frequency of computer use was associated with the loss of academic gain. In explaining the contradiction, there seems to be a diminishing-returns factor at work. Returning to the pipeline analogy, almost all prior research findings could be characterized as resulting from either the computer-valve being open or closed, with a moderate level of achievement gain accruing from the open flow of computer use. The current study's results indicate that when higher flows of computer use are reached; there is a small (mean of about -.20) loss in mathematics and science achievement. This is another example of how it is difficult to compare an off/on project design (i.e., previous computer research) with one that deals with incremental increases (i.e., the present study).

Contrary to almost all of the studies which have comprised previous meta-analyses on this education topic (i.e., use of classroom technology and academic achievement), the present study consisted of a large-scale, randomly selected, longitudinal, nation-wide sample of both public and private high school students. This approach to education research is in stark contrast to the norm: (a) local/regional, (b) convenient (i.e., non-random) sampling, (c) public or private schools, (d) cross-sectional (i.e., non-longitudinal), and (e) small scale. These major differences in how most earlier education research has been structured, as compared to the framework applied in the present study, may help explain some of the conflicting outcomes regarding the frequency of computer use and achievement.

Implications for Practice

Keeping in mind the difference between statistical significance and practical significance, every statistically significant ($p < .001$) finding in the present study has small practical significance for educators, administrators, and policymakers. According to the current study's findings, varying the frequency of technology (calculator, computer) use in mathematics and science classrooms has a small impact on students' achievement outcomes. With that caveat, this study presents several implications for educators working in U.S. public and private high schools.

A question posed at the beginning of this study asked if the frequency of calculator use by high school students in mathematics and science classrooms significantly ($p < .001$) impacts academic gain. This study's findings indicate that greater use of calculators in mathematics and science classrooms translates to higher academic performance in both content areas. Although that increase in performance is meaningfully small, it nonetheless points to an academic advantage for students who employ that type of technology (i.e., calculator use) at higher rates.

Because of those findings, it is appropriate for high school educators, administrators, and policymakers to promote, fund, and implement the increased use of classroom calculators in both mathematics and science courses. Emphasis should be given to continuing-education programs for teachers concerning calculator use in mathematics and science classrooms.

When the current study began, one major question dealt with whether the frequency of computer use in mathematics and science classrooms by high school students significantly ($p < .001$) impacts academic achievement in those two subjects. The present findings indicate that the increased employment of computers in mathematics and science classes translates to lower academic performance in those two content areas. Even though that decline in academic gain has small practical significance, it still points toward an achievement advantage for those students who use computers at a lesser frequency. This finding suggests that high school educators, administrators, and policymakers should, for the near future, maintain their current levels of promotion, funding, and implementation of computers in mathematics and science classrooms.

Because of the present study's findings, expenditures for the purchase of additional computers and computer software for high school mathematics and science classrooms should, for the near future, be questioned or postponed. If any computer or computer-related equipment in mathematics or science classrooms ceases to work properly, repair/replace it; but there should be no up-grading (assuming the up-grade costs more than the repair/replacement). Any, and all, funding associated with classroom computer use (excluding maintenance/repair/replacement expenses) in these two content areas should be diverted toward continuing-education programs for teachers, or for additional research on the effects of computers for their particular school or district.

On the issue of calculator use and achievement in high school mathematics and science classes, prior research findings (.14/mathematics), along with the results (.15/mathematics; .17/science) from the current study, suggest that academic gain from calculator use is more stable and predictable than the achievement results from computer use (.34/prior; -.20/current). A possible explanation might be that calculators have been a commonplace technology instrument longer than computers have been. Most classroom teachers are probably more experienced in the use of calculators as compared to computers. While calculators have become more sophisticated since the 1960s, computer complexity and improvement have advanced to a far greater degree during that same time-frame. Teachers, therefore, are probably more comfortable with the integration of calculator technology into their classrooms, as compared to computers. This higher level of ease for calculators over computers could be reflected in a more stable pattern of curriculum integration, which may then be associated with more consistent academic outcomes.

Many mathematics and science educators who are not highly interested in or motivated to teach with technology may consider calculators an easier and simpler first step toward integrating technology into their classes, when compared to personal computers. Calculators are probably less intimidating to most educators, in part, because they involve little or no: (a) peripheral attachments, (b) connectors, (c) drive units, (d) software packages, or (e) external hookups. The result of this lower amount of intimidation may be that when the calculators are used by the teachers, they are employed properly. If teachers are more comfortable with calculator use than with computer use, this could translate to: (a) more stable achievement findings for calculator use, and (b) higher levels of calculator use.

Computers, on the other hand, may be more frightening to teachers because of the additional hardware and software requirements necessary for proper classroom application. Many teachers may consider the addition of computers to their classrooms as a very complicated endeavor, when compared to the classroom integration of hand-held calculators. In some teachers' views, the more complex computer is far more threatening to the status quo of their classrooms than is the more simple calculator.

Many teachers become quite nervous when they are confronted with the prospect of integrating computers into their mathematics and/or science courses; especially when mention is made of terms like: (a) hard drive, (b) web address, (c) default printer, (d) monitor resolution, (e) RAM, (f) CD-ROM, (g) CPU, (h) ISP, (i) byte, and (j) crash. Even when the computer equipment and the facilities for its use are present in the classroom; since most teachers are not yet at ease with this innovative method of teaching, there may be under-use/misuse.

If classroom teachers are not comfortable with computers in their classes, the tendency may be to mis-apply that technology in only a drill & practice fashion. This approach, from the instructor's viewpoint, might accomplish two goals: (a) the technology is put to use, and (b) the teacher does not, at least for the time being, have to deal with the comfort issue. The main problem with this scenario is that the huge potential of computers in the classroom is being under-used/misused. With regard to improving student achievement levels, classroom computers bring their greatest benefits to the area of higher-order thinking skills by employing software which encourages: (a) discovery, (b) enrichment, and (c) exploration by each student. The acquisition of these higher-order thinking skills is ignored, to a large extent, when the computer is used only for drill & practice exercises (i.e., misapplication).

Since classroom teachers are the primary gatekeepers when it comes to innovative additions of technology to their classrooms, the more familiar calculator may represent less of a change-threat. A teacher's customary routines and attitudes might not be altered to a large degree by the integration of calculators into the classroom curriculum; whereas, computers becoming a regular part of the classroom environment could represent too much of an intrusion into the accepted norms. The culture of the traditional (non-computer) classroom may be considered by many teachers to be the natural environment for effective teaching/learning, and the threat that computers pose to that historical approach for educating might impact how they are used, under-used, or misused.

Educators, administrators, and policymakers may want to consider some of the other possible advantages that hand-held calculators have as compared to non-lap-top computers: (a) easy portability, (b) lower purchase price, (c) individual ownership (issued to each student as a textbook is), (d) higher learning-curve, and (e) easily within reach of the purse or shirt pocket. Recently the increased power and sophistication of some types of hand-held calculators (i.e., graphing, scientific, and programmable) have in some areas of mathematical computation come close to being comparable to desk-top computing systems.

Concerning the advantages that hand-held calculators may have as compared to stationary classroom computers, those in the education profession may also want to consider how calculator use among high school students in mathematics and science can be an introductory gateway to other forms of technology. Once those students become comfortable with, and experienced in, calculator applications; the chances of their future acceptance and use of other kinds of technology increase. Their introduction to the benefits of technology use will probably encourage continued interest in the area of learning with technology; and eventually encompass the more powerful and more versatile personal computer, as well as other forms of technology.

High school educators, administrators, and policymakers should consider some of the possible advantages that classroom computers have when compared with hand-held calculators: (a) greater versatility, (b) continuing decline in purchase price, (c) highly interactive, (d) promotes positive socialization skills, (e) individualized instruction levels, (f) fosters group projects, (g) internet access, (h) encourages exploration, (i) teaches teamwork, (j) encourages independent learning, and (k) accommodates a vast array of education software packages.

While calculator use is mainly appropriate for mathematical and scientific computations, personal computers can be applied to almost any area of classroom education. Because of their increasing power and broad areas of application, computers are being used more frequently in classrooms for new instructional approaches, such as: (a) interactive video, (b) multi-media, and (c) internet publishing. The recent popularity of computer tele-communications in education has opened up an entire new frontier for students to, essentially, gain access to the world right from their classroom keyboard.

A teacher can also take advantage of the computer by using it as a presentation tool, where part or all of the class can learn by viewing the class material being projected on a large screen. The lesson can be graphically demonstrated by using the hi-tech capabilities of the computer, rather than simply: (a) lecturing, (b) writing on the chalkboard, or (c) showing overhead transparencies. Since the computer images are more life-like, each student tends to acquire greater: (a) motivation, (b) interest, (c) enjoyment, and (d) understanding.

One major benefit of computers for classroom educators, has less to do with the actual teaching/learning process, and more to do with increasing the teacher's productivity and time-management skills (Simon, 1988). By accessing the managerial powers of computers, many of the less-exciting duties can be handled quickly, such as: (a) attendance recording/reporting, (b) grade recording/reporting, (c) lesson plan design/filing, (d) calendar organization, and (e) e-mail correspondence. These approaches to productivity enhancement make it possible for teachers to concentrate of what they do best, teach.

As evidenced in the preceding paragraphs; educators, administrators, and policymakers should consider, in addition to academic achievement, other areas of education which are positively impacted by the use of instructional technology. A large body of research data indicates that students working with technology obtain many beneficial affective and psycho-motor skills, in addition to the more-often quoted cognitive skills. Classrooms with technology tend to be more student-focused, where each student takes more personal responsibility for learning. Because of the manipulation requirements of the technology equipment, there is usually an improvement in hand-eye coordination. Most often, the technology learning environment resembles a group of learners who work together as a team, where adventure and exploration replace the more traditional student-to-student competition.

In this section, earlier mention was made of a proposed continuing-education program for in-service high school educators of mathematics and science. That proposed program would include the subject areas of mathematics and science, and concentrate on achieving the professional integration of calculators and computers into those two content areas. The present study's, Review of Research, suggests that, in general, calculators and computers have not been systematically integrated into mathematics and science, even though there is ample data showing that both types of technological equipment are available in those classrooms. A teacher's attitude toward, and experience with, classroom technology have been found to be two primary factors which determine whether calculators and computers become an integral part of that instructor's classroom environment.

Before detailing the proposed continuing-education program, two fundamental philosophies need addressing; in that, those two factors are the framework for the entire proposed program. The first of the two philosophies is that in order to bring about a fundamental change in an instructor's attitude toward, and experience with, classroom technology, that change process takes at least one school-year of regularly-scheduled weekly learning/practicing sessions. The sessions should be established on each local high school campus by those mathematics and science teachers at that particular school who are interested in becoming master-tech instructors.

The reason for the extended length of the program is because an occasional in-service seminar on the use of classroom technology, with (possibly) a few accompanying follow-up sessions, has little chance of bringing about any long-term change in a teacher's professional implementation of classroom technology. For the previous 20-30 years, thousands of high school mathematics and science instructors have attended short-term technology-use seminars; and yet, the use of technology has not become an integral component in a majority of our nation's mathematics and science classrooms.

Administration support is mandatory in order for this proposed program to be successful. The authority to allow teachers the required release time from their many duties can only come from their supervisors. An adequate amount of continuing-education time is needed for teachers to become hi-tech instructors in their classrooms. Without the endorsement and encouragement from education administrators, the general integration of technology into mathematics and science classrooms will be slow in coming.

The second of the two philosophies which form the basic structure of the proposed continuing-education program is that the classroom teacher is the key to any teaching innovation. The teacher in the mathematics or science class is the central gatekeeper for whatever occurs in that class, and must be included during all phases of innovative design. If a change in any classroom curriculum is requested/demanded, whether from: (a) policymakers, (b) administrators, (c) taxpayers, or (d) researchers, the ultimate person who decides whether and how that change eventually occurs is the classroom teacher. To summarize the two philosophies that form the framework of the proposed continuing-education program, they include: (a) the classroom teacher as the central change-agent, and (b) at least one year of support from administrators for that change to happen.

The proposed continuing-education program is named CECER (pronounced, Caesar), which is an acronym for its five phases: (a) comfort, (b) expert, (c) curriculum, (d) employ, and (e) re-evaluate. The beginning phase for those in-service mathematics and science teachers who want to become master-tech instructors focuses on each teacher becoming comfortable using calculators and computers.

The goal for the first phase is to remove the tech-anxiety that many teachers have, and replace it with a feeling of ease when working with technology. This part of the program could best be described as calculator and computer play-time, where the following issues/concerns/topics are discussed/discovered: (a) pressing the wrong key won't break it [try it], (b) color televisions and microwaves are technology too, (c) the equipment can't 'byte', (d) computers will not take your job, (e) technology is a tool to make you more successful, and (f) technology is fun to play with. There are no stringent deadlines or exact time-frames for the coverage of material/topics: this portion of the program consists only of fun & enjoyment. Progression to phase two is up to the individual teacher.

In the second phase, the teacher becomes an expert in using calculators and/or computers. The expertise should be centered around what the teacher desires to bring to the classroom. For example, a geology instructor may want to focus on software programs which explain the Earth's crust and plate formations, and not spend a lot of time becoming experienced with programs dealing with algebraic configurations or quantitative chemistry. Each technology application which a teachers selects should be explored so that the strengths and weaknesses are understood; in order to answer the basic question, "What benefits, if any, will this bring to my students?" Of the program's five phases, this one is the least important, and some adventurous teachers who are only at the novice stage of understanding technology may decide to proceed directly to phase three. Each teacher decides when the time is right to move to phase three.

Phase three of the proposed program addresses the issue of how this technological approach to learning will become an integral part of the classroom curriculum. The objective is discovering the proper, and most beneficial method of integrating this innovation into the teaching environment in order to take advantage of what technology has to offer students. Key factors to consider are: (a) team-work, (b) independent and small group exploration, (c) higher-order cognitive skills, (d) interactive learning, and (e) socialization skills. This phase of the program will, in general, be the most difficult to accomplish; since, for a majority of teachers of mathematics and science, it requires a major alteration in their philosophy of teaching/learning.

In order for technology to become an integral component in mathematics and science classes; the teachers should adopt a more-constructivist approach toward teaching/learning, and relinquish the center-stage to their students. When technology is effectively brought into the classroom, teachers normally take on the roles of guides and co-learners; while the curriculum revolves around the students. From the instructor's standpoint, probably the most difficult aspect of a student-focused (i.e., technology-centered) curriculum is that the teacher gives up a lot of control. That loss of teacher control brings with it a decrease in certainty and predictability, which means the teacher has to accept more risk as an educator. Progression to phase four is up to each teacher.

Phase four of the proposed continuing-education program brings all that the teachers have learned and experienced during the previous three stages into their classrooms. This is the point where teachers can employ their acquired knowledge and understanding about the professional integration of technology in order to better educate their students. After all the effort put forth by these highly-motivated professional teachers, their just and earned reward occurs during this phase of the proposed program.

Evidence will be abundant from their students as to the benefits which instructional technology has provided them. Each teacher moves to phase five, when ready; although, practically speaking, phases four and five occur simultaneously.

The final phase of the proposed continuing-education program, as previously mentioned, is actually a concomitant extension of phase four. As with a majority of curricular changes, constant re-evaluation has to be a core requirement if that curricular change is to be sustained beyond the initial implementation period. Re-adjustments and fine-tunings occur during this phase of the program, to make sure that the technology which has been integrated into the classroom is still serving its original functions and purposes. Innovations in instructional technology probably occur at the highest rate of any area of education curriculum, requiring continued re-assessment by instructors as to what benefits their students the most. Not if, but when improvements in technology hardware/software become available; teachers can incorporate those into their classroom environments for the betterment of their students.

Another query posed at the start of this research project asked whether the increased use of calculators and computers in mathematics and science classrooms is equally effective in raising achievement scores. This study's results showed higher levels of academic achievement from increased levels of calculator-use when compared with increased levels of computer-use. In fact, increased frequency of computer use in mathematics and science classes showed a loss in academic gain. The findings from the current study indicate that increased calculator use is more effective in raising mathematics and science test scores than increased levels of computer use.

The present study began by asking whether a point of diminishing returns might be reached, whereby the increased use of calculators and computers yielded little or no improvement in mathematics and science achievement. First, with regard to frequency of calculator use; the present study's results indicate that higher levels of use are associated with greater academic achievement in both subject areas (mathematics and science). Increased levels of calculator use in mathematics and science classrooms show no signs of diminishing returns; therefore, educators need not be concerned that higher frequencies of calculator use could become associated with lower academic gain.

Second, with reference to the frequency of computer use; the present study's results indicate that increased computer use in mathematics and science classrooms is associated with lower academic performance in those two subjects. This finding indicates that a diminishing-returns factor is probably at work regarding achievement and the increased employment of computers by high school students enrolled in mathematics and science courses. Teachers of high school mathematics and science, therefore, should be concerned that increased frequencies of computer use could translate to a loss in their students' academic gains.

Implications for Future Research

The major weakness of the current study is not knowing how calculators and computers were used in mathematics and science, when they were in use. Knowing the frequency of technology (calculator, computer) use in those high school classrooms tells the education community a lot; but without knowing the method of technology employment, only part of the total picture is available. The following recommendations will go far in addressing that major weakness.

The most informative and beneficial, future research project would be very similar to the one (i.e., NELS:88) which was the basis for the current study. There would, however, be several important changes. The proposed endeavor would be entitled NELS:2000, and would be conducted by the professionals at the U.S. Department of Education starting in the year 2000. It would be a longitudinal, large scale study which would begin with the random sampling of this nation's sixth-grade public and private schools (~ 1,000), to be followed by a random selection of students (~ 25) in each of those schools. Random selection is a very powerful research method, in that each possible participant has an equal chance of being selected (Babbie, 1990, p. 75). That original panel of approximately 25,000 sixth grade students would be followed annually until high school graduation.

NELS:2000 would use cognitive multiple-choice exams in mathematics and science, as in NELS:88; but would also document other assessment procedures such as: (a) essay, (b) personal portfolio, and (c) small-group project evaluations. This additional assessment framework would help alleviate the limitation of employing only pencil and paper multiple-choice examinations. There are many students who can better express their understanding of subject material by means other than objective questions. For those students, writing about a topic or presenting a personal project may better reflect changes in achievement level.

There is considerable evidence to support the claim that multiple-choice exams may not accurately measure improvement in higher-order thinking skills. If, as many education measurement experts contend, academic improvement from the use of classroom technology is better reflected by other assessment means, alternative evaluations would be helpful. By using a variety of academic assessment techniques, a clearer understanding of student progress associated with the use of classroom technology can be realized.

To obtain a more precise view of how calculators and computers are used in mathematics and science classes, two ethnographic approaches (semi-structured interview, systematic observation) would be included, in addition to teacher and student self-report survey data. The following categories of technology use would be investigated: (a) remedial, (b) enrichment, (c) seat-work, (d) exploration, (e) drill, (f) practice, and (g) discovery. The classroom teachers would be interviewed by experts trained in employing a semi-structured interview format in order to learn why a particular approach to teaching with technology was used. Also investigated would be each teacher's attitudes concerning classroom technology and: (a) computer anxiety, (b) equipment/software preferences, (c) its importance to learning, and (d) level of comfort.

Experienced observers would be employed in NELS:2000 so that a systematic record of the interactions and behaviors of the teachers and students could be recorded and evaluated. During the data analysis phase of the study, a comparison would be made between the observational data and the self-report survey data obtained from teachers and students. If a significant difference is found between the observation findings and the self-report results (assuming the observer inter-rater reliability is above .80), preference would be given to the direct observation data. Most researchers give more weight to a study's findings when a triangulation (i.e., more than one data-collection methodology) of data sources is part of the project design.

Additional observational data in NELS:2000 would include: (a) characteristics of master-tech instructors, (b) characteristics of technology-avoiding instructors, (c) student-teacher interactional qualities of technology classrooms vs. non-technology classes, and (d) student-student interactional characteristics in technology-using classes vs. non-technology classes. Since each of the three research methodologies in the proposed project (i.e., self-report survey, semi-structured interview, systematic observation) has inherent weaknesses, a primary goal in NELS:2000 is to use more than one form of data collection, so a truer understanding is obtained.

In NELS:2000, survey data would be collected from teachers who are both expert in, and comfortable with, the professional integration of technology into their mathematics and science classrooms; with the objective of discovering what personal skills, attitudes, and experiences they possess. Information on that same topic would be obtained from those teachers who are unfamiliar and uncomfortable with the appropriate methods for the professional integration of technology into their classroom curriculum. The purpose of this approach is to discover those impediments which keep the non-tech teachers from joining the ranks of the tech-using teacher population. After that information is detailed, the end objective is to structure a continuing-education program (see Implications for Practice) which addresses the constraints that are keeping calculators and computers out of the tech-avoiders' teaching/learning environments.

A deficiency of NELS:88 is that student survey questions concerning their attitudes towards mathematics and science courses were predicated on current enrollment in those two subject areas. NELS:2000 would employ several generic attitudinal survey questions (regardless of the student's current course enrollment) in order to discover the student's attitudes toward: (a) mathematics, (b) science, and (c) technology. The series of survey questions would be similar to: (a) "It is important that I understand mathematics/science", (b) "My career goals require that I have a solid background in technology", (c) "I think learning about calculators/computers is fun", (d) "I look forward to mathematics/science class", (e) "I'm good at solving problems when I use calculators/computers", (f) "Knowing about mathematics/science will be useful throughout my life", and (g) "Working with calculators/computers is the best part of my mathematics/science class".

With the understanding that NELS:2000 may not come to fruition, there are several additional areas of education investigation that this researcher would propose. Using a local/regional participant base, a study should be conducted that examines how mathematics and science high school students': (a) attitudes toward classroom technology, (b) student-to-student interaction, (c) student-to-teacher interaction, (d) small-group interaction, and (e) academic achievement; change as their frequency of technology (calculator/computer) use increases. This proposed study would include not only student survey questionnaires; but systematic classroom observations by expert researchers, as well as, structured interviews of students and teachers. If possible, students would be selected on a random basis.

Since the current study only addressed the question of how frequently classroom technology was used, and not the (as) important question of how that same technology was employed; local/regional studies would be very helpful in better understanding how the various methods of using classroom technology impact academic achievement. Statistical comparisons would be made regarding the numerous methods of using classroom technology, and their impact on cognitive achievement. Although it may not be practical, random selection of students should be a part of the project in order to have the strongest study design. The following seven technology-method classroom groups would be used, with the same mathematics/science subject material being covered in each: (a) remedial, (b) enrichment, (c) seat-work, (d) exploration, (e) drill, (f) practice, and (g) discovery. These results should provide a clearer understanding of the comparative influences that several different technology-use classroom methodologies have on students' mathematics and science achievement.

Understanding the attitudes and experiences of teachers who are high users of classroom technology, and comparing those data with the attitudes and experiences of instructors who avoid classroom technology can help highlight those factors which are most important for teachers to become professional integrators of classroom technology. A regional/local study which addresses this issue would aid administrators in designing and implementing continuing-education programs to assist those non-tech teachers in becoming more accepting and comfortable with instructional technology. After the tech-avoiders gain a personal ease with technology, they then receive further continuing education which emphasizes the academic and affective benefits of integrating calculators/computers into their classrooms.

To carry out the proposed project, surveys would be sent to all high school principals in a school district requesting that the most hi-tech and low-(non-)tech teachers in that school be a part of the research study. After randomly selecting a sample of schools, and obtaining agreement from the hi-tech/low-tech teachers, semi-structured interviews would be conducted by experienced ethnographers.

The goal is to investigate the differences between those teachers who are experienced/comfortable with classroom technology and employ it as an integral part of their classroom curriculum; and those teachers who are inexperienced/uncomfortable with classroom technology, or who consider it not important in teaching their students. The data obtained would be used to design, implement, and update a five-phase, continuing-education program (see Implications for Practice).

Closing Comments

This researcher experienced two surprises while conducting the current study; one small, one major. First to the small surprise: a previous meta-analysis (79 independent studies) dealing with calculator use and mathematics achievement indicated an overall effect size of .14, which was almost identical to the current study's results (.15) dealing with the same type of technology (calculator) use and content area (mathematics). In addition, the present study's findings (.17) with regard to calculator use and science achievement was quite similar to the prior results (.14) which examined the same type of technology (calculator) use, but different content area (mathematics).

Now for the major surprise: prior research, in general, has consistently shown a moderate advantage (effect sizes of approximately .30-.40) regarding classroom computer use and academic gain. Contrary to that large body of previous research, in the present study the increased frequency of computer use in mathematics and science classrooms was associated with lower academic performance (mathematics/-.23; science/ -.16). Although the magnitude of the current findings was somewhat smaller than prior research findings, the major surprise came as a result of the contradictory direction.

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IMAGE EVALUATION
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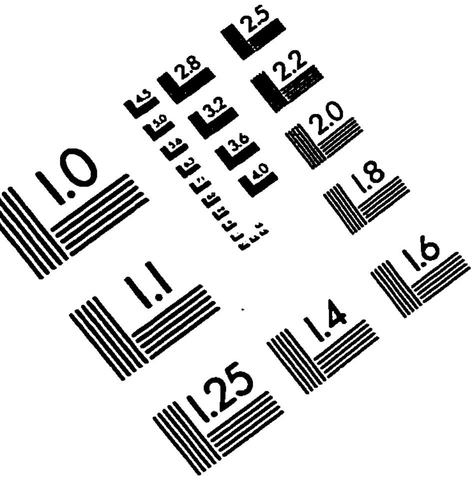

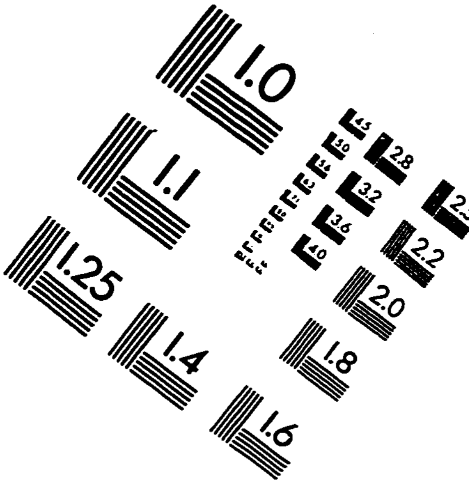

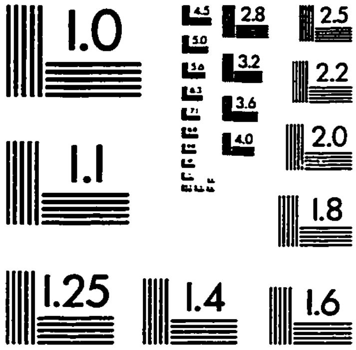

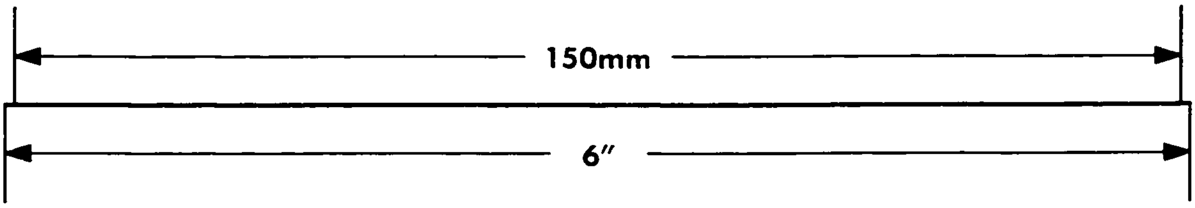

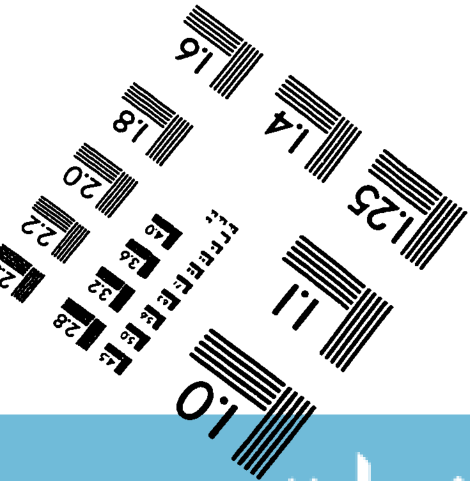

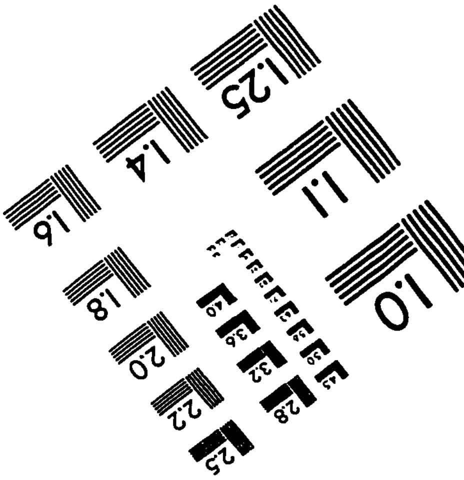

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