COMPUTER AVAILABILITY AND STUDENTS' SCIENCE ACHIEVEMENT IN TAIWAN AND THE UNITED STATES

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by
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ABSTRACT

The purpose of the study was to examine the differences associated with nationality, computer availability at school, and computer availability at home on eighth-grade students' science achievement. Achievement scores were obtained from the Third International Mathematics and Science Study—Repeat dataset for Taiwan and the United States (U.S.) students. One hundred thirty-seven schools in Taiwan and 152 schools in the U.S. were selected with 5270 Taiwanese students and 6236 American students.

A three-way analysis of variance was conducted using house weight to weight the selected sample. The dependent variable was TIMSS 1999 science overall score, and the independent variables were nationality, four levels of number of students per computer, and two levels of computer availability at home. An Omega Squared (ω^2) was calculated for each of the significant main effects. Follow-up analyses were included for statistically significant interactions.

Descriptive statistics revealed that the average class size in Taiwan was significantly larger than the class size in the U.S. The statistical analysis found a difference in mean science achievement score between Taiwan and the United States,

among the four levels of number of students per computer, and between the two levels of computer availability at home. Taiwanese students performed significantly better than American students (ω^2= 5.8 %). Students in the group with the least number of students per computer performed significantly better than rest of the three groups (ω^2= 0.3 %). The statistically significant difference among the levels of computer availability at school might be due to large sample size rather than true differences among groups because of the small amount of variance accounted. Furthermore, students who had a computer at home had significantly higher achievement in science than those without a computer at home (ω^2= 4.8 %).

Statistically significant interactions were found between 1) nationality and the number of students per computer and 2) the number of students per computer and home computer availability. Discussion of and recommendations for the study were presented.

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CHAPTER ONE

INTRODUCTION

The incorporation of educational technologies into the K-12 classrooms has recently received an increased amount of attention of education policy-makers. However, the term "educational technology" has had a variety of meanings throughout history. For example, in a policy report by Coley, Cradler, and Engel (1997), the term educational technology "includes any resources used in the education of students (p.7)." When this term was used after World War II it meant visual-aid technologies such as filmstrips, slide projectors, audiotapes and television. Subsequently, educational technology has become to refer to computer-based learning since the onset of personal computing in the 1980s. Most recently, educational technology means any learning environment that is established with computer and communication technologies (Coley et al., 1997).

With the advances of computer technology during the last two decades, more computers are found in K-12 classrooms across the United States (U.S.). Research documents had projected that almost all schools in U.S. public schools would have computers at the end of 20^{th} century (Quality Education Data, 1997). In 1998, the Center for Research on Information Technology and Organizations at the University of California, Irvine, and the University of Minnesota conducted a national survey about teaching, learning and computing in U.S. schools (Anderson & Ronnkvist, 1999). These researchers reported that, in 1983, there were only 250,000 instructional computers in K-12 schools in the U.S. However, that number increased dramatically to 8,600,000 during 1998. In fact, from 1983 to 1998 there was a 3,400 % increase in the number of instructional computers in schools.

There is an emergent concern among educators about the impact of instructional computers on student learning. Schwarz (1996) argues that computer technology is immoral because it provides information but not understanding. He questions the effectiveness of computers and whether access to large amounts of information will result in progressive learning. Schacter and Fagnano (1999) argue that computer technologies need to be designed according to accepted learning theories. They assert that computer technologies are most effective when different educational and psychological theories are taken into account during the designing phases of software development. In contrast, Rowe (1998) questions whether computer technology should be used in the classrooms. Nevertheless, he argues that computers are an important tool in improving communication between school administrators and classroom teachers.

The National Council for Teachers in Mathematics (NCTM) Standards require that every middle school classroom should have at least one computer available at all times (NCTM, 1991). With respect to computers, 99% of the elementary and secondary schools in the U.S. had installed computers by 1992, and 92% of the students reported using them during the school year. The U.S. was the world leader in this respect, with the typical middle school having one computer for every 14 students (Anderson, 1993). However, lack of computer hardware and software poses serious problems for mathematics and science teachers (Anderson, 1993; Becker, 1990; Weiss et al., 1994), though equipment shortages are probably not the only reason; perhaps the main reason causing the problems is the lack of integration of technology into instruction. Not surprisingly, a number of U.S. school principals of the Third International Mathematics and Science Study (TIMSS 1995) reported that their schools faced shortages of computer hardware and software. Approximately 33 % viewed these shortages as having "a lot" of impact on school education (National Center for Educational Statistics [NCES], 2000).

In the TIMSS questionnaires, eighth-grade science teachers were asked to report how often they asked their students to use computers to solve exercises or problems. Approximately three quarters of the U.S. teachers reported that students were "never or almost never" asked to use computers to solve exercises or problems (NCES, 2000). Students were also asked how often they used computers in science classes and reported a similar level of non-use; at least 65% of the U.S. students reported they never use computers in science class. For whatever reason, according to the TIMSS 1995, it is clear that computers did not figure significantly in the eighth-grade science curriculum.

While two-thirds of the eighth-grade students of the U.S. did not use computers in their science classrooms, those students who did have access to computers in class reported that they liked to use them (NCES, 2000). Indeed, access to computers is not limited to the classroom. The Current Population Survey suggested that approximately half of U.S. children had computers at home (U.S. Census Bureau, 1999). According to a TIMSS 1995 study (Beaton et al., 1996), approximately 58% reported having desktop computers, and 22% having laptops or notebook computers at home. Research studies confirm that computer experience and having a computer at home are related to positive attitudes toward computers and computing (Lockheed, Thorpe, Brooks-Gunn, Casserly, & McAloon, 1985; Wenglinsky, 1998). These students—whose families may be more able to afford or more likely to want a computer in the home—may also be likely to respond affirmatively to this question (NCES, 2000).

There are other concerns about the effectiveness of computer technologies, such as the location of computers and the way teachers use them. For example, Wood (1998) noted that the allocation of computer resources influence the teaching and learning process. Schwarz (1996) asks the question, "Are educators thinking critically about the place of computer technology in the curriculum?" (p.76) Schwarz reported that the fundamental curricular questions remain largely unasked. Schacter and Fagnano (1999) also argue for the importance of proper use of computers by teachers.

Need for the Study

Many studies have shown the effectiveness of using certain computer softwares to enhance subject learning in classroom or laboratory settings (Christmann, Badgett, & Lucking, 1997a; Kulik, 1994; Liao, 1998). However, a closer examination of computer use in individual classrooms is needed to assess the effectiveness of computer technology on student achievement. Not only a further examination is necessary, but also one within a broader context to represent a general pattern across the country is equally essential. With the release of the Third International Mathematics and Science Study-Repeat (TIMSS 1999) Science Report by Martin, Mullis, and Gonzalez (2000) and the database by Gonzalez and Miles (2001), it is possible to examine the relationship between computer use and eighth-grade students' science achievement. Results from the report shown that U.S. students performed above the international average in science, while Taiwanese students have the highest average performance. Therefore, comparing U.S. and Taiwanese students' science achievement in terms of levels of computer use will provide a better understanding of the effectiveness of computer technologies.

The TIMSS 1999 is one of the many international comparisons that are sponsored by the International Association for the Evaluation of Educational Achievement (IEA) since the 1970s. IEA is a non-profit international scientific society established and licensed in Belgium in 1959 for the purpose of pedagogical research worldwide. The information about IEA and its studies can be found on the Web site http://www.iea.nl.

Very few studies, especially large-scale ones, have examined the effect of computer availability upon science achievement. Generally, those research findings indicate that computer-based instruction improves students' achievement (Christmann, Badgett, & Lucking, 1997a, 1997b; Kulik, 1994; Liao, 1998). If schools have more computers for instructional purposes and one computer is shared by only a few students, students should have more opportunities to use the computer. As a result, higher exposure-rate to computers should improve students' achievement as speculated. However, there is even less research about the frequency of computer use and its effect on achievement. One report by Wenglinsky (1998) analyzed the effect of frequency of computer use on students' mathematics achievement and found a negative relationship for both fourth and eighth graders. The large quantity of data collected by the TIMSS 1999 provides researchers with a unique opportunity to examine the effectiveness of computer availability at school on student achievement in science.

In addition, it is of interest to examine the effectiveness of computer availability at home on science achievement. Wenglinsky (1998) found a positive relationship between frequency of home computer use and academic achievement for fourth graders, but a negative relationship for eighth graders. There is a need for further research to clarify the effect of home computer availability on eighth-grade students' achievement.

Finally, simply analyzing computer use in the U.S. would not be sufficient to provide an international perspective of U.S. students' science achievement. Because students from Chinese Taipei (Taiwan) performed the best among the other countries in the TIMSS 1999 study, adding them to the analysis could help to compare the differences and similarities between the U.S. and a high-achieving country (Taiwan).

Purpose of the Study

The purpose of this study is to examine the differences among levels of computer availability at school, computer availability at home, and nationality on the TIMSS 1999 eighth-grade students' science achievement. Levels of computer availability at school are categorized based on the number of students per computer. This study is intended to examine the effect of these factors and their interactions on students' science achievement from a quantitative perspective.

Definitions of Terms

For the purpose of this study, the following terms are defined:

Achievement is eighth-grade students' total science achievement scores measured from the TIMSS 1999 study.

Computer availability at home is the measurement of whether at least one computer is available at participating students' home.

Computer availability at school is the measurement of the number of students per computer at participating schools. In this study, computer availability at school is divided into four groups with the range from 1) 0.0001-1.7115 students per computer, 2) 1.7116-4.0000 students per computer, 3) 4.0001-6.0536 students per computer, and 4) 6.0537 and more students per computer.

Chinese Taipei is the term to represent Taiwan when participating in international events, and is used interchangeably with the term "Taiwan."

Levels of computer availability at school are the four levels of number of students per computer at participating schools for both Taiwan and the U.S. grouped from highest, high, low, to lowest computer availability.

Number of students per computer is number of eighth-grade students enrolled in the participating schools divided by number of instructional computers available for eighth-grade students and their teachers. It is the unit for measuring computer availability at school.

Taiwanese students participating in the TIMSS 1999 are those students of Chinese

Taipei.

TIMSS 1999 is the Third International Mathematics and Science Study-Repeat conducted in 1999, also known as TIMSS-Repeat or TIMSS-R.

Assumptions of the Study

This study is based on the following assumptions.

1. The results of the TIMSS 1999 are valid and reliable.
2. There are no errors in the TIMSS 1999 data or data collection procedures that would significantly affect the results of this study.
3. Achievement scores of the TIMSS 1999 participating students in Taiwan and in the U.S. are normally distributed.
4. Sampled students and schools are representative of the population in both Taiwan and the U.S.
5. Participating students and school principals responded to the questionnaires honestly.
6. Participating students' science achievement scores from eight individual test booklets were representative of their science achievement as a whole.

Limitations of the Study

The following limitations apply to this study:

1. This study was limited to participating eighth-grade students of the TIMSS 1999 in Taiwan and in the U.S. and not extended to other countries and students in other grade levels.

2. The measurement of student achievement was limited to the total general science achievement scores assessed by the TIMSS 1999 and not extended to specific science content areas (e.g. earth science, life science, physics, chemistry, environmental and resource issues, and scientific inquiry and the nature of science).
3. The samples of eighth-grade students were limited to those participating principals in the TIMSS 1999 who provided information about their computer availability at school.

Summary

A review of the literature suggests positive effects of computer-based instruction on students' achievement. However, few studies involve a large-scale examination on computer technology. The TIMSS 1999 data provide an additional opportunity to quantitatively examine the computer availability at home and at school and their effect on science achievement of eighth-graders. The TIMSS 1999 also provides an international perspective by comparing science achievement and related issues in science education between/among countries. The need for the study, purpose of the study, definitions of terms, assumptions of the study as well as the limitations of the study were included in this chapter.

Chapter II addresses a review of the relevant literature covering the findings from the TIMSS 1995 and 1999, history and status of computer use in the U.S., and related studies about computer use and achievement. Chapter III explains the research questions and hypotheses, data collection, description of the population and sample, instrument, questionnaires, independent variables and dependent variable, and statistical analysis. Chapter IV presents the findings of the study. Finally, the summary of findings, discussions and conclusions, and recommendations for future research are provided in Chapter V.

CHAPTER TWO

REVIEW OF LITERATURE

Introduction

This chapter reviews the relevant literature regarding international comparisons and the effectiveness of computer use on students' achievement. Related reports of science achievement from the TIMSS 1995 and TIMSS 1999 are summarized to provide an overall understanding of the background of this study. The current status of computer use at school and at home for K-12 students in the U.S. is outlined. A review of the effectiveness of computer technology on students' achievement is presented followed by an additional discussion of computer technology and students' achievement in science.

International Assessment

IEA has sponsored several international science-related comparisons of student achievement, including the First IEA Science Study (FISS) in 1970-71, the Second IEA Science Study (SISS) in 1983-84, the TIMSS 1995, and the TIMSS 1999. Another repeated study of TIMSS will be conducted in 2003.

Comber and Keeves (1973) analyzed data related to science achievement from IEA's Six-Subject Study and formed the report—FISS. IEA's Six-Subject Study is an international study of six subject areas (science, literature, reading comprehension, English as a foreign language, French as a foreign language, and civic education) in 21 countries between 1966 and 1973. FISS compared the science achievement of approximately 258,000 students of 10-yr-old, 14-yr-old, and final year of secondary school and 50,000 teachers. FISS reported that home factors seemed to be most highly correlated to achievement in science, male students outperformed female students, and a relationship existed between opportunity to learn and science achievement (Comber & Keeves, 1973; Featherstone, 1974; Jacobson & Doran, 1988; Platt, 1974).

SISS involved 23 countries with the purpose of describing and examining the science curricula at the levels of primary and secondary schooling. SISS involved the participation of 262,276 students, 22,755 teachers, and 9582 schools (Postlethwaite & Wiley, 1992). Findings of SISS were similar to those of FISS. Home factors and opportunity to learn were identified as major factors influencing science achievement, and gender differences in science achievement favored boys (Jacobson & Doran, 1988). Neither FISS nor SISS discussed the role of computer technology because computers were not commonplace at that time.

The TIMSS 1995 was the largest and most complex IEA study to date. This study includes mathematics and science at third and fourth grades, seventh and eighth grades, and the final year of secondary school in more than 40 countries (NCES, 1999). TIMSS 1995 researchers examined schools, curricula, instruction, lessons, textbooks, policy issues, and the lives of teachers and students to understand the educational context in which mathematics and science learning take place. For U.S. students, the TIMSS 1995 revealed that they outperformed their peers in other countries at the fourth grade level science, they were near the international average in eighth grade, and were among the lowest in the world in twelfth grade (NCES, 1996, 1997, 1998). From 1998 to 1999, IEA once again sponsored the TIMSS. The TIMSS 1999 involved 38 countries and focused only on eighth-grade science and mathematics achievement. This time, Taiwan and Singapore had the highest average science performance, and the U.S. had the performance above international average (Martin, Mullis & Gonzalez, 2000). Whereas the TIMSS 1995 did not include sufficient information about computer use at school, the TIMSS 1999 provided descriptive information about the number of computers available by eighth-grade students and teachers (Gonzalez & Miles, 2001).

TIMSS 1995 and 1999

The TIMSS 1995 included three target populations: third and fourth graders (population 1), seventh and eighth graders (population 2), and students in the last year of secondary school (population 3) and two subject areas, mathematics and science, with the participation of 41 countries (NCES, 1999). The TIMSS results were released in 1996 and 1997 in a series of reports and complete international database.

Among the 26 participating nations of the TIMSS 1995 in population 1, U.S. fourth-grade students were outperformed by only one country, Korea, in the subject of science (NCES, 1997). Japanese students performed slightly better, but not significantly different from, than their U.S. counterparts. U.S. fourth-grade students were among the top nations in Earth Science; Life Science; and Environmental Issues and the Nature of Science. In Physical Science, U.S. students were outperformed by five other nations. Sixteen percent of U.S. fourth graders were among the top 10% of all fourth graders of participating countries. The number of topics included in U.S. textbooks and curriculum guides was to some extent below the international average in fourth-grade science (NCES, 1997).

In population 2, U.S. eighth-grade students scored above the international average in science (NCES, 1996). Many participating Asian countries were among the top of science performance led by Singapore. U.S. students scored above the international average in Earth Science; Life Science; and Environmental Issues and the Nature of Science. In Chemistry and in Physics, the U.S. students performed at the international average. Thirteen percent of U.S. students were among the top 10% of all participating eighth graders in science achievement. The U.S. eighth-grade science curriculum closely reflected international practices.

At the final year of secondary school (population 3), U.S. twelfth graders scored significantly below the international average and among the lowest of the 21 participating nations in science general knowledge (NCES, 1998). European countries, such as Sweden and Switzerland, were among the top nations with science performance above international average. U.S. students only outperformed South Africa and Cyprus students on science. U.S. students in their final year of secondary school were less likely to be taking science than were their counterparts in other countries. While 53% of graduating students in the U.S. were currently enrolled in science classes, the average in all the countries participating in the general knowledge assessments was 67%. In addition to a general achievement assessment, advanced science (physics) achievement tests were administered to a sample of the top 10-20% of students in each of the 16 nations participating in this part of the TIMSS 1995. U.S. students who had taken or were taking physics or Advanced Placement physics were compared to advanced science students in other nations. The average score of U.S. students in physics was the lowest of the 16 nations in this advanced science achievement comparison.

The TIMSS 1995 also investigated the mathematics and science curricula of the participating countries through analyses of curriculum guides, textbooks, and other curricular materials. In addition, the TIMSS 1995 analyzed eighth-grade mathematics classroom videotapes from several participating countries (Stigler, Gonzales, Kawanaka, Knoll, & Serrano, 1999). The videotape study found that U.S. eighth-grade mathematics teachers' goal was to teach students how to do something, whereas Japanese teachers' goal was to help students learn how to do something and to understand mathematical concepts. The U.S. eighth-grade mathematics curriculum was less focused and less advanced relative to Germany and Japan.

The TIMSS 1999 is a replication of the TIMSS 1995 at the lower-secondary or middle school level – the eighth grade in most countries. Of the 38 countries taking part in 1999, 19 had also participated in 1995 at fourth grade. The results of the TIMSS 1999 science achievement revealed substantial differences between the high- and low-performing countries, from an average of 569 for Chinese Taipei (Taiwan)—who participated in the TIMSS 1999 study for the first time—to 243 for South Africa (Martin, Mullis & Gonzalez, 2000). Countries in Asia were among 4 of 5 top performing countries (Taiwan, Singapore, Japan, and Korea). The U.S. had an average science achievement of 515 at approximately the same level as Hong

Kong, the Russian Federation, Bulgaria, New Zealand, and Latvia. The international average of science achievement was 488 (Table 1).

Of the three countries with a relative decline from fourth to eighth grade in 1995, only the U.S. showed the same relative decline from fourth grade results in 1995 to eighth grade results in 1999 (Martin, Mullis, & Gonzalez, 2000). On average across countries, boys performed better than girls. Regarding specific science content areas, the U.S. performed better than the international average in earth science, life science, chemistry, environmental and resource issues, and scientific inquiry and the nature of science. The U.S. performed at approximately the same level as the international average in chemistry. Chinese Taipei (Taiwan) was ranked from the first to the fourth highest in these content areas. Taiwanese and U.S. boys tended to have higher achievement in these content areas than girls, except girls from Taiwan had higher scores than boys in scientific inquiry and the nature of science.

The TIMSS 1999 research team examined students' responses to the background questionnaire and found the following results related to this study (Martin, Mullis & Gonzalez, 2000). First, students who had all three of selected educational resources, which are a dictionary, a study desk, and a computer, performed better than those who did not have all three. Sixty-three percent of Taiwanese students had a computer at home compared to 80% of the U.S. students. In addition, 89% of Taiwanese students and 96% of U.S. students agreed that it is important to do well in science. Sixty-nine percent of students from Taiwan and 73% of students from the U.S. reported that they "liked" or "liked a lot"

Table 1

Mean Science Achievement Scores of Chinese Taipei, the U.S., and International Average

Country	Mean	Standard Errors of Mean
Chinese Taipei (Taiwan)	569	4.4
United States	515	4.6
International Average	488	0.7

Source: Martin, Mullis & Gonzalez, 2000.

about science. Regarding students' attitude toward science, U.S. students were more likely to have positive attitudes toward science than their Taiwanese peers. About the students' reports on the frequency of computer use in science class, 5% of Taiwanese students reported "almost always" or "pretty often" used a computer, compared to 21% of U.S. students. More U.S. students had a high level of school resources for science—such as computer hardware or software for science instruction, science laboratory equipment and materials, library materials, and audio-visual resources—than did Taiwanese students. Finally, the TIMSS 1999 researchers reported that 90% of Taiwanese schools and 97% of U.S. schools had fewer than 15 students per computer.

Computer Use

Ehrmann (1999) argues that "technologies such as computers (or pencils) don't have predetermined impacts; it's their uses that influence outcomes"(p.32). It is true that computers in and of themselves do very little to aid learning; both teachers and students need to learn how to take advantage of them.

Computers were not popular during the 1980s in schools. Cuban (1986) investigated the history of technology use from 1920 to 1980's and concluded that computers at schools were rare (approximately 30,000) in 1980, but the number increased dramatically afterwards. Becker (1985) reported that, in 1983, only 250,000 computers were found in U.S. schools for instructional purposes. Anderson and Ronnkvist (1999) combined the several research findings from 1983 to 1998 (Anderson, 1993; Becker 1985, 1991) to show the growth of number of instructional computers (Table 2). During this time, the number of instructional computers in elementary and secondary schools in the U.S. has increased by approximately 15% per year. In 1998, the student-computer ratio decreased to approximately six students per computer. Anderson and Ronnkvist (1999) predicted that this pattern of growth is likely to increase in the future because of reduced technology costs and the increased interest and funding for telecommunication.

While students have more computers to use, researchers and educators are concerned about the use and effectiveness of these instructional computers. Anderson and Ronnkvist (1999) examined the 1998 national survey, "Teaching, Learning and Computing," and reported findings pertaining to computer density, computer capability, computer renewal, peripherals, computer location, software, Internet access, and distributions and disparities. According to Anderson and Ronnkvist, the most appropriate indicator of computer density is the student-computer ratio, which is the number of students enrolled divided by the total number of instructional computers available for students and teachers. They also reported that schools are shifting their computers from Macintosh to IBM as the grade level increases. For middle schools, approximately 49% of computers were for Windows with DOS, 39% Macintosh and 8% Apple II. Middle school computers were located mainly in the computer laboratories and classrooms (44% and 40%, respectively), and most computers had Internet access (94%). They feel that, although the rapid connection and computer renewal are impressive, the "digital divide" (p.17) among schools remains and disparities still exist.

A similar study concerning computer use in the classrooms was conducted

Table 2

Total Instructional Computers and Student-Computer Ratio in U.S. K-12 Schools from 1983 to 1998

Year	1983	1985	1989	1992	1995	1998
Total number of instructional computers in 1000's	250	1,000	2,400	3,500	5,400	8,600
Overall student-computer ratio	168	39.1	19.2	13.7	9.2	6.0

Source: Anderson & Ronnkvist, 1999.

by Coley, Cradler, and Engel (1997) to explore school access to technology and student use of computer technology in the U.S. Their results are similar to what Anderson and Ronnkvist (1999) reported. The number of students per computer ranged from 5.9 in Florida to 16 in Louisiana. Among eleventh graders, writing stories and papers was the most frequent computer use at home and school. Among fourth and eighth graders, playing games (presumably at home) was the prevalent computer use. Nine percent of fourth graders, 10% of eighth graders, and 19% of twelfth graders reported they used a computer for schoolwork almost every day. While 60% of fourth graders, 51% of eighth graders, and 37% of twelfth graders reported that they never used a computer for schoolwork.

Rocheleau (1995) studied the patterns of computer use based on analysis of data from the Longitudinal Study of American Youth. Variables potentially influencing student computer use were investigated, including parental background variables, parental attitudinal and interest variables, student-related variables, computer use variables, and educational outcome variables. Rocheleau (1995) found that 1) students with a computer at home reported better overall grades and also better grades in English and mathematics; 2) more frequent computer users excelled consistently in various academic areas in overall grades, English, mathematics, and scientific knowledge, and they were more satisfied with themselves; 3) according to the parents, students spent a large and growing portion of their computer usage time for educational purposes; and 4) males were significantly more likely to use computers than females. They concluded that computer ownership and parents interest had the greatest influence on the use of computers by students.

Although computers are popular at school, a survey by Huinker (1996) revealed that these computers were not properly used. Elementary teachers in an urban school district participated in the survey about the status of mathematics and science teaching regarding instructional and assessment practices, adequacy of resources, and perceptions toward teaching mathematics and sciences. Approximately half of the elementary teachers reported having access to computers in their classrooms. Computers were reported to be used frequently by 64% of mathematics teachers, but were rarely or even not used for teaching science.

Research on computer use in Taiwan is seldom found due to low availability of Taiwanese journals and of the late implementation of computers in Taiwanese schools. Wei (1993) cited Wu (1987) and explained that computer-assisted instruction (CAI) in Taiwan was at its tenth year, while it had been in the U.S. for over 30 years.

To determine the use of computers in Taiwan, Wei (1993) conducted a survey for senior high schools. A total of 118 of 382 schools participated in the survey, including 15 boys-only, 37 girls-only, and 66 coeducational schools. He found that all responding schools had at least one computer, and coeducational schools had more computers than boys-only or girls-only schools. Most computers in the schools were IBM compatibles, and only two schools had some Macintosh. This trend reflects the Taiwan computer industry as producers of IBM-compatibles; therefore, these computers are cheaper than Macintosh computers to purchase. At that time, the average student-computer ratio in Taiwan was 40:1, which was higher than the 30:1 ratio for the U.S. as reported by Becker (1986). Therefore, it is inferred that computer availability was lower in Taiwan than in the U.S. when Wei surveyed the schools a decade ago.

Wei's study (1993) provided substantial information regarding computers in Taiwanese schools. Wei reported that all of the schools arranged most computers in a laboratory room for easy management and maintenance. These computers were primarily used for computer classes, including computer literacy, programming (mostly BASIC), or Computer Clubs. More than half of the Taiwanese teachers used computers as tools. Science teachers reported using computers more frequently than artistic/technical teachers and math teachers. Compared to these three subject areas, fewer English, Chinese, and social studies teachers used computers as tools.

Computer Use and Students' Achievement

The public supports the reform effort on putting computers in the classroom (American School Board Journal [ASBJ], 1997). Approximately 81% of the public believes that placing a computer in every classroom would improve student achievement. Therefore, by increasing the number of computers in the schools or classrooms, student achievement would be improved. However, is computer technology effective?

Various meta-analytic comparisons of the effectiveness of computer technology on student achievement have shown promising results of technology intervention. Glass, McGaw and Smith's definition (1981) of a meta-analysis is a secondary statistical re-analysis of prior research that provides answers to new questions through the manipulation of previously collected data. Effect size (ES) is calculated through the meta-analysis procedure in standard deviation units, indicating the degree of overlap between control and experimental groups. One common measure of effect size is the statistical difference in mean standard deviation units. According to Cohen (cited in Christmann, Lucking and Badgett, 1997), the ES between 0.200 and 0.499 means small effect, ES = 0.500 to 0.799 is medium effect, and ES = 0.800 and above is large effect.

The amount of research on the effectiveness of computers has increased while more computers are incorporated into the classrooms and schools. However, results of these studies are varied. Kulik (1994) used a meta-analysis to examine over 500 individual studies regarding the effectiveness of computer-based instruction. He reported that students usually learn more in less instructional time in classes which they receive computer-based instruction. In addition, students had more positive attitudes toward computers and toward the classes. Kulik's study was criticized as emphasizing drill-and-practice type of instructions (Coley, Cradler, & Engel, 1997). Subsequently, the Software Publishers Association commissioned an independent consulting firm to prepare another meta-analysis on the effectiveness of technology in schools (Sivin-Kachala & Bialo, 1994). Their study concluded that educational technology could improve student achievement, attitudes, and interactions with teachers and others.

Wenglinsky (1998) used data from the 1996 National Assessment of Educational Progress in mathematics to study the relationship between different uses of educational technology and various educational outcomes. The sample included 6,277 fourth graders and 7,146 eighth graders. For eighth graders, the frequency of home computer use was positively related to academic achievement and the social context/environment of the school; the frequency of school computer use was unrelated to the social context of the school and negatively related to academic achievement. For fourth graders, using computers for learning games was positively related to academic achievement and the social context of the school; the frequencies of home and school computer use were negatively related to academic achievement and the social context of the school. Wenglinsky concluded that computers do have an impact on student learning, but computers are not cure-alls for the problems facing schools.

An earlier study of meta-analysis on the effectiveness of computer-based education (Kulik & Kulik, 1986) reported that computer-based instruction had a positive impact on students in higher education. Conducted specifically for elementary school settings, Ryan's (1991) meta-analytic study about the effect of microcomputer application on achievement analyzed data from 40 independent documents. The mean effect size was 0.309 with a small achievement effect of microcomputer on achievement. Ryan explained this effect size indicated that the effect of the treatment (computer instruction) is approximately one-third greater than the effect of traditional instruction. Additionally, 0.309 can be interpreted as one third greater than the expected gain in a school year, or approximately three months additional gain in terms of grade-equivalent units—a grade-equivalent unit is explained as, in each of the 10 school months, an average student is expected to gain 0.1 grade-equivalent units.

More recently, Christmann and his colleagues (1997a) examined 27 studies regarding the effectiveness of computer-assisted instruction from grade 6-12. They reported a mean ES of 0.209. This indicates that on average computer-assisted instructions had a positive effect on students' achievement. The mean ES of CAI on science students' achievement was the largest ES (0.639) in their study; however, negative mean ES occurred with English (-0.420) students' academic achievement in comparisons between the effects of CAI and traditional instruction. Based on the results, they concluded that an average science student exposed to CAI attained achievement greater than that of 73.9% of those science students exposed to traditional instruction.

Christmann, Badgett and Lucking (1997b) examined the effect of CAI on the academic achievement of secondary students. Their meta-analysis revealed a mean effect size of 0.187, and they reported that students receiving traditional instruction supplemented with CAI had higher achievement than did 57.2% of those receiving traditional instruction only. The results indicated a declining pattern on the effect of CAI for academic achievement. They explained that this pattern is a result of extensive exposure of computers both at home and at school, which might lead the students to be less excitied than those students who previously experienced the novelty of working with mainframe-based software before the influx of microcomputers.

Christmann, Lucking and Badgett (1997) also investigate the effectiveness of CAI in urban, suburban, and rural settings. They used the data from the Christmann, Badgett, and Lucking (1997b) study and found a mean effect size of

0.172. The ES for urban studies was 0.388, 0.137 for suburban studies, and 0.077 for rural studies. These mean effect sizes were fairly small, but indicated that CAI was most effective in urban areas, followed by suburban areas, and then by rural areas.

Using K-12 grade levels, Liao (1998) conducted a meta-analysis on the effect of hypermedia on students' achievement. Data from 35 studies published from 1986 to 1997 were transformed to ES and reported the mean ES was 0.48. This indicates that hypermedia has a moderate effect on students' achievement as compared to traditional instruction.

According to the explanation using grade-equivalent units, some of the meta-analysis studies reviewed above indicated that CAI had a large effect on science achievement (Christmann, Badgett, & Lucking, 1997a). CAI may also have an effect on urban area students (Christmann, Lucking and Badgett, 1997) or on general academic achievement (Liao, 1998).

Christmann and Badgett (1999) conducted a meta-analysis from 11 studies concerning the effect of CAI in four science content areas: physics, general science, biology and chemistry, and three educational settings: urban, suburban, and rural. The overall effect size (ES) was 0.266, which is a small effect. The ES was 0.280 for physics, ES = 0.707 for general science, ES = 0.042 for biology, and ES = 0.085 for chemistry. Similar to the result of Christmann, Lucking and Badgett (1997), Christmann and Badgett (1999) reported a highest ES (0.685) in an urban setting, 0.273 for a suburban area, and 0.156 for rural areas. Christmann and Badgett concluded that microcomputer simulations enable students to learn science through their actual experiences rather than through traditional lectures, and hence improved students' achievement in science.

Alspaugh (1999) investigated the effect of number of computer resources at public school districts on students' academic achievement. The number of computer resources was expressed as the number of students per computer. Tjos was found to have no effect on students' achievement in reading, mathematics, science, or social studies on a state-wide test. However, because of the sampling procedure, the school districts selected in the Alspaugh's study were all small, rural districts. Christmann, Lucking and Badgett's findings (1997) regarding the little effect of CAI on rural areas may be able to explain the non-effectiveness of computer resources. A similar study, using the same school districts as Alspaugh (1999), was conducted by Wen, Barrow, and Alspaugh (2002). They reported that both general computer availability in schools and Internet-connected computer availability in schools had a positive impact on students' science achievement scores on a state-wide test.

Other studies about the positive effect of computer-assisted instruction on achievement were reported by Dixon (1997), Lu, Voss, and Kleinsmith (1997), and Yalçinalp, Geban, and Özkan (1995). Although there are some contradicting findings by Liu, Macmillan, and Timmons (1998) and Morrell (1992), this may be a function of rural school settings since most research shows a positive effect of computer technology on students' academic achievement.

Coley, Cradler, and Engel (1997) reported on the status of computers in the classrooms and concluded that educational technology might improve students' achievement and attitude. However, they also warned

> Technology is not the only component of an instructional activity. Assessments of the impact of technology are really assessments of instruction enabled by technology, and the outcomes are highly dependent on the quality of the implementation of the instructional design. …There are also a host of methodological issues to confront. First, standardized achievement tests may not measure the types of changes in students that educational technology reformers are looking for. …There is also a need to include outcome measures that go beyond student achievement, because student achievement may be affected by students' attitudes about themselves, school, and learning, and by the types of interactions that go on in schools. In addition, technological changes are likely to be nonlinear, and may show effects not only on student learning, but also on the curricula, the nature of instruction, the school culture, and the fundamental ways that teachers do their jobs. (p. 38)

The points made by Coley and colleagues should be considered when conducting research on the effect of computer technology on academic outcomes, and researchers should be cautious when they interpret the data and discuss their findings.

Summary

An introduction to the findings from the TIMSS 1995 and 1999 associated with science achievement in eighth grade was followed by a summary of the history and current status of computer use in the U.S. Results of relevant literature concerning the effect of computer use on students' achievement in general and achievement in science were reviewed.

CHAPTER THREE

METHODS AND PROCEDURES

Introduction

In this chapter, research questions and hypotheses are presented. The collection of data procedure is explained, including the description of the background of the TIMSS 1999 study, description of the population and sample, test instrument, and questionnaires. In addition, the independent variables, dependent variables, and the statistical procedures used to analyze the data are presented.

Research Questions and Hypotheses

In the TIMSS 1999 science report, Martin, Mullis and Gonzalez (2000) reported that Taiwanese students scored significantly higher than U.S. students. Therefore, the difference in students' science achievement scores between Taiwan and the U.S. was not included in the research questions. The research questions and hypotheses of the study were:

1. Is there a difference in eighth-grade students' science achievement scores for students with different levels of computer availability at school?

   Ho_1: There is no statistically significant difference between the mean eighth-grade students' science achievement scores for the four levels of computer availability at school.

2. Is there a difference in eighth-grade students' science achievement for students with different levels of computer availability at home?

Ho_2: There is no statistically significant difference among eighth-grade students' mean science achievement score for the two levels of computer availability at home.

3. Is there an interaction between students' nationality and levels of computer availability at school in their influence on the mean eighth-grade students' science achievement scores?

   Ho_3: There is no statistically significant interaction between students' nationality and levels of computer availability at school in their influence on the mean eighth-grade students' science achievement scores.

4. Is there an interaction between students' nationality and levels of computer availability at home in their influence on the mean eighth-grade students' science achievement scores?

   Ho_4: There is no statistically significant interaction between students' nationality and levels of computer availability at home in their influence on the mean eighth-grade students' science achievement scores.

5. Is there an interaction between students' levels of computer availability at school and levels of computer availability at home in their influence on the mean eighth-grade students' science achievement scores?

   Ho_5: There is no statistically significant interaction between students' levels of computer availability at school and levels of computer availability at home in their influence on the mean eighth-grade students' science achievement scores.

6. Is there an interaction among students' nationality, levels of computer availability at school, and levels of computer availability at home in their

influence on eighth-grade students' mean science achievement score?

Ho_6: There is no statistically significant interaction among students' nationality, levels of computer availability at school and levels of computer availability at home in their influence on eighth graders' mean science achievement score.

Collection of Data

Data were gathered from the database of the TIMSS 1999, which were obtained from Gonzalez and Miles (2001). Achievement and school background data of students in Taiwan and in the U.S. were selected from the database. The complete database released from the TIMSS 1995 and the TIMSS 1999 can be downloaded from the website www.timss.org.

Description of Population and Sample

The target populations of the TIMSS 1999 were students enrolled in the two adjacent grades that contained the largest proportion of thirteen-year-old students at the time of testing, corresponding to seventh- and eighth-grade students for most countries. All participating students in Taiwan and in the U.S. were eighth-grade students.

The samples of this study were drawn from the TIMSS 1999 database. The basic sample design of the TIMSS 1999 is referred to as a two-stage stratified cluster sample design. The first stage consisted of a sample of schools; the second stage consisted of a single classroom selected at random from the target grade in sampled schools. The TIMSS 1995 and 1999 standard for sampling required that all population samples have an effective sample size of at least 400 students for mathematics and science achievement. In addition, at least 150 schools were to be selected from the target population in each country, which results in 95% confidence limits for school-level and classroom-level mean estimates that are precise to within plus or minus 16% of their standard deviations.

The students within each country were selected using probability sampling. This means that the probability of each student being selected as part of the sample is known. The inverse of this selection probability is the sampling weight. According to the *TIMSS 1999 User Guide* (Gonzalez & Miles, 2001), the sampling weights must be used whenever population estimates are required. The user guide provides three types of sampling weights: total weight, senate weight, and house weight. Gonzalez and Miles (2001) recommend that researchers use house weight as the weight variable when they want the actual sample size to be used in performing significance tests. House weight is recommended by Gonzalez and Miles (2001) when the actual sample size to be used in performing significant tests and was used in this study.

Students in participating countries of the TIMSS 1999 completed a set of achievement tests in mathematics and science and responded to student background questionnaire. Mathematics and science teachers of the selected classrooms and principals of the selected schools completed the background questionnaires for their classrooms and schools. In this study, data were gathered from student achievement tests in science, student background questionnaire, and school background questionnaire.

Instrument

The TIMSS 1999 test design is similar to the TIMSS 1995 design (Adams & Gonzalez, 1996). Regarding science achievement tests specifically, each of the Taiwanese and U.S. students participating the TIMSS 1999 completed one of eight booklets in the context of general science, including earth science, life science, physics, chemistry, environmental and resource issues, and scientific inquiry and the nature of science. The TIMSS 1999 achievement test included multiple-choice and free-response items and were scored and coded into the database. The TIMSS 1999 used multiple imputation or "plausible values" methodology to provide estimates of student proficiency in mathematics and science (Gonzalez & Miles, 2001). Because every participating student completed only one of eight booklets of the TIMSS 1999 science achievement tests, the TIMSS 1999 produced five sets of plausible values for each student (variables BSSSCI01-BSSSCI05) to estimate students' proficiency in science. Overall science plausible values for eighth graders were standardized to a mean of 500 and a standard deviation of 100. Only one of the five sets of plausible values was used and it was chosen randomly. Total science achievement scores instead of scores from individual science subject were used in this study for the purpose of examining general science achievement scores from the TIMSS 1999.

Student Background Questionnaire

The TIMSS 1999 involved a student background questionnaire for eighth grade students in the participating countries. The questionnaire required the students to answer questions pertaining to their attitude toward mathematics and science, their academic self-concept, classroom activities, home background, demographic information, and out-of-school activities. Students also answered if they had computers at home, and this item is coded at SQ2-11B.

School Background Questionnaire

Principals of the selected schools completed a school background questionnaire regarding school staffing and resources, mathematics and science course offerings, and support for teachers. The question items included the enrollment number of eighth-grade boys (coded at SCQ2-14A1) and girls (coded at SCQ2-14A2) and number of computers available for eighth graders and their teachers for instructional activities (coded at SCQ2-15C). From the school background questionnaire completed by the principals, the number of students per computer for every participating school in Taiwan and in the U.S. was calculated and four levels were established. The four levels of the number of students per computer were selected to include equal sample size in each level as close as possible. These data were utilized in this study for discussion of the effectiveness of computer availability at school and at home for eighth-grade students' science achievement. In addition, description of school enrollment size, class size, student/teacher ratio, and type of community were gathered from the dataset to present the demographic information of this study.

Data Analysis

Independent Variables

The independent variables are students' nationality (Taiwan and the U.S.), computer availability at school (four levels of number of students per computer—0.0001-1.7115, 1.7116-4.0000, 4.0001-6.0536, and 6.0537 or more students per computer), and computer availability at home (yes/no).

Dependent Variable

The dependent variable, for both analyses of differences of computer availability at school and at home, is eighth-grade students' overall science achievement score as represented in average plausible values.

Statistics Analysis

The TIMSS 1999 database was released with the TIMSS 1999 User Guide (Gonzalez & Miles, 2001). Data for individual country (Taiwan and the U.S.) were selected from the database. The country ID code for this study is one for Taiwan, and two for the U.S.

To assess the effect of computer availability at school, computer availability at home, and nationality on eighth-grade students' science achievement, three-way analysis of variance (ANOVA) was conducted with a Statistical Package for the Social Sciences (SPSS) v.10.0 using the general linear model. Gonzalez and Miles (2001) recommended using a TIMSS-generated SPSS macro for running the student-level analysis. The ANOVA generated by the macro had a R-Squared (R^2) = 0.121 and is close to the R^2 of 0.117 generated by the univariate general linear model in the SPSS menu. Therefore, the general linear model was selected for the statistical analysis in this study.

The database provided five sets of plausible values for overall science scores. One set of these plausible values was randomly chosen for the analysis. The number of students per computer for each participating school in Taiwan and the U.S., which was the measure of computer availability at school, was computed by dividing the enrollment number of eighth-grade students by the number of computers available for eighth graders and their teachers. Approximately 5.3 % of Taiwanese students and 2.8 % of U.S. students were treated as outliers and were deleted from the study based on the distribution of the data. Of all 5,565 participating Taiwanese students, 5,270 of them were selected for this study. In addition, 6,236 out of 6,413 U.S. students were selected. Computer availability at school was categorized into four levels—ranging from 0.001-1.7115 students per computer, 1.7116-4.0000 students per computer, 4.0001-6.0536 students per computer, and 6.0537 and more students per computer—based on criteria that represent the nature of the dataset of Taiwan and the U.S. Computer availability at home was coded one as yes (the student had at least one computer at home) and two as no (the student did not have any computer at home). The ANOVA involved using house weight to weight the achievement scores.

An alpha value ($\alpha = 0.01$) was pre-determined for the statistical analyses in this study due to the large sample size. Omega Squared (ω^2) was calculated for each of the significant main effects to examine the amount of variance that the dependent variable could be associated with a specific independent variable (Myers & Well, 1995). Post-hoc comparisons were performed for significant main effects utilizing Scheffee's contrast for unequal cell sizes (Myers & Well, 1995). Additional follow-up analyses were conducted for significant interactions.

Summary

The purpose of this study was to examine the effect of nationality and computer availability at school and at home on eighth-grade students' science achievement. Analysis of variance was used for statistical analysis. The independent variables were nationality, levels of computer availability at school, and computer availability at home. The dependent variable was the TIMSS 1999 overall science achievement score.

CHAPTER FOUR

RESULTS OF THE STUDY

Introduction

Descriptive information of the sample in this study is presented in this chapter, including student age, gender, types of community and class size of participating schools, and student/teacher ratio. The descriptive statistics and results of main effect and interaction of the three-way ANOVA are reported. Post-hoc comparisons and follow-up analyses for significant interactions are conducted.

Descriptive Statistics

A total of 150 schools in Taiwan and 240 schools in the U.S. participated in the TIMSS 1999. Only 137 schools in Taiwan and 152 schools in the U.S. were selected for this study since they were the only schools that provided information of the number of students per computer.

House weight was used for all statistical analyses in this study. The weighted sample included 5251 Taiwanese students and 6222 U.S. students. The average age for Taiwanese and U.S. students were 14.20 (SD = 0.37) and 14.18 (SD = 0.55) years, respectively (Table 3).

The two samples from two different countries had similar composition in gender (Table 4). Approximately 49.5 % of Taiwanese students were girls and 50.5 % were boys. For U.S. students, 49.1 % of them were girls and 50.9 % were boys.

Table 3

Mean and Standard Deviation of Students Ages in Years in Taiwan and the U.S.

	n	Minimum	Maximum	Mean	SD
Taiwan	5251	10.25	17.00	14.20	0.37
No response	0				
U.S.	6145	9.33	18.25	14.18	0.55
No response	77				

Table 4

Frequencies and Percentage of Students Gender in Taiwan and the U.S.

	n	%
Taiwan		
Girls	2600	49.5
Boys	2651	50.5
U.S.		
Girls	3057	49.1
Boys	3165	50.9

The information on the types of communities of participating schools is presented in Table 5. The TIMSS 1999 classified the four types of community as 1) a geographically isolated area, 2) village or rural (farm) area, 3) on the outskirts of a town/city (suburban), and 4) close to the center of a town/city (urban). Ten point two percent of Taiwanese schools and 17.8 % of U.S. schools were from rural settings. Additionally, 37.2 % of Taiwanese schools and 23 % of U.S. schools located at suburban areas. Approximately 50 % of these selected schools in Taiwan and in the U.S. were from urban communities.

The average eighth-grade class size for the participating schools in Taiwan was 39.01 (SD = 5.07) students per class, and 25.96 (SD = 5.80) students per class in the U.S (Table 6).

The student/teacher ratios of selected schools are displayed in Table 7. The student/teacher ratio of Taiwanese schools ranged from 4.1 to 46.8 with an average of 17.67 (SD = 4.90), as compared to of U.S. schools ranging from 7.6 to 29.4 with an average of 18.01 and standard deviation of 4.57.

Inferential Analysis

The 3-way ANOVA was conducted using the randomly-chosen fifth set of plausible value (BSSSCI05) as the dependent variable. The independent variables were two levels of nationality (Taiwan and the U.S.), four levels of number of students per computer (0.0001-1.7115, 1.7116-4.0000, 4.0001-6.0536, and 6.0537 and greater), and two levels of home computer availability (yes/no). The boundaries of the four levels of number of students per computer were selected for

Table 5

Frequencies and Percentage of Types of Community of Participating Schools in Taiwan and the U.S.

	Taiwan		U.S.	
	n	%	n	%
A geographically isolated area	4	2.9	6	3.9
Village or rural (farm) area	14	10.2	27	17.8
Outskirts of a town/city	51	37.2	35	23.0
Center of a town/city	68	49.6	83	54.6
No response	0	0.0	1	0.7
Total	137	100.0	152	100.0

Note. School sample not weighted.

Table 6

Mean and Standard Deviation of Average Eighth-Grade Class Size of Participating Schools in Taiwan and the U.S.

	n	Minimum	Maximum	Mean	SD
Taiwan	137	23	56	39.01	5.07
No response	0				
U.S.	151	9	60	25.96	5.80
No response	1				

Table 7

Mean and Standard Deviation of Student/Teacher Ratio in Participating Schools in Taiwan and the U.S.

	n	Minimum	Maximum	Mean	SD
Taiwan	132	4.1	46.8	17.67	4.90
No response	5				
U.S.	135	7.6	29.4	18.01	4.57
No response	17				

similar sample size in each group in the analysis. The sample was weighted using house weight to represent the whole population. The descriptive statistics of analysis are presented in Table 8. Sample size, mean and standard deviation of each individual cell are included. The mean science score for Taiwanese students was 565.95 (SD = 91.72), which was higher than the mean score for U.S. students of 523.86 (SD = 96.76). Students with the highest computer availability at school (0.0001-1.7115 students per computer) had the highest science score among the four levels (mean = 552.51; SD = 91.74). The average science score for the students who had a computer at home was 553.50 (SD = 93.73), and was higher than the average score of 510.94 (SD = 98.47) for students without a computer at home.

Results from the 3-way ANOVA are shown in Table 9. The between-subject effects for nationality (N), number of students per computer (S), and home computer availability (H) were all statistically significant at the 0.01 level. Two of the three first-order interactions (N × S, and S × N) were both statistically significant at the 0.01, level. The second-order interaction (N × S × H) was not statistically significant at 0.01 the level. The R^2 value for the ANOVA was 0.119, and the adjusted R^2 was 0.117. The interaction between nationality and computer availability at school (N × S) is graphed in Figure 1. Interaction between computer availability at school and computer availability at home (S × H) is graphed in Figure 2.

Omega Squared was calculated for the independent variables. Omega Squared revealed that 5.8 % of the variance in the mean science achievement scores

Table 8

Mean and Standard Deviation of Computer Availability in Taiwan and the U.S.

	Computer Availability at School (Number of Students per Computer)														
	0.0001-1.7115			1.7116-4.0000			4.0001-6.0536			6.0537 and greater			Total		
	n	M	SD	n	M	SD	n	M	SD	n	M	SD	n	M	SD
Taiwan															
HC[a]	882	589.97	80.09	448	570.25	89.39	717	596.44	87.47	1245	576.42	89.17	3292	583.57	86.97
NHC[b]	416	549.08	85.52	298	528.99	89.69	427	530.20	90.79	815	535.62	95.83	1956	536.29	91.90
Total	1298	576.87	84.03	746	553.77	91.70	1144	571.72	94.30	2060	560.28	93.98	5248	565.95	91.72
U.S.															
HC[a]	1256	539.85	89.55	2628	543.79	90.25	890	532.90	99.62	814	506.80	94.25	5588	535.78	93.06
NHC[b]	237	486.19	97.50	482	472.86	96.48	231	465.11	97.09	367	470.72	92.70	1317	473.30	95.85
Total	1493	531.33	92.92	3110	532.79	94.77	1121	518.93	102.79	1181	495.59	95.21	6905	523.86	96.76

[a]HC: Students had a computer at home. [b]NHC: Students had no computer at home.

Table 8 (Continued)

Mean and Standard Deviation of Computer Availability in Taiwan and the U.S.

	Computer Availability at School (Number of Students per Computer)														
	0.0001-1.7115			1.7116-4.0000			4.0001-6.0536			6.0537 and greater			Total		
	n	M	SD	n	M	SD	n	M	SD	n	M	SD	n	M	SD
Total															
HC[a]	2138	560.53	89.24	3076	547.64	90.60	1607	561.25	99.51	2059	548.90	97.34	8880	553.50	93.73
NHC[b]	653	526.25	94.93	780	494.30	97.77	658	507.35	98.04	1182	515.46	99.47	3273	510.94	98.47
Total	2791	552.51	91.74	3856	536.85	94.54	2265	545.59	102.04	3241	536.71	99.42	12153	542.04	96.88

[a]HC: Students had a computer at home. [b]NHC: Students had no computer at home.

Table 9

Three-Way Analysis of Variance for Computer Availability at School and at Home in Taiwan and the U.S.

Source	SS	df	MS	F
Between				
Nationality (N)	6624998.00	1	6624998.00	799.71*
Number of students per computer (S)	396922.35	3	132307.45	15.97*
Home computer (H)	5490900.12	1	5490900.12	662.82*
N × S	214467.72	3	71489.24	8.63*
N × H	48517.14	1	48517.14	5.86
S × H	236164.30	3	78721.44	9.50*
N × S × H	92281.97	3	30760.66	3.71
S/N × S × H (Within)	100545386.74	12137	8284.20	
Total	114066497.81	12152		

Note. Adjusted $R^2 = 0.117$.

*$p < 0.01$.

Figure 1. Interaction between Nationality and Computer Availability at School

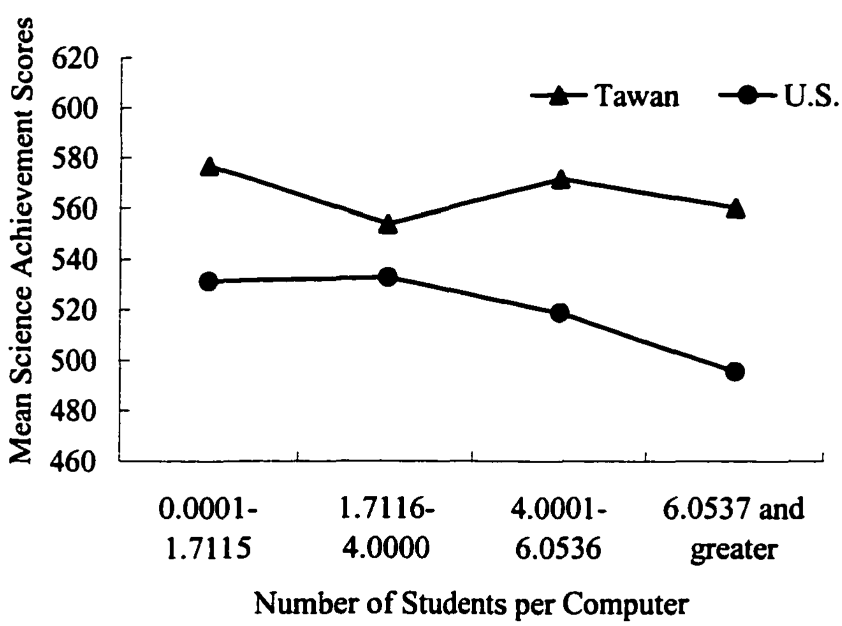
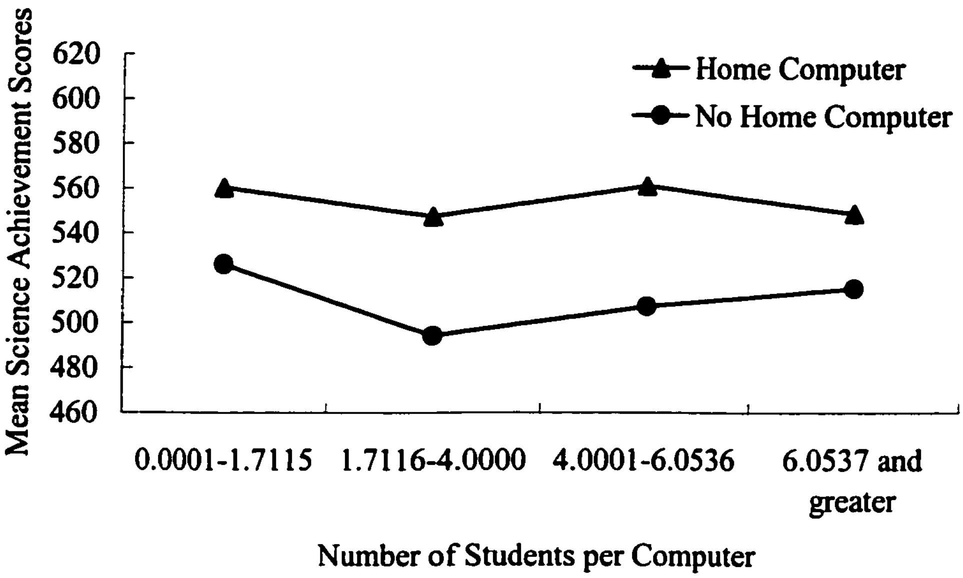


Figure 2. Interaction between Computer Availability at School and at Home



could be associated with nationality, 0.3 % associated with the four levels of number of students per computer, and 4.8 % associated with home computer availability.

Post-Hoc Comparisons for Main Effects

Nationality and home computer availability both only had two levels and therefore, do not require a post-hoc analysis. A post-hoc analysis for the four levels of the number of students per computer was applied (Table 10). Due to unequal sample sizes in each cell, Scheffee's test was used (Table 8). Scheffee's post-hoc comparison revealed significant difference at the 0.01 level between group 1 and 2, 1 and 4, 2 and 3, and, 3 and 4.

Follow-Ups for Interactions

There were two statistically significant first-order interactions for the 3-way ANOVA (N × S and S × H) at the 0.01 level. Follow-up for the interaction between nationality and number of students per computer (N × S) included a one-way ANOVA for each of the two nations. For Taiwanese students, there were significant differences for the mean science achievement scores among the four levels of computer availability at school at the 0.01 level with R^2 equaled to 0.01 (Table 11). Omega Squared revealed that 0.8 % of the variance in the mean science achievement scores was associated with the levels of computer availability at school in Taiwan. Scheffee's post-hoc comparison (Table 12) revealed statistically significant differences between group 1 and 2, 1 and 4, 2 and 3, and, 3 and 4 at the 0.01 level. For U.S. students, there were statistically significant differences for the mean science achievement scores among the four levels of computer availability at

Table 10

Scheffee's Post-Hoc Comparison for the Number of Students per Computer

Number of students/computer	0.0001-1.7115	1.7116-4.0000	4.0001-6.0536	6.0537 and greater
0.0001-1.7115		15.65*	6.92	15.80*
1.7116-4.0000			-8.74*	0.15
4.0001-6.0536				8.89*
6.0537 and greater				

*p < 0.01.

Table 11

One-Way Analysis of Variance for Computer Availability at School in Taiwan

Source	SS	df	MS	F
Between				
Number of students per computer (S)	369569.48	3	176715.19	14.76*
S/S (Within)	43775367.72	5244	8347.71	
Total	44144937.20	5247		

Note. Adjusted $R^2 = 0.008$.

*$p < 0.01$.

Table 12

Scheffee's Post-Hoc Comparison for the Number of Students per Computer in Taiwan

Number of students/computer	0.0001-1.7115	1.7116-4.0000	4.0001-6.0536	6.0537 and greater
0.0001-1.7115		23.09*	5.15	16.59*
1.7116-4.0000			-17.95*	-6.51
4.0001-6.0536				11.44*
6.0537 and greater				

*p < 0.01.

school at the 0.01 level with $R^2 = 0.02$ (Table 13). Omega Squared indicated that 2.0 % of the variance in the mean science achievement scores was related to the levels of computer availability at school in the U.S. To examine the differences among the means, Scheffee's post-hoc comparison was conducted (Table 14) and revealed significant differences between group 1 and 4, 2 and 3, 2 and 4, and 3 and 4.

For the second significant interaction between school computer availability and home computer availability (S × H), two separate one-way ANOVA were conducted for students with a computer at home and students with no computer at home. For the students who had a computer at home, there was a statistically significant difference in the mean science achievement scores among the four levels of computer availability at school at the 0.01 level (Table 15). Omega Squared showed that 0.4 % of the variance in the mean science achievement scores for students with a computer at home could be associated with the computer availability at school. A Scheffee's post-hoc comparison in Table 16 revealed statistically significant differences in mean science achievement scores for students with a computer at home between group 1 and 2, 1 and 4, 2 and 3, and 3 and 4. The results from the one-way ANOVA for computer availability at school for students with no computer at home are presented at Table 17. The statistical analysis showed a significant difference in mean science achievement scores for students with no computer at home among the four levels of computer availability at 0.01 level. Omega Squared was calculated showing that 1.2 % of the variance in mean science achievement scores for students with no computer at home could be related to the computer

Table 13

One-Way Analysis of Variance for Computer Availability at School in the U.S.

Source	SS	df	MS	F
Between				
Number of students per computer (S)	1302921.70	3	434307.23	47.32*
S/S (Within)	63337117.16	6901	9177.96	
Total	64640038.86	6904		

Note. Adjusted $R^2 = 0.020$.

*$p < 0.01$.

Table 14

Scheffee's Post-Hoc Comparison for the Number of Students per Computer in the U.S.

Number of students/computer	0.0001-1.7115	1.7116-4.0000	4.0001-6.0536	6.0537 and greater
0.0001-1.7115		-1.46	12.40	35.74*
1.7116-4.0000			13.87*	37.21*
4.0001-6.0536				23.34*
6.0537 and greater				

*$p < 0.01$.

Table 15

One-Way Analysis of Variance for Computer Availability at School for Students with a Computer at Home

Source	SS	df	MS	F
Between				
Number of students per computer (N)	351186.87	3	117062.29	13.38*
S/N (Within)	77659792.34	8876	8749.41	
Total	78010979.22	8879		

Note. Adjusted $R^2 = 0.004$.

*$p < 0.01$.

Table 16

Scheffee's Post-Hoc Comparison for the Number of Students per Computer for Students with a Computer at Home

Number of students/computer	0.0001-1.7115	1.7116-4.0000	4.0001-6.0536	6.0537 and greater
0.0001-1.7115		12.88*	-0.72	11.63*
1.7116-4.0000			-13.61*	-1.26
4.0001-6.0536				12.35*
6.0537 and greater				

*$p < 0.01$.

Table 17

One-Way Analysis of Variance for Computer Availability at School for Students with No Computer at Home

Source	SS	df	MS	F
Between				
Number of students per computer (N)	401623.91	3	133874.64	13.97*
S/N (Within)	31323082.15	3269	9581.854	
Total	31724706.06	3272		

Note. Adjusted $R^2 = 0.012$.

*$p < 0.01$.

availability at school. Scheffee's post-hoc comparison showed statistically significant differences between group 1 and 2, 1 and 3, and, 2 and 4 (Table 18).

Summary

In this chapter, descriptive statistics of the analysis was first presented. Results of the three-way ANOVA showed statistically significant differences in the mean science achievement scores for each of the three independent variables at the 0.01 level. Post-hoc comparisons for the significant main effects were conducted and the results were discussed. There were two significant first-order interactions in the three-way ANOVA, and the interactions were graphed. Follow-ups analyses for the interactions were presented accordingly.

Table 18

Scheffee's Post-Hoc Comparison for the Number of Students per Computer for Students with No Computer at Home

Number of students/computer	0.0001-1.7115	1.7116-4.0000	4.0001-6.0536	6.0537 and greater
0.0001-1.7115		31.95*	18.90*	10.79
1.7116-4.0000			-13.05	-21.16*
4.0001-6.0536				-8.11
6.0537 and greater				

*p < 0.01.

CHAPTER FIVE

SUMMARY, FINDINGS, DISCUSSION, AND RECOMMENDATIONS

Introduction

In this chapter, a summary of the study is first reviewed. The findings from this study are presented next. Discussion regarding the findings of this study and comparisons to other research are included. A list of recommendations for future study is stated. Finally, the chapter is summarized.

Summary of the Study

The data set used in this study was gathered from the TIMSS 1999 (Gonzalez & Miles, 2001). TIMSS studies were conducted by IEA and are the most comprehensive and largest scale of international study ever. The TIMSS 1995 examined the mathematics and science education in 4, 8, and 12 grades, while the TIMSS 1999 only focused on eighth graders. TIMSS provides information of students' achievement in math and science, students' background information, math and science teachers' background information, and school background information from principals. The TIMSS 1995 revealed that fourth-grade U.S. students outperformed most other countries in science, eighth-grade students scored above the international average, and grade 12 students were among the countries with lowest performance (NCES, 1996, 1997, 1998). The TIMSS 1995 also showed that many of the top-ten countries were Asian countries.

The TIMSS 1999 included some countries who participated in 1995 and others participated TIMSS for the first time, for example, Chinese Taipei (Taiwan). Taiwanese students scored the highest among the 38 participating countries in science, and U.S. students performed above the international level, which showed similar level of performance in the TIMSS 1995. The TIMSS 1999 reported that students who had more educational resources at home performed better than those who had fewer resources; 63% of Taiwanese and 80 % of U.S. students had a computer at home; 5 % of Taiwanese students and 21 % of U.S. students reported using computers frequently in science class; 90% of Taiwanese schools and 97% of U.S. schools had a student-computer ratio of less than 15 (Martin, Mullis & Gonzalez, 2000).

The number of computers in the classroom has increased tremendously over the last two decades (Anderson & Ronnkvist, 1999). However, students do not use computers regularly for schoolwork at home. Coley, Cradler, and Engel (1997) reported that less than 20 % of students used a computer for homework everyday, and approximately half of the students had never used a computer for homework. Teachers were also found not to be using computers. Huinker (1996) reported that elementary teachers seldom used computers for science classes.

The effectiveness of computers on student learning has been the focus of many research studies. Computer technology and CAI does improve student learning in various ways. Meta-analyses from Christmann and the colleagues (1997a; 1997b), Kulik and Kulik (1986), and Liao (1998) revealed that CAI has an effect on student academic achievement, especially science. Kulik (1994) found that students would learn more if they received CAI. Sivin-Kachala and Bialo (1994) reported that computer technology improved student learning and motivation, and increased student interactions with teachers and their peers.

Although researchers have reported a positive impact of computer technology on student's learning, only a few of the studies centered on the use of computer technology quantitatively in the classroom (Anderson & Ronnkvist, 1999; Coley, Cradler, & Engel, 1997). In addition, few studies have examined the effect of the quantity of computer on student learning (Alspaugh, 1999; Wen, Barrow, & Alspaugh, 2002). Furthermore, Wenglinsky (1998) reported that home computer availability might be one of the factors effecting students' achievement.

Utilizing the dataset of the TIMSS 1999, this study investigated the role of nationality (Taiwan versus the U.S.), computer availability at school, and computer availability at home on eighth-grade students' science achievement. The two countries were selected because of the interests in comparing the U.S. with one of the highest achieving country in the science portion of the TIMSS 1999. Computer availability at school was calculated by dividing the number of total eighth-grade enrollment of a participating school by the total number of computers available for eighth-grade students and teachers. It was later grouped into four categories ranging from 0.001-1.7115, 1.7116-4.0000, 4.0001-6.0536, and 6.0537 and more students per computer. Computer availability at home included students with a computer at home, and students with no computer at home.

A 3-way ANOVA was conducted and weighted by the factor house weight as recommended in the *TIMSS 1999 User Guide* (Gonzalez & Miles, 2001). The three independent variables were nationality, computer availability at school, and computer availability at home. The dependent variable was the randomly-chosen fifth-set of the plausible values, which was a representation of the overall science achievement score for the TIMSS 1999. Post-hoc comparisons were conducted for significant main effects, and follow-up analyses were included for significant interactions.

The schools involved in this study were selected from the original dataset because they provided sufficient information for the study. One hundred and thirty-seven Taiwanese schools and 152 U.S. schools were included, and the weighted sample was comprised of 5251 Taiwanese students and 6222 U.S. students. Descriptive statistics showed that the average age of the students was 14.20 (SD = 0.37) for Taiwan, which is similar to 14.18 (SD = 0.55) for the U.S. For both populations, the sample included approximately 50 % girls and 50 % boys. Schools of the two populations had similar composition in terms of geographic community as well. Approximately half of the schools were located at the center of a city, and less than 4 % of the schools were at a geographically isolated area. The samples from Taiwan and the U.S. had a statistically significant difference in terms of class size. Taiwanese schools tended to have a larger class size than U.S. schools. The average class size of the participating Taiwanese schools was 39.01 (SD = 5.07), and 25.96 (SD = 5.80) for U.S. schools.

Summary of Findings

Due to the large sample size of this study, the statistical significant level was set to be 0.01. Based on the findings above, statistical differences in mean science achievement scores were found between Taiwan and the U.S., among the four levels of computer availability at school, and between students with or without a computer at home. Interactions between 1) nationality and school computer availability and 2) school computer availability and home computer availability were both significant at the 0.01 level. The interactions were statistically significant because of the large sample size, but were not educationally/practically significant.

Discussion

There were six research questions and hypotheses involved in this study. The research question, which was intentionally omitted from this study, concerned the difference in the mean science achievement score between Taiwanese and U.S. students and was previously answered by Gonzalez and Miles (2001). The 3-way ANOVA confirmed their findings that, in the TIMSS 1999, Taiwanese students performed significantly higher than U.S. students in overall science ($p < 0.01$). The average score for Taiwanese students was 565.95 (SD = 91.72), and was 523.86 (SD = 96.76) for U.S. students. Omega Squared revealed that 5.8 % of the variance in the mean science achievement scores could be associated with nationality. There was a practical/educational difference in students' science achievement scores between Taiwan and the U.S. although the Omega Squared value was small.

At the eighth-grade level, the TIMSS 1995 (NCES, 1996) and the TIMSS 1999 (Martin, Mullis, & Gonzalez, 2000) both reported that Asian countries were among the high-performing countries. U.S. eighth-graders performed at the international average level in the TIMSS 1995 and above the average in the TIMSS 1999. This study could not answer why Taiwanese students performed much better than the remainder of the participating countries, but presumably, the difference of educational system between Asian countries and other countries is one of the factors.

The first research question in this study concerned the difference in the mean science achievement for the four levels of computer availability at school. The results revealed that there was a difference across the four levels, but a post-hoc analysis using a Scheffee's comparison revealed a non-linear pattern as the number of students per computer increased. Nevertheless, Omega Squared indicated only 0.3 % of variance in the mean science achievement score was associated with the four levels of number of students per computer. Therefore, the significance among the four levels was not due to the difference in computer availability at school, but the large sample size of the study. The results are not in agreement with the study by Alspaugh (1999). Alspaugh reported that no difference among the four levels of computer availability at school in terms of student achievement. However, schools participating in Alspaugh's study were relatively small; therefore, the samples were different from a large-scale sample like TIMSS. Additionally, the small Omega Squared value showed that the difference reported in this study may be due to large sample size. Although previous research studies (Coley, Cradler, & Engel, 1997;

Kulik, 1994; Wenglinsky, 1998) reported that CAI has an effect on students' achievement, results from this study revealed no effect of quantity of school computers on achievement. Furthermore, Wenglinsky (1998) reported that the frequency of school computer use was negatively related to eighth-grade students' academic achievement. The effect of school computer availability on students' science achievement still needs more investigation before making conclusions.

The Scheffee's comparison revealed that group 1 with least number of students per computer had a higher mean science achievement score than group 2 (1.7116-4.0000 students per computer) and group 4 (6.0537 and more students per computer), but was not different from group 3 (4.0001-6.0536 students per computer). Group 2 students' science achievement was lower than group 3 students, but not different from group 4. The Scheffee's comparison basically illustrated that group 1 and 3 were statistically the same in terms of science achievement scores, and statistically higher than group 2 and 4, which were statistically the same as well. This result was not expected because there seemed to be no pattern in describing science achievement by computer availability at school overall. Because of the small Omega Squared value, the statistically significant difference among groups was simply due to the large sample size. This point is illustrated further in the later section discussing the interaction between nationality and computer availability at school.

This study found a statistically significant difference in science achievement for the two levels of computer availability at home. The Omega Squared revealed that 4.8 % of variance in the mean science achievement scores could be related to home computer availability. Computer availability at home certainly played an important role in students' science achievement. Previous research has shown that home computer availability would effect students' achievement (Martin, Mullis & Gonzalez, 2000; Rocheleau, 1995). Wenglinsky (1998) reported that the frequency of home computer use was positively related to eighth-grade students' achievement. In conclusion, home computer availability is positively related to and has an effect on students' achievement at school. However, in this study, because there is no single factor determining the socio-economical status (SES) that could be used, one cannot rule out the effect of SES on students' performance. It is true that home background affects students' achievement (Martin, Mullis, Gregory, et al. 2000), hence, conclusions were unable to be drawn as how having a computer at home, with the effect of SES removed, would impact students' science achievement.

Regarding the interaction between nationality and computer availability at school, the patterns of the mean of students' science achievement score in computer availability at school differed from Taiwan to the U.S. Taiwanese students showed a more unstable pattern and fluctuated from one group to another. U.S. students, however, showed a steady pattern that, as the number of students per computer increased, students' achievement scores decreased. Although it revealed a slight increase of achievement score from group 1 (0.0001-1.7115 students per computer) to group 2 (1.7116-4.0000 students per computer), additional follow-up study revealed that there was no statistically significant difference between group 1 and group 2 U.S. students for science achievement. The results showed that students' science achievement increased when school computer availability increased in the

U.S. schools. However, for Taiwanese schools, school computer availability didn't affect students' science achievement at all. A possible reason for this difference between Taiwan and the U.S. might be that the implementation of computers into U.S. schools is 20 years ahead of Taiwanese schools (Wei, 1993). It is possible that it takes a long time to see the effects of computer technology in schools on students' science achievement. Therefore, the impact of school computers on Taiwanese students may not have been revealed in this study.

Regarding the interaction between computer availability at school and computer availability at home, there was a statistically significant interaction. Follow-up analyses revealed small Omega Squared values (0.4 % and 1.2 %) and no pattern could be found for the interaction. Again, the large sample size contributed to the statistical significance.

Both the recommended macro and the univariate general linear model generated a small R^2 value (0.121 and 0.117, respectively). Caution is advised in interpretation of the results of the study since the three independent variables could only account for approximately 12 % of the variance in students' science achievement.

Recommendations for Future Studies

The results of this study served as a basis for the following recommendations for additional study.

1. It is suggested that this study be replicated after a SES factor can be gathered

from the TIMSS 1999 dataset. Martin, Mullis, Gregory et al. (2000) examined the TIMSS 1995 dataset and used the following categories to indicate both academic emphasis and SES: 1) number of books in the home, 2) presence of study aids (dictionary, study desk, computer), 3) possessions in the home, 4) level of educational attainment of parents, and 5) number of hours spent working at home. Factor analysis may be used for extracting a single factor accounted for SES. This factor can be later used as the covariate to remove the effect of SES in the study.

2. It is recommended that this study be conducted using data from other participating countries, which were involved in both TIMSS 1995 and 1999. For example, instead of using Taiwan—first-time participating in the TIMSS 1999, using other countries that participated in both TIMSS 1995 and 1999 would offer more information in terms of trends in time. Because Taiwan had never participated in TIMSS before 1999, the interpretation of the results were limited to only one international study.

3. It is additionally recommended that this study be conducted using countries with similar distribution of number of students per computer. This distribution was very different in Taiwan and in the U.S. because U.S. schools had more computers than Taiwanese schools in general. This difference made it difficult to find the cutting points for the four levels of number of students per computer and resulted in different sample sizes across the levels.

4. Future research should be undertaken using the frequency of home computer use rather than home computer availability. This would avoid the interference

of SES and offer more useful information on the effect of home computer use on achievement.

5. It is recommended that future studies might benefit from exploring the gender and affect (i.e., "liking science") factor on home computer use. This would provide further information about home computer use and achievement among different groups of students simply by extending the dataset of the TIMSS 1999.
6. Further studies could investigate the role that teachers play in computer availability and students' science achievement. It is true that how computers are used and the location of computers is as important to student learning as the quantity of them, and teachers are the ones to decide the frequency of computer use in a classroom. The possible factors that can be included are teachers' professional development in computer technology, teachers' experience of and attitude toward using computer technology, and the frequency that teachers use computer technology during instruction.

Summary

In this chapter, a brief summary of the literature relevant to the study was presented. A short outline of the research design and research questions was provided followed by the findings based on statistical analysis of the data. This study found that there was a statistically significant difference in the mean science achievement scores for each of the followings: 1) two levels of nationality, 2) four levels of computer availability at school, and 3) two levels of computer availability at home. There was a statistically significant interaction between nationality and computer availability at school, and between computer availability at school and computer availability at home. These significant interactions might be due to the large sample size involved in the study. Conclusions and discussion of the results were analyzed in relation to findings from previous research. Finally, a description of possible future studies and recommendations to similar studies were explained.

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