The relationship between classroom computer technology and students' academic achievement

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ABSTRACT

The main objective of this research is to investigate the relationship between computer technology in classrooms and students' academic achievement. The investigation of the relationship applies with the direction and significance of the relationship as well as the universality of the relationship. The technology/achievement relationship was investigated in the United States and Singapore. An additional objective is the nature of the relationship identified through investigating intermediate factor(s) that may influence the relationship, such as the way technology is used in schools.

The TIMSS-R 1999 data is used in this study to investigate the research questions. Statistical/empirical analyses carried out included descriptive statistics, Pearson correlation coefficient, ANOVA and MANOVA.

Conclusions show the technology/achievement relationship in the United States to be statistically insignificant and negative. Further investigation revealed that computer technology in schools in the United States is improperly used, as was illustrated by the rare use of computers for math and science instruction by students or teachers. However, the technology/achievement relationship in Singapore schools shows a significant positive relationship. Further investigation for how computer technology is used in Singapore schools indicated more proper use than in the U.S. Therefore, the relationship was found to be non-universal, but depends on how technology is used in schools. A technology use comparison between U.S. and Singapore schools shows that the difference in how each country uses the technology is classroom is statistically significant. Therefore, the technology use was found to be an important intermediate factor in the technology/achievement relationship which influences the relationship drastically.

Keywords: TIMSS, technology, achievement

INTRODUCTION

Statement of Problem

Does the use of computer technology in classrooms enhance students' learning and academic achievement? Is it a universal relationship? Is there an intermediate factor that influences the relationship? Specifically, this study investigates the relationship between the use of computer technology in U.S. schools and the students' academic achievement in math and science. To investigate the universality of the relationship, this study compares the technology/achievement relationship in U.S. with the technology/achievement relationship in Singapore, the highest ranked country in math and science achievement among the 36 countries surveyed in TIMSS-R 1999 (Mullis et. al., 1999). In addition, to understand the nature of the technology/achievement relationship, the study investigates whether the how technology is used in schools is an important intermediate factor that influences the relationship or not.

Research Questions

The general above statement of problem led to the specific following research questions:

1. Is there a significant relationship between computer technology in classrooms and students academic achievements in the U.S. schools?
2. How this relationship compares between the U.S. and Singapore? If it is different, what is the reason?
3. Is the way technology is being used in schools an important factor that influence the technology/achievement relationship?

Theoretical Approach

The theory behind this study is the interconnection between the effectiveness of the instructional tools and the school outcome in term of student academic achievements. Among several instructional tools, computer technology is investigated in this study. Atkinson (1968) and Suppes (1968) are among the first investigators to study the computer technologies as enhancement tool for learning and understanding. The view that computer technology plays a major role in students' academic achievements grew significantly, especially with the dramatic growth of computer technology (U.S. Department of Education, 1994). On the other hand, other investigators argue that computer technology will enhance learning if it is used appropriately (Cognition and Technology Group, 1996; Shields and Behrman, 2000). The focus of this study is to investigate the relationship between the classroom computer technology and students' academic achievement in U.S., which will be compared with the relationship in Singapore. Furthermore, the study shed some lights on the nature of the relationship through studying the way technology is being used in both countries to provide a rational for the non-universality of the relationship. In other word, the study will elaborate on whether the relationship is direct or indirect, i.e. through an intermediate factor (the appropriate use of technology).

Analytical Approach

Statistical/empirical approach will be carried out in this study including descriptive statistics, Pearson correlation coefficient, Analysis of variance (ANOVA) and Multivariate Analysis of Variance (MANOVA). MANOVA is used when there are more than one dependent variable. Using multiple ANOVA's for multivariate problem may cause two problems, namely inflation of a Type I error, and neglecting the correlation within the dependent variable.

Propositions and Hypotheses

Hypotheses development requires refining the constructs stated in the research questions (i.e. computer technology, student academic achievement, and technology use) to measurable indicators. Then these indicators are used as building blocks of the hypotheses. Table 1 (Appendix) summarizes the investigated constructs and their corresponding indicators. The indicators were selected based on their suitability to measure the corresponding construct and based on the questionnaire of TIMMS-R 1999.

From the above indicators of the investigated constructs, three hypotheses were tested to investigate the significance of the relationship:

1. The lack of computer availability for students and teacher leads to low Math and Science test scores.
2. The increase and decrease of math and science test scores as a function of the number of available computer in non-universal relationship.
3. Even with high computer availability in school, the improper use of computer technology by teachers and student leads to low Math and science scores.

Data

In this study, the TIMSS-R (Third International Mathematics and Science Study) 1999 data is used to investigate the research problem and questions. This data is available on-line to the public. The 1999 TIMSS-R is the second assessment in the series of IEA studies to measure trends in students' mathematics and science achievement. TIMSS 1999 was conducted by the International Study Center at Boston College and included 38 countries. The 1999 assessment measured the mathematics and science achievements of eighth-grade student (ages 13 and 14 years) and collected extensive information from students, teachers, and school principals about mathematics and science curricula, instruction, home contexts, and school characteristics and policies. Of the 38 participating countries, 26 also participated in the 1995 TIMSS assessment, which enabled these countries to measure trends in their children's mathematics and science achievement and in schools and home contexts for learning. The next TIMSS assessment was conducted in 2003. In this study, only the school and student data of U.S. and Singapore were used.

TIMSS QUESTIONS

Computer Technology

For the computer technology construct, question # 15c (BCBGCMP3) of the school background questionnaire is selected which reads as follows:

1. How many total numbers of computers that can be used for instruction purposes by either students or teachers.

Math and Science Academic Achievements

For the academic achievement construct, math and science scores of the students background questionnaire is selected, these are the following:

1. First plausible value in mathematics (BSMMAT01)
2. First plausible in science (BSSSCI01)

Computer Technology Use

For the computer technology use construct, question # 26g (BSBMCOMP), 26t (BSBMIDEA), 31g (BSBSCOMP), and 31v (BSBSIDEA) of the students background questionnaire is selected which reads as follows:

1. How often do the students use computers in their mathematics lessons?
   a) Almost always (1) b) Pretty often (2) c) Once in a while (3)
   d) Never (4)
2. How often does the teacher use computers to demonstrate ideas in mathematics in mathematics lessons?
   a) Almost always (1) b) Pretty often (2) c) Once in a while (3)
   d) Never (4)
3. How often do the students use computers in their science lessons?
   a) Almost always (1) b) Pretty often (2) c) Once in a while (3)
   d) Never (4)
4. How often does the teacher use computers to demonstrate ideas in science in science lessons?
   a) Almost always (1) b) Pretty often (2) c) Once in a while (3)
   d) Never (4)

LITERATURE REVIEW

Computer technology and internet use is growing significantly in businesses, homes and schools. From October 1994 to July 1995 about 30,000 new users came online each day (Mckinney, 1995). In late 1996, about 65% of U.S.A educators had access to the internet in their school, and 14% had internet access in their classrooms (Heaviside, Riggins, and Farris 1997). By the turn of this century there were 800 million e-mail users online (Quarterman, 1997). More than 20 million children and teens use internet from their homes by 1997 (Jupiter Communications, Inc. 1997). By 2002, as many as 70 million people in the U. S. were using the internet solely from their homes and almost 70 million people were accessing the internet on a daily basis at work (Powell, 2003). World reports showed that by August, 2006, there were over 200 million Internet users in the United States alone, roughly 25 % of more than 800 million world-wide Internet users (Neilsen/NetRatings, 2006).

Although the general romanticized view of technology is that it enhances the student learning and achievement, other views argues that the money spent on technology for the student as well as teacher time is a waste of resources (Education Policy Network, 1997). A more balanced view suggests that technology will enhance school achievement if used properly (Morris, 1995; Cognition and Technology Group at Vanderbilt, 1996; President's Committee of Advisors on Science and Technology, 1997; Dede, 1998). Additionally, a digital divide has been shown for years in regards to the Internet at home and at schools. IT was estimated, in 2002, that 65% of households headed by college graduates had Internet access yet only 11% of households led by parents with less than a high school education had the Internet (Digital Divide network, 2002). With the digital divide, is money spent on the Internet a waste of time for all, or just some of U. S. citizens?

Technology can be used in several ways in schools; our model summarizes only three ways. First, bringing exciting curricula based on real-world problems in classrooms; second, giving students and teachers more opportunities for feedback, reflection, and revision; and third, building local and global communities (National Academy Press, 1999). Learning through a real-world environment is a very important element of students' understanding and knowledge building. Technology is a powerful tool that could be used by educators to create a real life learning environment to solve a real life problem. Because many technologies are interactive, students can learn by doing receiving feedback and refining their understanding while building new knowledge (Barron et al., 1998, Bereiter and Scardamalia, 1993, Kafai, 1995). A wide range of technological tools are available for this purpose including video-based problems, computer simulations, electronic communications systems, and tele-field trips to museums, historical sites, parks and zoos (Barron et al., 1995.)

Feedback and reflection for better understanding is an important instructional tool for teachers. Technology cuts time in half for teachers to provide feedback on their students' work (Cognition and Technology Group at Vanderbilt, 1996.) Furthermore, technology provides opportunities to interact with working scientists to learn from their feedback and experience. Classroom communication technology (such as WebCT and Blackboard discussion boards, Classtalk and chat rooms) promote classroom interaction which provides peers feedback. In Classtalk the instructor prepares and demonstrates a problem, the students (as individuals or groups) enter their solution using hand held input devices, the technology is collected and analyzed, and a display of the different proposed solution is presented in histogram format. This provides feedback for the students and teachers which reflect the students' understanding of the concept behind the problem (Mestre et al., 1997.) Similar technologies (including the internet) engage students in dialogues that integrate information and contributions from different perspectives and resources to produce a new knowledge (Scardamalia and Bereiter, 1993; Driscoll, 2002).

A major advantage of technology is connecting the classroom with communities, including homes. Schools are an important part of communities from which they need the support for development. Parents are an important constituent of community as well.

New technologies help in establishing a continuous communication with parents to share important information regarding assignments, students' behaviors and school calendars (Bauch, 1997). Furthermore, technology provides the chance for classrooms to communicate with electrical communities of scientists, authors, and other practicing professionals (Riel and Levin, 1990).

Technology deployment in schools has led to a transformation of teachers' roles in classrooms. Instead of being the source of information, teachers now are facilitator and coaches to their students. Furthermore, telecomputing teachers' roles changed from lessons planner to instructional designers. With technology in classrooms, student can access huge amount of information which can be used to generate knowledge. The teacher's new role now allows them to help students generate the knowledge from his or her information search. Teachers' role, in the age of information, is more to help the student to focus on a specific purpose and goal; to guide their search to be a purposeful and targeted. Five teacher-directed purposes for students' information searching include: practicing information-seeking skills, learning about a topic or answer a question, reviewing multiple perspectives on an issue, and solving an authentic problem or to publish information overviews for other students to use (Harris, 1998).

DATA ANALYSIS AND DISCUSION (UNITED STATES SCHOOLS)

Computer Technology

The computer technology is this study is measured by the number of computers available for instruction for students and teachers. The following descriptive statistics are seen in Table 2 (Appendix) and describe the of number of computers in each U.S. school.

Graphically, Figure 1 (Appendix) illustrates the data in histogram form, which shows that the data is highly left (positive) skewed, with a mode of 30 available computers in each school at the time of the study. Since the data is skewed, the mode may be the best central tendency representative.

Academic Achievement

Academic achievement of students is measured by the math and science test scores of each student. Table 3 (Appendix) summarizes and compares the math and science test scores of U.S. students. Table 3 lists the important statistical parameters of math and science test scores. Furthermore, the data is presented graphically illustrated in histogram to illustrate and compare the math and science achievement scores as in Figure 1 (Appendix).

Figure 2 (Appendix) shows that both math and science test scores are normally distributed with slightly higher science scores mean than math. Since this is a test score data, percentile representation of the data may be desirable and suitable. Figure 3 (Appendix) is Whisker-Box plot which presents the data in percentiles form and use the median as central tendency representative and the Inter Quartile (IQR) to represent the data dispersion. The median is the middle score or the 50^{th} percentile which is represented in the line in the middle of the box. The lower side of the box is the 1^{st} quartile (25^{th} percentile) and the upper side of the box is the 3^{rd} quartile (the 75^{th}

percentile). The IQR is the difference between the 1st quartile and 3rd quartile (the box thickness). The outliners are identified based on the inner fence and outer fence. The outer fence is located at the 3rd quartile +3(IQR) and the 1st quartile-3(IQR). Any data point exceeds this range is identified as extreme outlier (not observed in this data). Similarly, the inner fence is located at the 3rd quartile +1.5(IQR) and the 1st quartile-1.5(IQR). Any data point falls between inner fence and outer fence is identified as an outliner (filled circles).

Figure 3 (Appendix) connects the medians of both samples for comparison reason. The medians are very close to one another, with slightly higher median in science scores. The IQR of the science score sample is also slightly higher than math scores IQR as the box's thickness indicates.

Technology/Achievement Correlation

Our primary objective in this study is to investigate the relationship between technology and academic achievement. A Pearson Product correlation coefficient (r) is used in this study to investigate the relationship. The Pearson correlation coefficient is a dimensionless parameter and always lies between -1 and +1. A positive correlation coefficient indicates a direct relationship while a negative correlation coefficient indicates an inverse relationship. The square of the correlation coefficient is the proportions of the total variation in the academic achievement explained by the technology. To carry out the calculation of correlation between technology and achievement, the mean of the academic achievement in each school is determined first, then correlated with the number of computers available in each school. Table 4 (Appendix) summarizes the correlation coefficient results.

The correlation coefficient between technology (total # of computers) and math (math mean) and science (Sci. mean) test scores is negative. This indicates that math and science achievement decreases, as the number of available computers for students and teachers for instruction purpose increases. Although this result may be unexpected, there may be theoretical basis to it as will be explained later in this chapter. The next step in the correlation analysis is to investigate the significance of the correlation. This is carried out by calculated P-value to test a null hypothesis of the significance of the relationship. The following null (H_0) and alternative (H_a) hypotheses are tested with 5% significance level (□ = 0.05).

H_0: there is NO significant relationship between the number of computer in a school (technology) and the math and science academic achievement of the students in that school.

H_a: there is significant relationship between the number of computer in a school (technology) and the math and science academic achievement of the students in that school.

Table 5 (Appendix) summarizes the P-value of the Pearson correlation between the investigated variables. The P-values between total # of computer (technology) and math and science scores (achievement) are both greater than 0.05, leading to insignificant probability, thus the above null hypothesis (H_0) is accepted (P-value>0.05). Therefore, although the relationship is negative, it is insignificant relationship, meaning there is no correlation between technology and achievement.

Technology Use

One explanation of the findings of insignificant relationship between technology and academic achievement in U.S. schools is the inefficient use of technology in schools which leads to a waste of student time and school resources (Education Policy Network, 1997). In this study we investigate how the technology is used in U.S. schools to explain the insignificant relationship found between technology and achievement. Furthermore, we are interested in understanding the nature of the relationship in terms of whether the way that the technology is being used in schools is an intermediate factor that should be included in the relationship.

Figure 4 (Appendix) is a histogram that shows the distribution of the data on how the computer technology is being used in the classrooms by the student and teachers. This data pertains to the questions listed in the Introduction, under *TIMSS Questions, Computer Technology Use.* The histogram illustrates that most of the data is clustered around the inefficient and misuse of the computer technology, i.e. “Never” category. Approximately 63% of the data falls in the “Never” category while only 37% of the data is distributed among the “Once in a while”, “Pretty often” and “Almost always” categories. This phenomenon explains the insignificant negative correlation coefficient between technology and achievement in U.S. schools.

To study whether the insignificant negative correlation between technology and achievement in U.S. schools is universal or case specific, a similar analysis is conducted on the Singapore school data. The specific selection of Singapore is related to its lead in math and science achievement in TIMSS-R 1999 data which makes its educational system a role model for other school systems around the world. Exploring the technology/achievement relationship in Singapore may be useful for other countries to learn from.

DATA ANALYSIS AND DISCUSION (SINGAPORE SCHOOLS)

Computer Technology

Similar to the U.S. analysis, the computer technology in Singapore schools is indicated by the number of computers available for instruction for students and teachers in each school. The following descriptive statistics Table 6 (Appendix) summarizes the computer technology data in Singapore schools.

Graphically, Figure 5 (Appendix) illustrates the data in histogram form, which shows that the data is slightly right (positive) skewed, with a mean of approximately 127 computers per school. Unlike the U.S. technology (number of computers) data distribution, Singapore data is fairly normally distributed.

Academic Achievement

Academic achievement of Singapore students is measured by the math and science test scores of each student. The following descriptive statistics summarizes and compares the math and science test scores of Singapore students. Table 7 (Appendix) lists the important statistical parameters of math and science test scores. Furthermore, the data is graphically illustrated and compared by a histogram as in Figure 6 (Appendix).

The distribution of the math and science scores is fairly normal distribution with a slightly higher mean of math scores unlike the U.S. achievement data. Since this is a test score data, Whisker-Box plot is a suitable graphical tool to better illustration and compare the median (for central tendency), the Inter Quartile (IQR) (for dispersion) and outliers of each sample.

Figure 7 (Appendix) shows that the median of both samples are very close to one another, with slightly higher median of math scores. The IQR of the science score sample is also slightly higher than math scores IQR.

Technology/Achievement Correlation

Similar to the U.S. analysis, Pearson Product correlation coefficient (r) is used to investigate the technology/achievement relationship. To carry out the calculation of correlation between technology and achievement, the mean of the academic achievement in each school is determined first, then correlated with the number of computers available in each school. Table 8 (Appendix) summarizes the correlation coefficient results.

The correlation coefficient between technology (total # of computers in a school) and math (math mean) and science (Sci. mean) test scores is positive. This indicates that math and science achievement in Singapore increases as the number of computers in Singapore schools increases. This result is completely in disagreement with the negative correlation found in the U.S. analysis. The next step in the correlation analysis is to investigate the significance of this correlation. This is carried out by calculated P-value to test a null hypothesis of the significance of the relationship. The following null (H_0) and alternative (H_a) hypotheses are tested with 5% significance level (α = 0.05).

H_0: there is NO significant relationship between the number of computer in a school (technology) and the math and science academic achievement of the students in that school.

H_a: there is significant relationship between the number of computer in a school (technology) and the math and science academic achievement of the students in that school.

Table 9 (Appendix) summarizes the P-value of the Pearson correlation between the investigated variables. The P-values between total # of computer (technology) and math and science scores (achievement) are both less than the 0.05 significance level, leading to the rejection of the above null hypothesis (H_0). Therefore, the relationship between the number of computers and achievement in Singapore schools is a significant relationship. To understand this relationship deeper, a brief analysis of the use of computer technology in Singapore will be presented.

Technology Use

One explanation of the findings of significant relationship between technology and academic achievement in Singapore schools is the efficient and proper use of technology in the classroom (Education Policy Network, 1997). The following analysis investigates this explanation which also will assist in understanding if the proper use of technology is an important intermediate factor in the relationship between technology and achievement.

Figure 8 (Appendix) is a histogram that shows the distribution of the data on how the computer technology is used in the classrooms by the student and teachers in Singapore. This data pertains to the questions listed in Introduction, under the heading *TIMSS Questions, Computer Technology Use*. Unlike the U.S. data, Figure 9 (Appendix) illustrates a better distribution of the data among the four categories, although the major cluster is still on the "Never" category. In the Singapore data, 54% of the data is distributed among the "almost always", "pretty often" and "once in a while" categories, while 46% of the data fall in "Never" category. This fair distribution in Singapore technology use data is related to the positive significant relationship between technology and achievement in Singapore schools. The analysis shows that the efficient and proper use of technology is an important intermediate factor in the relationship between technology and achievement. This finding emphasizes the importance of the efficient use of technology in order for the technology to enhance the academic achievement.

COMPARISON STUDY BETWEEN U.S. AND SINGAPORE SCHOOLS

In the previous two sections, the data analyses revealed two different phenomena, namely no significant technology/achievement relationship in the U.S. schools and significant technology/achievement relationship in Singapore schools. Further analysis on how the computer technology is used in the two countries showed that Singapore schools use computer technology more properly than U.S. schools. The objective of this section is to compare the findings in both countries in order to investigate whether this difference is significant or not. Additionally, the difference of the technology use variable between the two countries is analyzed to determine its significance. This analysis is important in finding the main reason behind the insignificant and significant relationship in U.S. and Singapore, respectively.

Technology Comparison

Table 10 (Appendix) summarizes the results from the one-way analysis of variance (ANOVA) which compares the difference in means of number of available computer (technology) variable in U.S. and Singapore. The following null hypothesis is tested:

$$H_0 : \mu_{USA} = \mu_{Singapore}$$

$$H_a : \mu_{USA} \neq \mu_{Singapore}$$

The ANOVA breaks down the total variation into two groups, namely between group and within groups variations, then calculates the sum of squares of deviations for each group. Using the sum of squares of deviation and the degrees of freedom of each variation source the mean square error in obtained. The F-value is the ratio of the mean square errors from between groups to within groups. Using SPPS™, the corresponding P-value (the area under the F-distribution curve that corresponds to the F value) of 32.709 is calculated. This area under the curve represents the probability of the null hypothesis to occur just by chance. Adopting a significance level of 5%, the null hypothesis is rejected in favor of the alternative hypothesis because the P-value is less than the 0.05 significance level. Descriptive statistics is presented in Table 11 (Appendix).

The ANOVA results and the descriptive statistics show that the number of computers in Singapore is significantly higher than in the U.S. To ensure the accuracy of the ANOVA results, a brief check on ANOVA assumption is carried out by SPSS™. The ANOVA assumptions are as follows:

1. Random Sampling
2. Homogeneity of variance
3. Normal populations
4. Samples independence
5. Interval or ratio dependent variable

From TIMSS data collection design, assumption 1, 4 and 5 are fulfilled (TIMSS handbook) and assumption 2 and 3 are fulfilled by the SPSS analysis.

Academic Achievement Comparison

The achievement construct is measured by two dependent variable, namely math and science test scores. A Multivariate Analysis Of Variance (MANOVA) compares the means of the dependent variable of each country. The investigated means of the dependent variable in the MANOVA are vector means because they represent the means of all the dependent variables. This is indicated by the bold faced symbol of means (□) which indicate a matrix of means. Furthermore, the MANOVA accounts for the correlation between the dependent variables as well. In this analysis, math and science scores are the dependent variables and the countries (the U.S. and Singapore) are the independent variables. The following null hypothesis is tested:

H_0: the centroid of math and science of U.S. and Singapore are equal

$(\boldsymbol{\mu}_{USA} = \boldsymbol{\mu}_{Singapore})$

H_a: the centroid of math and science of U.S. and Singapore are unequal

$(\boldsymbol{\mu}_{USA} \neq \boldsymbol{\mu}_{Singapore})$

In MANOVA analysis, the Wilks Lambda (□) is selected to represent the ratio of within variance to total variance. The Wilks Lambda (□) in the MANOVA is as F-value in the ANOVA. SPSS™ calculates □ = 0.684 and the corresponding P-value less than 0.0001. Selecting □=0.05, the above null hypothesis is rejected in favor of the alternative hypothesis, which states that the U.S. students achievement mean and Singapore students achievement mean are significantly different. To find out which mean is higher, Table 12 (Appendix) summarizes the achievement descriptive statistics of both countries. The MANOVA results and descriptive statistics show that Singapore achievement mean is significantly higher than the U.S. achievement mean.

Technology Use Comparison

The comparison results of both technology and achievement have shown that Singapore technology and achievement is significantly higher than U.S. technology and achievement. However, none of the above comparison results explains the reason of this significant difference. Earlier in this paper, a brief descriptive analysis of technology use is presented to explain the reason of the insignificant and significant technology/achievement correlation in U.S. and Singapore, respectively. In this section, a comparison between the U.S. use of technology and Singapore use of technology will be carried out to verify that the significant correlation in Singapore and the insignificant correlation in the U.S. are related to how technology is used in both countries' schools. In other words, the purpose of the following analysis is to investigate if the technology use is an intermediate variable in the relationship between technology and achievement.

In the following analysis, the MANOVA looks at four dependent variables and one independent variable. The four dependent variables are the items listed in the *Technology Computer Use* description, and the independent variable is the country. The tested means in the MANOVA are vectors which include several means of the dependent variables. The following hypothesis will be tested.

H_0: the centroid of technology use items of U.S. and Singapore are equal ($\boldsymbol{\mu}_{USA} = \boldsymbol{\mu}_{Singapore}$)

H_a: the centroid of the technology use items of U.S. and Singapore are unequal ($\boldsymbol{\mu}_{USA} \neq \boldsymbol{\mu}_{Singapore}$)

The calculated Wilks Lambda is Λ=0.972 and the corresponding P-value is less than 0.0001. With α of 0.05, the above null hypothesis is rejected in favor of the alternative hypothesis (P-value<α). The alternative hypothesis is that there is a significant difference in the means of the technology use between the two countries. Table 13 (Appendix) summarizes the mean technology use of student and teacher technology use in science and math classrooms, showing that the U.S. overall mean is higher than the Singapore mean indicating that computers are used more often in U.S. classrooms than in those in Singapore.

The results illustrate that computer technology in Singapore is more properly used than in the U.S., which explains the insignificant technology/achievement correlation in the U.S. and the significant technology/achievement correlation in Singapore.

CONCLUSIONS

Following are the general conclusion of this study:

- In the U.S., there is no relationship between technology in classrooms and students' academic achievement.
- The reason of the zero technology/achievement correlation in the U.S. is the improper use of technology as an instruction tool in math and science classrooms.
- In Singapore, the relationship between technology in classrooms and students' academic achievement is a positive significant relationship.
- The reason for this significant relationship is the proper use of the technology for instructional purposes in the classrooms.
- There is a significant difference in how technology is being used in the U.S. and Singapore which leads to the different technology/achievement relationships in both countries.
- The Technology/achievement relationship is not universal, but it is controlled by an intermediate factor of how the technology is used.

Appendix

Table 1. Constructs and indicators

Construct	Indicator
Computer Technology	The number of computers available for students and teachers as instructional tools.
Students' academic achievement	1. Math test scores 2. Science test scores
Computer Technology use	1. How often students use computer in math lessons. 2. How often teachers use computer in math lessons. 3. How often students use computer in science lessons. 4. How often teachers use computer in science lessons.

Table 2. U.S. computer technology descriptive statistics

Mean	78.92
Median	55
Mode	30
Standard Deviation	79.43
Kurtosis	14.78
Skewness	3.24
Range	600
Minimum	0
Maximum	600
Sample No. (N)	173

Figure 1. Histogram of the number of available computer in U.S. schools

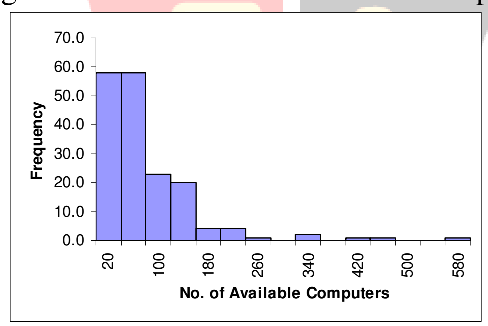

Table 3. U.S. academic achievement descriptive statistics

Parameter	Science	Math
Mean	504.74	495.14
Median	509.86	497.16
Mode	467.56	525.61
Standard Deviation	97.11	85.54
Kurtosis	-0.15	-0.04
Skewness	-0.14	-0.07
Range	769.07	626.16
Minimum	131.34	212.16
Maximum	900.41	838.32
Sample No. (N)	7818	7818

Figure 2. U.S. math and science achievement

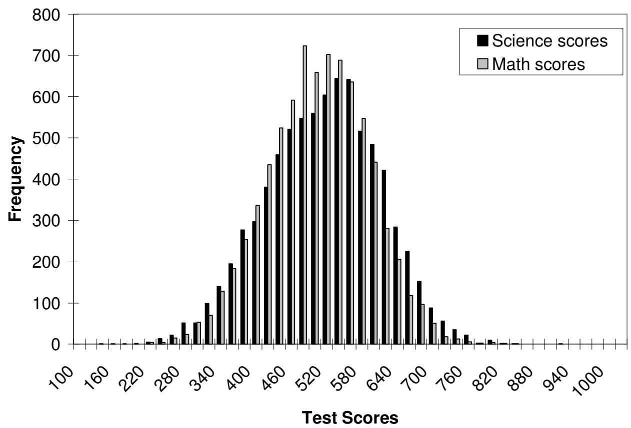

Figure 3. U.S. academic achievement data Whisker-Box plot

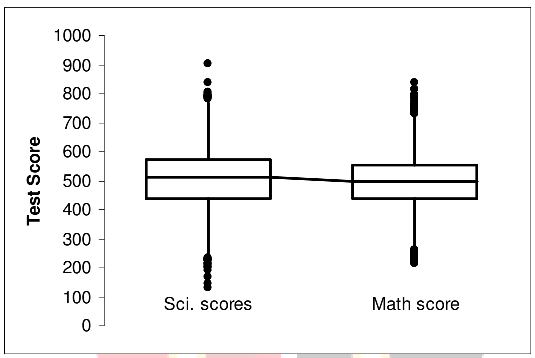

Table 4. U.S. technology/achievement Pearson Correlation

	Math Mean	Sci. Mean	Total # of Comp.
Math Mean	1.000	0.920	-0.052
Sci. Mean		1.000	-0.104
Total # of Comp.			1.000

Figure 4. Technology use in U.S. schools

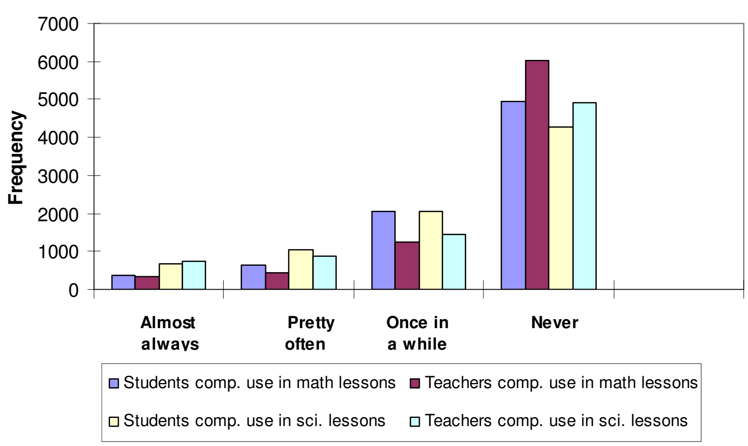

Table 5. U.S. technology/achievement correlation P-values

	Math Mean	Sci. Mean	Total # of Comp.
Math Mean	-	0.000	0.493
Sci. Mean		-	0.173
Total # of Comp.			-

Figure 5. Number of available computers in Singapore histogram

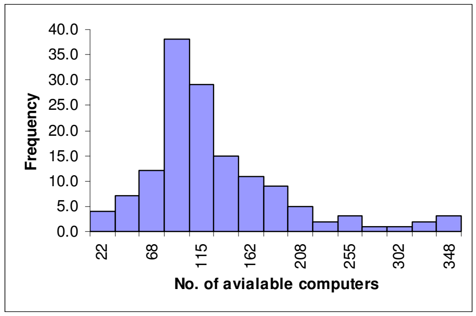

Table 6. Descriptive statistics of number of available computers in Singapore schools

Mean	126.66
Median	110.50
Mode	90
Standard Deviation	66.07
Kurtosis	2.43
Skewness	1.41
Range	350
Minimum	10
Maximum	360
No. of sample (N)	142

Figure 6. Math and Science achievement histogram in Singapore

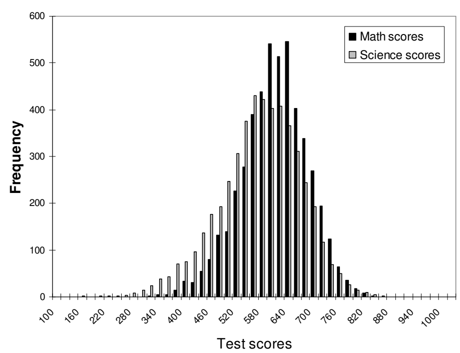

Table 7. Descriptive statistics of math and science achievement in Singapore

Parameters	Science	Math
Mean	563.47	599.28
Median	569.27	602.51
Mode	591.04	590.21
Standard Deviation	95.49	77.37
Kurtosis	0.22	0.19
Skewness	-0.38	-0.30
Range	699.91	518.57
Minimum	150.90	315.33
Maximum	850.81	833.90
No. of sample (N)	4884	4884

Table 8. Correlation Coefficient Matrix

	Total # of Comp.	Math Mean	Sci. Mean
Total # of Comp.	1.000	0.378	0.383
Math Mean		1.000	0.973
Sci. Mean			1.000

Figure 7. Achievement Whisker-Box plot in Singapore

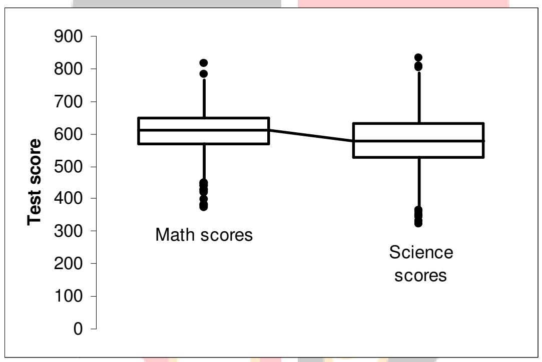

Figure 8. Technology use in Singapore schools

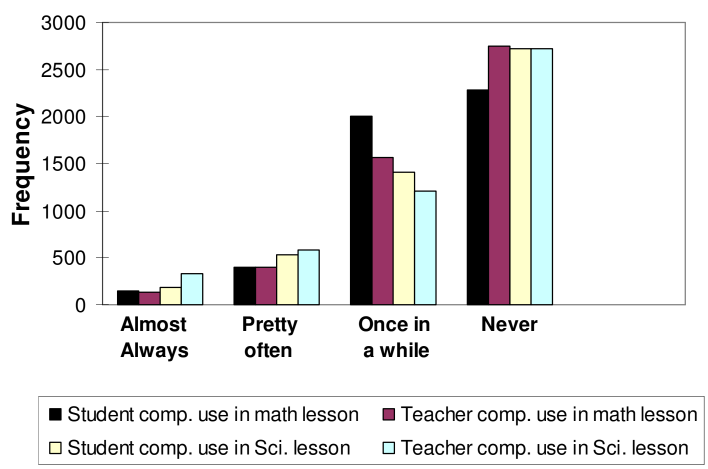

Table 9. Correlation coefficient P-value

	Total # of Comp.	Math Mean	Sci. Mean
Total # of Comp.	-	0.000	0.000
Math Mean		-	0.000
Sci. Mean			-

Table 10. Technology comparison ANOVA

Variation Source	Sum of Squares	df	Mean Square	F	P-value
Between Groups	177719.98	1	177719.98	32.709	<0.0001
Within Groups	1700625.8	313	5433.309		
Total	1878345.8	314			

Table 11. U.S. and Singapore number of computers descriptive statistics

	Mean	Standard Dev.	N
USA	79.92	79.43	173
Singapore	126.66	66.07	142
Total	206.58	145.5	315

Table 12. U.S. and Singapore achievement means

			Achievement Mean
Country	**USA**	**Sci.**	504.73
		Math	495.14
	Singapore	**Sci.**	563.5
		Math	559.27

Table 13. U.S. and Singapore technology use variable means

			Technology Use Mean
Country	USA	Student comp. use in math	3.44
		Teacher comp. use in math	3.62
		Student comp. use in sci.	3.24
		Teacher comp. use in sci.	3.31
	Singapore	Student comp. use in math	3.33
		Teacher comp. use in math	3.43
		Student comp. use in sci.	3.37
		Teacher comp. use in sci.	3.30

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