REEXAMINING PATTERNS OF NEGATIVE COMPUTER-USE AND ACHIEVEMENT RELATIONSHIPS. WHERE AND WHY DO THEY EXIST?

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Abstract

A close examination of the Third International Mathematics and Science Study (TIMSS) 1995 results showed that fourth grade students in Cyprus, Hong Kong and the USA who used computers most frequently in the classroom were the students with the lowest achievement in their countries. Previous studies we conducted showed similar results for 15-year-old students in various countries that took part in the Program for International Student Assessment (PISA). The purpose of this study was to look more closely at the computer use and achievement relationships to determine if similar patterns continue to exist in the TIMSS-R database. The results of this study did find similar types of relationships. More specifically, 15-year-old students in Cyprus who frequently used the Internet to communicate with other students, and who had teachers who frequently used computers in their classrooms tended to have lower scores than other students with fewer such opportunities. Similar results were found for science and mathematics. Finally, a non-surprising result of this study was that the students who own computers in their homes tend to have higher academic achievement than the students who do not have them.

INTRODUCTION

Since educators first began to use computers in the classroom, researchers have tried to evaluate whether the use of the computer had a reliable and significant impact on student achievement (Altschuld, 1995; Kulik & Kulik, 1991; Rocheleau, 1995). This is reflected in various debates about the relationship between technology use and student achievement (see e.g., Clark 1994; Jonassen, Campell & Davidson, 1994) which have shown that technology use alone cannot be treated as a single independent variable to explain its effects on the performance of students on various tests. Evaluating the impact of computer use requires an understanding of how it is used in the classroom and what learning goals are held by the educators involved, knowledge about the type of assessments that are used to evaluate improvements in student achievement, and an awareness of the complex nature of learning in the school environment.

In addition, the conclusions that can be reached about the interrelationship of these variables are confined by the research methods that are used, as well as by the type of statistical analysis performed on the data. Consequently, although prior studies have found positive correlations between computer use in the school and achievement (e.g., Berger et al., 1994; Khalili & Shashoani, 1994; Pedretti et al., 1998; Shaw, 1998) those correlations do not necessarily imply cause-effect relationships since those studies were not experimental. Based on the same rationale, non-experimental studies that found negative relationships between computer use in school and achievement do not imply that computer use decreases student achievement, or vice versa (Angrist & Lavy, 1999; Papanastasiou, 2002; Papanastasiou & Ferdig, 2003; Papanastasiou, Zembylas, & Vrasidas 2003; Ravitz, et al., 2002).

For example, the Third International Mathematics and Science Study (TIMSS) 1995 results indicated that fourth grade students in Cyprus, Hong Kong and the USA who used computers most frequently in the classroom were those with the lowest achievement in their countries. Although this was a surprising result, it did not leave much room for explanations because there were not enough details on how computers had been used in those classrooms. One possible hypothesis for explaining this negative relationship though, was that teachers assigned the use of the computers to low ability students who were not able to catch up with the instruction offered to the rest of the class (Papanastasiou, Zembylas, & Vrasidas, 2003). In this way, it might be assumed that the computers were used to provide individual practice and feedback to those lower achieving students. However, such an explanation is rather limiting because of the unavailability of richer information since the student questionnaire in TIMSS 1995 for population 1 included only one single question related to computer use of the students in their classrooms. That question asked the students how often they use computers in their classrooms.

Because of the increased use of computers in educational settings today, it was expected that the student background questionnaire in the repeat of TIMSS in 1999 (TIMSS-R) would be modified to reflect such changes. This was done by adding additional questions related to more specific uses of computers. Such questions ranged from asking "How often do you use computers in your mathematics lesson?" to more detailed questions such as "How often do you use e-mail to work with students in other schools on math projects?" Similar questions were asked for mathematics and for science. Although these questions are not sufficient to explain the relationship between computer use and achievement, they do provide additional insight on these relationships.

THEORETICAL FRAMEWORK

To date, the majority of research studies examining computer use and student achievement seem to emphasize that there is a positive correlation between these variables. This is not surprising since there is abundant of evidence to indicate that a positive relationship exists between technology use and student achievement (e.g., James & Lamb, 2000; Sivin-Kachala, 1998; Weaver, 2000; Weller, 1996; Wenglinsky, 1998). Recently however, some studies have identified negative correlations between computer use and student achievement (Papanastasiou, 2002; Papanastasiou, Zembylas & Vrasidas, 2003; Ravitz et al., 2002; Wenglinsky, 1998). These mixed results suggest that the relationship between computer use and student achievement is not only complex, but is also constantly evolving. In addition, with the rapid increase in the number of computers at homes, in the workplace, and in schools, teachers also need to adjust their practices because the daily interaction between students and computers is also changing. Therefore, some teachers might need to move away from the process of teaching how to use computers (if the students already know that), and move onto the process of demonstrating how educational technology could help students learn to learn. This cannot be accomplished, however, unless the ways in which students use computers are carefully examined.

Consequently, educators and researchers cannot assume that by installing computers with access to the Internet and various types of software in schools, the achievement level of the students will automatically increase. Careful re-examination of the results of this study is necessary in order to rethink the ways in which computers are used in the classroom today. Therefore, this study could also provide directions for up-to-date experimental research studies that could examine the exact direction and magnitude of such relationships. In addition, such results can provide leads for in-depth qualitative studies examining the impact of student and teacher computer use on achievement.

The purpose of this study is to re-examine the patterns of negative computer-use and achievement relationships found in TIMSS, and to try to determine why they exist. Specifically, this study considers the following questions:

1) What are the types of computer use variables in classroom settings that can explain a significant portion of the mathematics and science achievement variance in TIMSS-R?

2) Why, and in what ways do computer use activities have a shared variance with the achievement level of the students in mathematics and science?

3) How can variables of computer ownership and Internet access at various locations explain a portion of the mathematics and science achievement variance of students in TIMSS-R?

METHODS

The data for this study are based on the repeat of the TIMSS that took place in 1999 (TIMSS-R). The target population for the TIMSS-R study were all students who were enrolled in the upper of two adjacent grades that contain the largest proportion of students who were age 13 at the time of testing (Gonzales & Miles, 2001). In the case of Cyprus, this was grade 8. In order to select the sample of students from each country, a two stage sampling procedure was used. The first stage consisted of a stratified sample selection of schools within each country, and the second stage consisted of the selection of a random sample of a class within the targeted grade (grade 8 in Cyprus). Because of the small number of schools in Cyprus compared to other TIMSS countries, Cyprus randomly sampled two eighth grade classes from each of the selected schools.

The sample of the study included 3116 Cypriot students that were in eighth grade when the data were collected. The average age of the students in the sample was 13.81 years old (sd = 0.44), with a minimum age of 11 and a maximum age of 16. Of the whole sample, 49.1% were girls, 49.9% were boys.

Since the purpose of the study was to explain the computer use and achievement relationship, the dependent variables used in all analyses were the student's mathematics and science scores. The Rasch scale (150, 10) was selected for the measurement of the student's achievement in mathematics and science, since it allows for the scores of all students to be equated and placed on the same scale, regardless of which form/booklet of the TIMSS test was assigned to them. The Rasch scale also eliminates the use of plausible values, which were used to present the scores that students would likely have received if they were administered different test forms with different test items than the ones administered to them.

The specific computer-related questions that were used for the analyses of this paper are the following:

- How often do you use computers in your math (or science) lessons?
- How often do you use e-mail to work with students in other schools on math (or science projects?
- How often do you use the World Wide Web to access information for math (or science) projects?
- How often does the teacher use a computer to demonstrate ideas in your math (or science) lessons?
- Do you have a computer in your home?
- Do you have Internet access at home/ at school/ elsewhere?
- How much do you like using computers to learn mathematics (or science)?

The analyses in this study were based on a series of regressions and ANOVAs that were performed with SPSS 10.1.

RESULTS

The first analysis examined whether the ways in which students or teachers used computers could explain part of the variance in the student scores on the TIMSS. The independent variables used in this model were those of using the computer in math (or science) class, watching the teacher use the computer to present new ideas in math (or science), using the Internet to search for information for a math (or science) project, and using e-mail to communicate with students in other schools on math (or science) projects.

As presented in Table 1, the overall model for math was significant (F = 41.47, p = 0.00) and it explained 9.0% of the variance of the students' math score. The overall model for science was significant (F = 28.74, p = 0.00) and it explained 6.7% of the variance of the students' science score, as presented in Table 2. These results indicate that students who used computers frequently in their math or science class, and whose teachers used computers in class to explain ideas, had lower scores than the students who did not do so as often. This might be because the teacher limited computer use to demonstrations. Computers are interactive, and as such they should be used as cognitive tools for students to engage in problem solving, to collaborate with peers, and to construct knowledge. Only then it is more likely that student achievement will improve.

Table 1 presents the beta coefficients and the significance levels of the independent variables that were used to predict the mathematics achievement of the Cypriot students on TIMSS. As can be seen from this Table, the students who used e-mail frequently to work with students in other schools on math projects were more likely to have lower scores on the TIMSS mathematics test. However, using the World Wide Web for accessing information for math projects had no effect on the mathematics achievement of the students.

Table 1. Computer use and mathematics achievement regression results

	Unstandardized Coefficients		*Standardized Coefficients*	*t*	*Sig.*
	B	SE	Beta		
(Constant)	158.46	.68		232.95	.000
Use computers in math class	-2.39	.36	-.165	-6.60	.000
Teacher uses computer to explain ideas	-1.92	.35	-.136	-5.46	.000
Student uses e-mail to work with students in other schools on math projects	-1.25	.26	-.131	-4.77	.000
Student uses the WWW for accessing information for math projects	.13	.25	.014	.51	.60

Table 2 presents the results for the same students in science. As can be seen from Table 2, the students who used computers in science class, who had teachers who used the computer to explain ideas, and who used e-mail to work with students in other schools on math projects were more likely to have lower scores on the TIMSS mathematics test. However, in contrast to the results for mathematics, students who used the World Wide Web frequently for accessing information for science projects had higher scores in science than the students who did not use the computer as frequently for this purpose.

Table 2. Computer use and science achievement regression results

	Unstandardized Coefficients		*Standardized Coefficients*	*t*	*Sig.*
	B	SE	Beta		
(Constant)	155.47	.69		225.42	.000
Use computers in science class	-1.36	.36	-.10	-3.74	.000
Teacher uses computer to explain ideas	-1.81	.32	-.15	-5.61	.000
Student uses e-mail to work with students in other schools on science projects	-1.57	.31	-.14	-4.96	.000
Student uses the WWW for accessing information for science projects	1.14	.27	.11	4.18	.000

A series of exploratory ANOVAs were also performed to determine if there were differences in the achievement scores of the students who did and did not own computers, and of the students who had access to the Internet at various locations. For the subject area of mathematics, as presented in Table 3, the only significant variable was that of owning a computer ($F = 70.84$, $p = 0.000$). However, the size of these differences tended to be very small. For example, students who owned a computer in their house had an average achievement of 151.53 (sd = 0.47) in mathematics, in contrast to the average score of students who did not own computers, and which was 147.85 (sd = 0.54) Although this difference was statistically significant, the magnitude of the score difference was small since it equaled less than half a standard deviation on the Rasch scale.

It should also be noted that 42.33% of the sample did not own computers in their homes, while the other 57.67% did own computers. However, the variable of computer ownership needs to be interpreted cautiously. Computer ownership is a variable that is closely related to the socio-economic status (SES) of a family. That is, students who are of higher SES, and who have parents who are more highly educated, are more likely to own a computer. Therefore, it might not be the computer itself that has a significant effect on student achievement but the variable of SES.

Similar results were found for the subject of science ($F=39.45$, $p=0.000$), as presented in Table 4. Students who owned a computer had an average score of 151.18 (sd=0.46) in science, while the students who did not own a computer scored 148.46 (sd=0.53) on average. Although this difference was significant, its magnitude was very small. Again however, this variable should be interpreted cautiously since computer ownership is more closely related to the variable of SES which in turn has been found to influence achievement in numerous studies. Another possible explanation might be that having access to a computer on a daily basis at home might encourage computer usage towards the development of knowledge and skills that can lead to higher achievement in school.

Table 3. Effects of computer ownership and Internet access on mathematics achievement.

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Corrected Model	9555.30	4	2388.825	24.35	.000
Intercept	10628344.68	1	10628344.68	108369.82	.000
Own a computer at home	6947.78	1	6947.78	70.84	.000
Access to Internet at home	25.26	1	25.26	.25	.612
Access to Internet at school	13.80	1	13.80	.14	.708
Access to Internet somewhere else	126.92	1	126.92	1.29	.255
Error	287260.97	2929	98.07		
Total	66462260.09	2934			
Corrected Total	296816.27	2933			

R Squared = .032 (Adjusted R Squared = .031)

Another result that was similar for both mathematics and science is that the variables of having access to the Internet at various locations (home, school and elsewhere) were not significant. This verifies our hypothesis that it is not computer use (or Internet access) alone that affects student achievement but the ways in which these technologies are used.

Table 4. Effects of computer ownership and Internet access on science achievement.

Source	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Corrected Model	6826.09	4	1706.52	17.76	.000
Intercept	10647138.11	1	10647138.11	110806.08	.000
Own a computer at home	3790.80	1	3790.80	39.45	.000
Access to Internet at home	137.74	1	137.75	1.43	.231
Access to Internet at school	45.14	1	45.14	.47	.493
Access to Internet somewhere else	55.3091	1	55.31	.58	.448
Error	281441.85	2929	96.09		
Total	66449022.30	2934			
Corrected Total	288267.94	2933			

R Squared = .024 (Adjusted R Squared = .022)

Several correlations were also performed to examine the computer attitude and achievement relationship. Although quite small, the results tended to be statistically significant and surprising. More specifically, the correlation between achievement and liking to use computers for learning mathematics was negative ($r = -0.072$, $p = 0.000$). So the students who liked using computers to learn mathematics tended to have lower math scores than the students who did not like using the computer as much for learning mathematics. A similar relationship was found in science, i.e., students who had higher levels of higher achievement did not like to use computers to learn science as much ($r = -0.052$, $p = 0.004$). This result can be explained in the following way: it is likely that lower achieving students who have positive attitudes towards using computers in mathematics and science do so because they only use the computer for lower order thinking skills such as drill and practice activities or games that do not challenge them enough. In contrast, higher achieving students might challenge themselves when using computers in order to excel in their subjects, which might lead to the more negative attitudes. Again however, these correlations are very small so they should be interpreted cautiously.

DISCUSSION

The purpose of this study was to re-examine the negative relationship patterns between computer-use and achievement found in TIMSS, and investigate why they exist. The first research question examined what types of computer use variables in classroom settings could explain a significant portion of the mathematics and science achievement variance in TIMSS-R. The overall results of the study showed that for the subject area of mathematics, students who owned a computer at home tended to have higher levels of achievement, while students who used computers frequently in their mathematics classes, who used e-mail to work with students in other schools on mathematics projects, and who had teachers who used computers frequently to explain ideas were more likely to have lower levels of achievement than the students who were not involved in those activities as frequently.

In the subject area of science, students who owned a computer at home also tended to have higher levels of achievement than the students who did not own computers. In addition, the students who frequently used the World Wide Web (WWW) for assessing information for science projects also had higher achievement levels than the students who were not involved in this activity as frequently. However, students who used computers frequently in their science classes, who used e-mail to work with students in other schools on science projects, and who had teachers who used computers frequently to explain ideas were more likely to have lower levels of achievement than the students who were not involved in those activities as frequently. Finally, it was found that having access to the Internet was not associated with higher or lower levels of mathematics or science achievement.

Before discussing the findings further, we believe that we need to briefly comment on the issue of "computer use" as identified in TIMSS studies, and argue that the term itself needs to be further defined. For example, take the question: Why do teachers who "use computers" to explain ideas have students with lower levels of achievement? Although no conclusive explanations can be produced by these results, it is likely that when teachers use the computer to present ideas to their students, they only do so at a surface level of cognitive processing by mainly presenting content on the screen. If this is the case, then this use of the computer is an example of an ineffective use of technology and one that does not take advantage of the many uses of computers. Technology and computers should be used as cognitive tools, to allow students to engage in collaboration, negotiation, conversation, and problem solving. Unless teachers use computers in more creative and effective ways (e.g., other than presenting text and pictures on the screen) one cannot expect that computer use will automatically boost the achievement level of students.

Another result of this study indicates that students who use e-mail to collaborate with students from other schools on science projects have lower achievement levels than the students that do not engage in this practice as frequently. A possible explanation for this result is that students in Cyprus do not really understand the nature of effective collaboration. This is likely the case since student collaboration is not encouraged or promoted in Cyprus schools. Therefore, the students who indicated that they use e-mail to collaborate with students from other schools might do so in order to copy homework answers, without worrying about actually understanding the material. In addition, the students who do not collaborate with students in other schools on such projects (since this is not common in Cyprus schools) might avoid doing so since they try to solve homework problems by themselves, which effort would lead them to a better understanding of their school materials, and to an increased performance in the subject areas of mathematics and science.

In contrast to the relationship between e-mail use and achievement, the students in Cyprus who used the Internet frequently to obtain information for science projects had higher levels of achievement in science. It is possible that the students who make the extra effort to search the Internet and obtain information on science topics are the ones who are truly interested in the subject. This might also indicate that these students also spend part of their free time on Internet and science related activities, which can obviously increase their understanding and their achievement levels in science.

One final result of this study indicated that the use of the Internet at different locations was not related to the science or mathematics achievement of the students. Due to the generality of this question, it comes as no surprise that no relationship between the two variables was found for either subject matter. For example, some students who have access to the Internet might use it to chat on the net, as well as play games. Other students however, might use their access to the Internet to search for science information on the web. Therefore, if the students do not specify the specific use of the Internet, the effect of the Internet on student achievement cannot be determined.

One of the main purposes of this study was to try to explain why there is a negative relationship between computer use and achievement. The above results and analysis make it difficult to determine whether it is computer use that causes lower achievement or if lower achievement determines the kinds and frequency of computer use. In similar studies Hedges, Konstantopoulos and Thorenson (2003) argued that "there is a very plausible rival hypothesis that could explain any relation found between computer use and achievement" (p. 38), i.e., that the students selected to use computers are those with lower achievement. If this is the case, "one might find a spurious relation between computer use and achievement, much as one finds that elementary school students who spend more time doing homework do less well in school" (p. 38).

CONCLUSIONS

Overall, the results of this study offer a preliminary glance at how computer use variables affect achievement in mathematics and science. The analyses that were performed included achievement as a dependent variable, where computer use was used to explain a portion of the variance of the student's achievement. This does not rule out the possibility, however, that a student's patterns of computer use can be influenced by their achievement (Hedges, Konstantopoulos, & Thorenson, 2003).

The overall results of this study have shown that a significant proportion of the variance in students' scores can be explained by computer use variables. Since this was not an experimental study, however, it is not possible to determine if there is a cause-effect relationship between the computer use variables and science or mathematics scores. What is significant, however, is that common variation between these variables exists beyond the chance level. The negative relationships may arise because of *how* computers are used in the classroom. For example, teachers may sometimes assign the use of the computer to students who are low achievers and have problems catching up with the rest of the class (Papanastasiou, 2002). In addition, poor or rural students are less likely to be exposed to higher order uses of computers than non-poor and suburban students.

Another explanation might be that computers are often used in pedagogically unsound ways. This study finds that one of the greatest challenges in computer use is not in how often they are used, but in the ways in which they are used. Educators sometimes fail to recognize the value of technology, and instead of taking advantage of what technology can do, use computers merely to accommodate traditional ways of teaching. Therefore, when the design of computer integration in the classroom is not based on solid instructional design, it is likely that computer use might end up being associated with negative achievement. These situations are even more likely to occur when there is a lack of adequate professional development in technology (this is a serious problem in Cyprus).

Taken together, the findings in this study indicate that computers are neither a panacea for problems facing the schools, nor a mere trend without impact on student learning. When correctly utilized, computers may serve as important tools for improving student proficiency in mathematics and science and the overall learning environment of the school. Therefore, the challenge for educators and researchers is to identify the procedures and activities that allow the computer to be used as a cognitive tool for students to construct knowledge, engage in problem solving, and use higher order thinking skills to increase their achievement in subjects such as mathematics and science.

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