Can Computer Use Hurt Science Achievement?
The USA Results from PISA

Elena C. Papanastasiou,[1,4] **Michalinos Zembylas,**[2] **and Charalambos Vrasidas**[3]

A surprising result of the Third International Mathematics and Science Study (TIMSS) is that computer use was negatively associated with high student achievement in some countries. More specifically, the students from all three countries who indicated that they use computers in the classroom most frequently were those with the lowest achievement on the TIMSS in 1995. For the purpose of this study, a similar comparison was made for 15-year-old U.S.A. students, based on the data from the Program for International Student Assessment (PISA). The results of this study show that it is not computer use itself that has a positive or negative effect on the science achievement of students, but the way in which computers are used. For example, after controlling for the student's socioeconomic status in the United States of America, the results indicated that the students who used computers frequently at home, including for the purpose of writing papers, tended to have higher science achievement. However, the results of this study also show that science achievement was negatively related to the use of certain types of educational software. This indicates a result similar to that found in the TIMSS data, which might reflect the fact that teachers assign the use of the computer and of educational software to the lower achieving students more frequently, so that these students can obtain more personal and direct feedback through educational software.

KEY WORDS: computer use; science achievement; Program for International Student Assessment (PISA); science literacy; computers; technology.

INTRODUCTION

Science education reform has emphasized the need for integrating computer technology into learning and teaching. The hype over technology in education grows as the Internet and computers are becoming increasingly common in classrooms. Various technologies such as videodisc, CD-ROM, videoconferencing, the World Wide Web, and other innovations have changed learning and instruction in all subject matter areas, especially in mathematics and science (Kelly and Crawford, 1996; Weaver, 2000; Windschitl and Andre, 1998; Yalcinalp *et al.*, 1995). However, in order for technology to be successfully integrated in the science curriculum, there are several factors that need to be in place. Access to technology is not enough. For example, teacher training is crucial for successful technology integration (Vrasidas and McIsaac, 2001). It is only when teachers have the knowledge, skills, resources, and support available that they will be able to integrate technology in the science curriculum in order to maximize its effects on teaching and learning.

Since educators first began to use computers in the classroom, researchers have tried to evaluate whether the use of educational technology had a significant and reliable impact on student achievement (Altschuld, 1995; Kulik and Kulik, 1991; Rocheleau, 1995). Clark (1983, 1994), a known critic of the impact of media on learning has argued for decades that the media does not influence learning in any way.

[1]Department of Psychology and Research in Education, University of Kansas, Lawrence, Kansas.
[2]Department of Teacher Education, Michigan State University, East Lansing, Michigan.
[3]Center for the Application of Information Technologies, Western Illinois University, Macomb, Illinois.
[4]To whom correspondence should be addressed: Department of Education, University of Cyprus, P. O. Box 20537, 1678 Nicosia, Cyprus; e-mail: papanast@ku.edu

He argues that when studies show that media influence learning, there are several confounding variables leading to the effects of these studies. Such variables include the instructional method employed, the content of instruction, and the novelty effect that new media might bring to the learning situation. Specifically, he argued that

> The best current evidence is that media are mere vehicles that deliver instruction but do not influence students' achievement any more than the truck that delivers our groceries causes changes in our nutrition. Basically, the choice of vehicle might influence the cost or extent of distributing instruction, but only the content of the vehicle can influence achievement (Clark, 1983, p. 445).

> Jonassen *et al.* (1994), however, have disagreed with Clark and argued that the debate should not focus on the role of media. Rather, we should examine the process of learning first, then the role of context and the kinds of environments and cognitive tools needed to support that learning. Only then should we consider the affordances of media for creating those environments or for providing those tools (Jonassen *et al.*, 1994, p. 38).

Reiser (1994) has also disagreed with Clark since he failed to acknowledge that certain instructional methods require certain media attributes. Therefore, not all media can be employed for achieving all instructional goals. Further, Jonassen *et al.* (1994) argue that the aspect of technology, as used in the media and learning debates, fails to account for the learner as an active constructor of knowledge since the media are perceived as mere deliverers of instruction.

What can be concluded from the debate above is that computer use and educational technology more generally, cannot be treated as a single independent variable that affects student achievement. Evaluating the impact of educational technology 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 analyses 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; Pedretti *et al.*, 1998; Shaw, 1998) those correlations do not necessarily imply cause–effect relationships. Based on the same rationale, nonexperimental studies that found negative relationships between computer use in school and achievement do not imply that computer use decreases student achievement (Papanastasiou, 2002; Papanastasiou and Ferdig, 2003; Ravitz *et al.*, 2002).

Given that it is not the mere use of the computer itself that matters, but *how* the computer is used, the purpose of this study was to determine the specific types of computer use activities that were associated with high or low levels of science achievement for 15-year-old students in the United States of America. Such results could provide useful 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.

Computer Use and Student Achievement

So far, much of the research carried out that examines computer use and student achievement, seems to emphasize that there is a positive correlation between these variables. There is plenty of evidence to indicate a positive relationship between technology and student achievement (e.g., James and Lamb, 2000; Sivin-Kachala, 1998; Weaver, 2000; Weller, 1996; Wenglinsky, 1998), although most of these studies emphasize that for technology to have an effect on student achievement it must be challenging, focused on higher-order thinking skills, the teachers must be capable of using and teaching it and have the appropriate support. In other words, examining computer use or technology, by itself is not enough to determine its effects on student achievement. What seems to be important, however, is the way in which technology is used. While a number of factors may need to be addressed to improve science education, the appropriate use of computers and other technologies is an important way to upgrade science teaching and learning.

Recently, there have been a number of studies that identified negative correlations between computer use and student achievement. For example, Ravitz *et al.* (2002) conducted a study to explore questions about whether there is a positive or negative relationship between achievement and student computer use. They also wanted to examine whether results vary by the amount of computer use in school

or at home. The measures of student achievement used were those of the Iowa Test of Basic Skills and the Test of Academic Proficiency (ITBS/TAP). In order to get data relating to technology use, they also used the School Technology Inventory that school administrators completed throughout the state of Iowa. The results of this study found that there is a negative relationship between in-school computer use and student achievement. However, the authors found a positive overall relationship between student achievement and computer proficiency, which was measured by the student's reported capability of using a variety of software. In turn, the student's software capability was related to the frequency of use in both, the home and the school.

Another study by the Educational Testing Service (ETS) reported that students who spent more time on computers in school actually performed slightly worse than those who spent less time on them (see Wenglinsky, 1998). The results from this study suggest that technology can help academic achievement, depending on how it is used and on how trained the teachers are in using technology. In addition, this same study found that technology affects fourth graders less than eighth graders, that the eighth graders who used computers primarily for "drill and practice" scored more than half a grade lower than students who did not use them in that way, and that drill software had little impact on the performance of fourth grade students.

Further, a surprising result of the Third International Mathematics and Science Study (TIMSS) is that computer use in the classroom was negatively associated with high student achievement in a number of countries, including Cyprus, Hong Kong, and the United States of America. The students from all the three countries who indicated that they use computers in the classroom most frequently, were those with the lowest achievement on the TIMSS in 1995 (Papanastasiou, 2002).

Finally, according to data from National Center for Education Statistics (2000), fourth graders whose teachers had students use computers to play learning games scored higher, on average, than fourth graders whose teachers did not. Also, eighth graders whose teachers had students use computers for simulations and models or for data analysis scored higher, on average, than eighth graders whose teachers did not.

These mixed results suggest that the relationship between technology and student achievement is not only complex, but is also constantly evolving. With the rapid increase in the number of computers at homes, in the workplace, and in schools, teachers also need to adjust their practices. However, careful research—both controlled and naturalistic—needs to take place first, to explore the complexities of this relationship. Consequently, this study attempts to examine common variation, and the direction of the relationships that exist between student science achievement (specifically, science literacy defined broadly as described below) and various types of computer use variables. These variables include the frequency of computer availability, comfort with computer use, and software use variables. Specifically, this paper considers the following questions: 1) After controlling for the student's socioeconomic status (SES), how are the variables of computer availability and computer comfort are associated with higher or lower levels of science literacy and 2) what are the types of educational software that are associated with higher or lower levels of science literacy, after controlling for SES?

METHODS

The Program for International Student Assessment (PISA) that was sponsored by the Organization for Economic Cooperation and Development (OECD) is a new system that focuses on the international assessment of 15-year-old student's capabilities in reading, mathematics, and science literacy. The purpose of PISA in 2000 was to assess the cumulative educational experiences of students who were 15 years of age at the time of the assessment, irrespective of the grade levels or type of institutions that they were enrolled in (Lemke *et al.*, 2000). The way in which science literacy was defined by PISA was: "The capacity to use scientific knowledge, to identify questions, and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (OECD, 1999, p. 25).

There were 32 countries that participated in the PISA assessment in the year 2000. Twenty-eight of those countries were OECD countries, while the other four countries (Mexico, Latvia, Liechtenstein, and the Russian Federation) were non-OECD countries. Within each country, there was a three-stage sampling procedure that was used in order to obtain the sample of 15-year-olds within each country. The first stage included the selection of a sample based on geographical areas within each country. The second stage included a sample of schools within each geographic

area, while the third stage included a sampling of students who were born in 1984 in those schools.

Because of the large amount of content that this assessment covered, no single student could be administered all the science items in view of the large amount of time that would require. Consequently, not all students were given the same test items. For this reason, individual comparisons between student scores are not possible. However, five plausible science values were produced for each student, all of which when combined were used as the dependent variable for this study. The scaling for the scores that summarized the achievement results was done with a mixed coefficients multinomial logit IRT model (Lemke *et al.*, 2000). Finally, weighting was used for the analyses to compensate for some of the oversampling that took place, to ensure that the results are representative of the students within each country. To take care of all of these issues, all of the analyses were performed with the use of the software WESTVAR 4.2.

For the purpose of this study, only the data from the United States of America will be used since the United States of America is a representative of an average achieving country on PISA, but whose students tend to use computers quite frequently in a variety of settings. The average performance of the United States of America on the science literacy measure of PISA was 499 points. The OECD national average was 500 points, and the United States of America did not perform significantly higher than this average.

A series of multivariate regressions were performed to try to explain the student's science literacy based on their patterns of computer use and exposure. However, one of the problems with the use of computer experience variables is that they can be confounded with the socioeconomic status (SES) of the students. For this reason, an indicator for SES that was created in the PISA database was added into all regression models to control for the effects of SES on student achievement. By entering the variable of SES in the models, the authors are acknowledging that SES could significantly affect the interrelationships between the variables that are examined in this study. However, this paper is more interested in the ways in which the kind of computer use itself can affect the science literacy of students. This is significant in the sense that these computer-use-variables could be purposely manipulated in the future (if such results are found) in order to help the students increase their levels of science literacy. Since the variable of SES is not a variable that can easily be manipulated

in an educational setting in order to enhance the student's educational experiences, its effects will only be examined descriptively in this study.

The United States of America sample consisted of 2129 students, of which 51.8% were female. In addition, the majority of the 15-year-old students that participated in this study were in grade 10 (57.3%); 38.9% were in grade 9, 2.9% were in grade 8, 0.4% were in grade 7, while 0.5% were in grade 11.

RESULTS

Three regression models were examined for the purpose of this paper. In all models, the dependent variable was the same, and that was the student's science literacy. The first regression model examined the computer availability for the students at different locations, and how well that was able to predict their science literacy. The second regression examined the comfort that the students had with computers, and the third regression model examined the frequency of different types of computer software used.

All regression models included the variable of SES as an independent variable to control for any SES effects that could affect the results. As will be seen in the analyses that follow, the variable of SES was always significant for all models. However, since examining SES is not a focus of the study, this result will not be scrutinized. The focus of this study is to examine the interrelationship between science literacy and computer use, while controlling for any differences that might be influenced by SES.

Computer Availability

The first regression model examined if the frequency of computer availability for the students at home, in school, in the library, or in another place could significantly predict the science literacy of these 15-year-old students. This overall model was significant ($F_{5,76} = 30.35$, $p = 0.00$) and it explained 18.0% of the variance of the dependent variable. These results indicate that the students who had a computer that was frequently available for them to use at home or in the library, were more likely to have higher levels of science literacy, after controlling for SES differences. More specifically, on the basis of the results that are presented in Table I, computer availability for the students at home and in the library were associated with higher levels of science literacy. However, computer availability at school and at another place could not significantly predict science literacy.

Table I. Frequency of Computer Availability

Parameters	F Value	β	SE of β	t for β coefficient	Sig.
Intercept		359.48	15.12	23.78	0.00*
SES	40.67	1.40	0.22	6.38	0.00*
Availability at home	42.88	13.06	2.00	6.55	0.00*
Availability at school	0.93	−2.78	2.89	−0.96	0.34
Availability in the library	23.78	12.15	2.49	4.88	0.00*
Availability at another place	0.21	−1.03	2.26	−0.45	0.65
Overall model fit	30.35				0.00*

$^{*}p \leq 0.05$.

According to the results that are presented in Table II, 68.13% of the students never had a computer available for them to use at home, and 50.78% of them never had a computer available for them to use in school. What is also interesting is that there were 21.6% of the students who indicated that they never had a computer available for them to use anywhere. That includes their home, school, library, or any other location. In addition, there were no students in the sample that indicated that they had a computer available for them to use every day at home. At the same time, only 7.4% of the students had a computer available for them to use every day at school, 9.61% had a computer available every day at the library, and 13.32% had a computer available for them to use every day at another place, although these other places were never identified on the PISA questionnaire.

Level of Comfort with Computer Use

Although computers have become extremely popular nowadays, there are still people who avoid them because of their computer anxiety (Carlson and Wright, 1993; Hakkinen, 1994; Igbaria and Chakrabarti, 1990). This anxiety might be caused by their unfamiliarity and lack of comfort with the use of computers. In such situations, people with computer anxiety who have to use computers might end up being more focused on their anxiety and on the unfamiliar technology that is in front of them rather than on the task that they have to perform on the

computer. As a result, they will be less focused on the task that they have to perform or on the knowledge that they have to learn through the computer. However, it is possible that as their level of comfort with the use of computers increases, they might be able to benefit more from this technology since they can actually focus on the task that they have to perform on it. Thus the purpose of the second regression model was to examine whether the level of comfort that the students felt with performing various activities on the computer could explain some of their variation in science literacy. If such a relationship is found, that could indicate that students who are more comfortable with the use of computers are more likely to be able to benefit from such technology.

The independent variables included in this regression model were those of SES, level of comfort with using a computer, level of comfort with using a computer to write a paper, and level of comfort with taking a test on the computer. Table III presents the results of this model that explained 17.7% of the variance of science literacy, and was overall significant ($F_{4,77} = 28.84$, $p = 0.00$). More specifically, the results for this model show that as the student's level of comfort with the use of computers for writing papers increases, their science literacy scores increase as well. None of the other variables in this model was successful in predicting the science literacy for students in the United States of America.

What should also be noted is that the beta coefficient for the variables of comfort with overall computer use, and comfort with taking tests on a computer is negative. This indicates that as the students feel more comfortable with using the computer or with taking tests on the computer, their science literacy scores tend to decrease. However, these coefficients were not significant, so they should be interpreted cautiously.

Table IV describes the way in which the students indicated how familiar they were with using computers. There were 68.13% of the students who indicated

Table II. Frequency of Computer Availability in Four Locations

	Home (%)	School (%)	Library (%)	Other place (%)
Never	68.13	50.78	52.69	44.65
Less than once a month	22.03	21.96	20.77	21.16
Between once a week and once a month	8.14	10.90	10.45	12.27
A few times each week	1.71	8.96	6.48	8.60
Almost every day	0.00	7.40	9.61	13.32

Table III. Comfort With Computer Use for USA Students

Parameters	F Value	β	SE of β	t for β coefficient	Sig.
Intercept		343.68	18.28	18.81	0.00*
SES	51.89	1.57	0.22	7.20	0.00*
Comfort with computer use	2.19	−7.31	4.95	−1.48	0.14
Comfort with using a computer to write papers	52.32	36.84	5.09	7.23	0.00*
Comfort with taking tests on a computer	0.25	−2.25	4.54	−0.50	0.62
Overall model fit	28.84				0.00*

*$p \leq 0.05$.

that they were not at all comfortable with using a computer, while only 51.01% were not at all comfortable with taking a test on the computer. There were also 68.9% who were not at all comfortable with writing papers on the computer. At the same time, only 1.71% were very comfortable with using a computer, 2.33% were very comfortable with writing papers on the computer, and 7.36% were very comfortable with taking tests on the computer.

Software Use

The third regression model examined whether the frequency and types of software use could explain the variation in the student's science literacy scores. The variables that were used for this regression (in addition to SES) were the use of the computer for playing games, for word processing, for spreadsheets, for drawing or graphics, and for using educational software. Just like in the previous models, the results of this regression show that the variable of SES was again significant.

As presented in Table V, the model was significant ($F_{6,75} = 10.13$, $p = 0.00$) and it explained 15.2% of the variance of science literacy. On the basis of this set of data, frequent use of word processing software was associated with higher levels of science literacy. However, the frequent use of spreadsheets and of educational software was associated with lower levels of science literacy.

Table VI describes the way in which the students responded in terms of their frequency of use of differ-

ent types of software. The software types that were never used by the smallest proportion of students were those of spreadsheets (10.09%) and educational software (10.40%). This is especially surprising since at the same time 30.58% of the students indicated that they never use the computer to play games. This might be related to the fact that the students who use computers in school tend to use them more for educational types of activities rather than for playing games. That might also be the reason why 23.43% of the students in the United States of America indicated that they use spreadsheet software every day, and 20.14% also use educational software every day. There were only 7.27% of the students who played games on the computer every day, 4.43% who used word processing software daily, and 13.54% who used drawing software daily.

CONCLUSIONS

The purpose of this study was to determine the type of common variation that exists between science literacy and the various types of computer use variables, and to try to explain this common variation. This relationship could offer a preliminary glance at how these computer use variables affect science literacy or vice versa. The overall results of this paper have shown that there is a significant proportion of the variance of the student's science literacy scores that can be explained by computer use variables. For example, the students in the United States of America who felt most comfortable with using computers to write papers, who had frequent computer availability at home and in the library, and who frequently used word processing software were more likely to have higher science literacy scores. Since this is not an experimental study, however, it is not possible to determine if there is a cause–effect relationship between the technology type variables and science literacy. Thus, it is not clear if the activities that are associated with computer use

Table IV. Frequency of Comfort Levels

	Using a computer (%)	Writing papers (%)	Taking tests (%)
Not at all comfortable	68.13	68.90	51.01
Somewhat comfortable	22.03	21.92	26.79
Comfortable	8.14	6.86	14.84
Very comfortable	1.71	2.33	7.36

Table V. Software use

Parameters	F Value	β	SE of β	t for β coefficient	Sig.
Intercept		443.32	22.15	20.02	0.00*
SES	31.86	1.51	0.27	5.65	0.00*
Games	0.26	−1.32	2.62	−0.51	0.62
Word processing (e.g. Word ® or Word Perfect ®	20.50	17.42	3.85	4.53	0.00*
Spreadsheets (e.g. Lotus 123 ® or Microsoft Excel ®	10.65	−11.54	3.54	−3.26	0.00*
Drawing, painting, or graphics	1.03	−3.16	3.11	−1.02	0.31
Educational software	3.84	−4.90	2.50	−1.96	0.05*
Overall model fit	10.13				0.00*

$^* p \leq 0.05$.

influence the student's science literacy, if this relationship is vice-versa, or if this common variation is due to another extraneous factor that has not been examined in this study.

What is definite and significant, however, is that common variation between these variables exist beyond the chance level. In addition, this study has found that frequent use of spreadsheet software, and of educational software was associated with lower science literacy scores. This negative relationship may arise because teachers 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). However, carefully controlled experimental studies would have to be performed to determine if this is really the case and what is the exact direction of this relationship.

IMPLICATIONS FOR PRACTICE

There are some statistics that have evolved from the PISA dataset that should not be ignored. First of all, in the United States of America sample obtained from PISA, there were 21.6% of the students who indicated that they never have a computer available for them to use anywhere; neither at home, nor in school, nor in the library nor at any other place. At the same time, there were 68.13% of the students who indicated that they were not at all comfortable with using a computer. Consequently, educators and researchers cannot assume that by installing computers with various types of software in schools, the achievement level of the students will automatically increase. The relationship between computer use and achievement is much more complicated than it might initially appear.

Although this paper does not provide any suggestions on how this achievement can be increased, it identifies the types and magnitude of the relationships that exist between some computer activities and achievement on science literacy. Carefully controlled experimental studies would have to be conducted to examine these relationships more closely. This would include describing where these interrelationships are coming from, and what are the types of cognitive processes that carry over from one activity to the next. Furthermore, in-depth ethnographic studies of students using computers could shed light on the complexities of human–computer interaction and science literacy formation, from the perspective of the students and their teachers.

In light of the findings in this study and other research that supports similar assertions, it must be emphasized that it is not computer use itself that automatically affects the student's achievement in school, but the "how" it is used that affects the quality of its

Table VI. Frequency of Software Use

	Games	Word processing	Spreadsheets	Drawing	Educational software
Never	30.58	25.51	10.09	15.83	10.40
Less than once a month	28.00	35.66	15.89	22.73	17.45
Between once a week and once a month	21.15	25.77	25.75	23.18	27.36
A few times each week	12.99	8.63	24.84	24.71	24.64
Almost every day	7.27	4.43	23.43	13.54	20.14

results. Computers in education should not be studied in isolation nor as "mere vehicles," but within the context and structure of programs and settings in order to examine how the synergy of technology, instructional methods, subject matter, and other contextual factors provide the conditions necessary to support knowledge construction and learning when teachers and learners are separated (Vrasidas and Glass, 2002). Only after these relationships are determined experimentally should teachers start considering the implementation of these activities in their classrooms. In addition, in order for technology integration to prove successful, teachers first need to be able to use computers themselves. They would then need to be able to integrate technology in a way that should benefit all students, regardless of their levels of SES, and regardless of their prior computer experience or whether they have a computer available for them to use at home or not. For this to happen, teachers need ongoing training and support.

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