SCHOOL COMPUTER USE AND STUDENT ACADEMIC PERFORMANCE IN SECONDARY SCHOOLS

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Abstract

This study examined the influence of school computer use frequency on the test scores of 15-year-old students in the United States using data from the 2003 Programme for International Student Assessment (PISA). A MANCOVA test found that students who had never used a computer at school had the lowest performance among all comparison groups, after controlling for students' socioeconomic status. Surprisingly, students who used the computer almost every day had lower achievement scores than students who used computers in moderate or low frequencies. These findings suggest that frequency of computer use may not be an adequate indicator of academic achievement. Results lead to the discussion of educational input aiming at promoting computer use at school as a tool for learning. A further study should be conducted to investigate the characteristics of students who use computers almost every day at school in order to interpret their lower achievements in math, science and reading.

Keywords: computer use frequency, academic achievement, secondary school, PISA

The use of technology in school learning and teaching has been a priority in the United States and most European countries during the last decade. There is a general belief that technology is beneficial for children's academic development. For example, National Association for the Education of Young Children's (NAEYC) *Position Statement on Technology and Young Children* acknowledged that technology can enhance children's cognitive and social abilities if used appropriately[20]. NAEYC also recommended that technology be integrated into the learning environment as one of several support options. Similarly, as part of the No Child Left Behind Act of 2001, the Enhancing Education Through Technology program seeks to improve student academic achievement in elementary and secondary schools through the use of technology. Consequently, a rapid growth of student's access to computers and internet has been invested in many K-12 schools in the U.S.[29]. The 2007 U.S. Census Bureau statistics suggested that as of 2004, about 72% of students between age 5 and 7 use computers at school and about 89% of students between age 11 and 14 use computers at school. The wide adoption of internet and computers in classrooms has changed learning and instruction in all subjects [16[18],[37]. Even though the growth of technology investment is considerable, the access and use of technology in U.S. schools is unbalanced, with schools mainly composed of African American, Hispanic or low socioeconomic status (SES) students tending to have the lowest access to the usages of technology [4],[6],[35].

In recent years, there has been an increasing interest in investigating the relationship of home and school computer usage on student achievement outcomes in elementary and middle schools. Research on this topic has provided mixed results. For example, Angrist and Lavy[3] investigated the impact of computer-aided instruction (CAI) intensity on Israeli students' achievement using a variety of estimation strategies (e.g., ordinary least squares, two-stage least squares). They found that using computers for instruction has marginally negative impact on math scores, but has no significant impact on Hebrew scores for 4th graders. No linear relationship between CAI intensity and test scores was found in either math or Hebrew for 8th graders. In a similar study, Rouse and Krueger[28] assessed the impact of an instructional computer program on low reading achievement students using four different measures of language and reading ability. Their study suggested that while using computers for instruction may improve students' language skills in some aspects, there was no evidence that these gains can translate into a broader measure of language and reading achievements. Moreover, Wenglinsky[38] explored the effectiveness of computer use using the 1996 National Assessment of Education Progress (NAPE). He found that computer usage was negatively related to mathematics achievement among 4th and 8th graders.

In contrast with the ineffective findings of computer use in students' academic performance, several studies provide preliminary evidence that computer use is positively related to academic performance. For instance, Lee, Brescia and Kissinger[18] examined the influence of the amount of after-school computer use on 10th grade students' academic achievements. Their results indicated that both computer use for school work and computer use for other than school work positively influenced students' math and reading scores as well as their classroom behavior. Moreover, other studies about the effectiveness of computer use for instruction have found positive relationships between computer use and students' academic achievements [9],[31],[32]. These latter studies provide evidence for the argument that technology-assisted instructional activities help students access a wider range of educational resources and capture the interest of students, which facilitates their understanding of the content, provides different ways of expressing knowledge and therefore have a positive influence on performance [10],[32].

The mixed results from previous studies make it difficult to generalize about the overall influence of computer use on improving students' learning. One of the reasons that cause this difficulty is that the samples used for computer effectiveness studies were not representative, they were either too small or focused only on a particular group (e.g., low achievement students)[28] Therefore, a large, nationally representative sample is needed to explore the effectiveness of computer use. Another limitation of previous research is that most of those studies were subject-specific research. Subject areas like math, reading, science or writing were examined separately when studying the relationship between computer use and academic performance [12].[28],[32],[38]. Since students' knowledge in subject areas is not isolated, but interrelated with each other to reflect students' knowledge and experience and apply them to solve cross-curricular problems and real-world issues[24], it is more proper and meaningful to use a collection of subject areas as a measure of student academic outcomes in this kind of research. The validity of studies on computer effectiveness can also be weakened by confounding school computer use with home computer use. Studies found that that children use computers most for nonacademic reasons in their after-school hours[11],[8]. Their performance can be reduced when they invest most time on features like games and other entertainment systems through computers or internet[36]. To better support students' learning using technology like computers, we should pay more attention to the effectiveness of school computer use and focus more on what conditions (e.g., frequency of computer availability and comfort with computer use) would be necessary for computer use at school to become effective for learning [10], [26].

A great number of studies have established an empirical relationship between students' family SES and their academic performance[5], [13], [34]. SES is characterized by an individual or family's economic, social standing, and educational background relative to others in the society [2]. [27], [30]. Dika and Singh[7] pointed that family SES influences student's academic performance by determining the location of the child's neighborhood and school, and providing home resources as well as the "social capital," that is, supportive relationships among schools and individuals (i.e., parentschool collaborations) that promote the sharing of societal norms and values, which are necessary to success in school. Therefore, it is necessary to give considerable attention to the role of family SES in determining student academic performance in educational studies. In addition, there is little available data that explain the interaction between financial conditions, computer use, and academic performance[18]. Therefore, an empirical study is needed to determine which condition of computer use (e.g., amount of computer use) that is most effective on students' learning, when other important variables (e.g., family SES) are controlled.

To better evaluate the effectiveness of computer use and overcome many of the limitations of previous research, a nationally representative sample, 2003 Programme for International Student Assessment (PISA) U.S. sample, was used for the current study. Since our primary goal was to explore how student characteristics (i.e., school computer use frequency, student SES) differentiate their academic performance, the data were analyzed from a single-level approach. Our purpose was to use multivariate analyses of covariance (MANCOVA) to explore the influence of frequency of computer use at school on the achievement scores (reading, math and science) of 15-year-old students in the United States. Specifically, do secondary school students who frequently use the computer at school perform better than those making a more limited use of it, after controlling for student's family SES background?

Method

Data Sources

Data for the present study were derived from the 2003 PISA U.S. sample. PISA is an internationally standardized assessment that measures students' capabilities in mathematics, reading, and science literacy. According to OECD (2001), PISA focuses on young people's ability to use their knowledge and skills to meet real-life challenges, rather than merely on the extent to which they have mastered a specific school curriculum. Beginning from 2000, PISA is administrated every three years to randomly selected groups of 15-year-old students in principal industrialized countries. The original 2003 PISA U.S. sample includes 5,456 participants; 445 cases (8.16%) of them have missing information of school computer use frequency and family SES. After listwise deleting the outliers and missing data, the final effective sample includes 5,003 students age 15 (girls = 2,551, boys = 2,451, invalid sex = 1) from 274 schools.

Variables

The dependent variables in the current study were literacy or academic achievement scores in math, science, and reading that were collected in the 2003 PISA. To reduce the length of the test, PISA applied matrix sampling, which splits one long test booklet into several short test booklets. Therefore, each student works on only one test booklet. Because students complete different tests, science achievement cannot be obtained using traditional test scores, but instead by using plausible values. Plausible values are multiple imputations of unobservable latent achievement for each student. Adams and Wu[1] provided details about how plausible values are created and used. The 2003 PISA used five plausible values to present each literacy achievement. According to the PISA data analysis manual (OECD, 2009), working with one plausible value instead of five will provide unbiased estimates of population parameters and the larger the sample is, the smaller imputation error will be. Since our primary research purpose was to explore the effectiveness of students' school computer use frequency and our sample size is relatively large, one plausible value from each domain was randomly selected by SPSS as a measure of students' academic achievement. Specifically, PV3MATH, PV1READ, and PV2SCIE were selected as literacy scores for math, reading and science.

Type of school computer use frequency was used as the independent variable in this study, while student SES was used as a covariate. The index variable ESCS from 2003 PISA data was selected as a measure of student SES. According to the PISA 2003 technical report (OECD, 2005), ESCS is the index of students' socio-economic and cultural status with higher values indicating a higher level of SES. It is derived from three variables related to family background: highest level of parental education, highest parental occupation, and number of home possessions. Type of school computer use frequency was used as a grouping variable. There were five groups, denoted 1 to 5, in this variable referring to: almost every day, a few times each week, between once a week and once a month, less than once a month, and never.

Analysis

The original data set consisted of 5,456 student scores. To produce valid and accurate results, cases with missing data and outliers were removed before analyses. According to the purpose and research question of the study, a MANCOVA test was conducted to detect if school computer use frequency groups differed on the set of student academic achievement variables when controlling for students' SES. According to Huberty and Morris[14], multivariate analysis can be applied when dependent variables are conceptually interrelated, and at least potentially, determine one or more meaningful underlying variates or constructs. The dependent variables in this study constructed a system of variables: they were a collection of conceptually interrelated measures of student academic learning outcomes. However, the variables in our study do not necessarily measure the same construct, which suggests this system can be characterized as an emergent variable system. This study also determined the relative contribution of the three measures to the resultant group differences, contributing to the use of a multivariate analysis.

Results

Prior to inspecting the MANCOVA results, it was of interest to determine whether or not statistical assumptions were tenable for MANCOVA. Both univariate normality and multivariate normality of dependent variables were examined within each group. Univariate normality test results are summarized in Table 1. Since the sample size in each group is large, a Kolmogorov-Smirnov test was used to detect if deviation from normality occured within each group, and a Bonferroni adjustment of .017 ([19], p. 126) was applied to control Type I error.

Results suggested that univariate normality was tenable for most of the variables in each group. However, non-normal distribution was found in reading for the group of almost every day (Kolmogorov-Smirnov = .045, $p < .001$) and between once a week and once a month (Kolmogorov-Smirnov = .039, $p < .001$). According to Stevens (2009), univariate normality is a concern if two or more variables deviate from normality. Since reading deviates from normality in just two groups, it appears non-normality will have a small effect on power, and hence was not of concern. Next, multivariate normality was inspected within each group. Both graphical plots and Mardia's multivariate statistics suggested a multivariate normal distribution of dependent variables for all the groups, except the groups of almost every day and between once a week and once a month. A statistically significant multivariate skewness was found in these two groups (see Table 2), indicating a concern about the assumption of multivariate symmetry.

After listwise deletion of univariate outliers (using a criterion of $| Z | > 3$)[25] and multivariate outliers (using a criterion of Mahalanobis distance > 16.26624) in these two groups, the final effective sample includes 5,003 students from 274 schools. Univariate statistics for the five school computer use frequency groups are summarized in Table 3.

Table 1: *Summary of Univariate Normality within Groups.*

Dependent variable within school computer use frequency groups	Kolmogorov -Smirnov	*p*	Shapiro-Wilk	*p*	Skewness	Kurtosis
Almost every day						
Math	.02	.20	.99	.39	-.05	-.22
Reading	.05	< .001	.99	< .001	-.37	.071
Science	.03	.07	.99	.04	-.05	-.39
A few times each week						
Math	.01	.20	.99	.06	.02	-.35
Reading	.02	.15	.99	.02	-.12	-.29
Science	.02	.20	.99	.02	-.08	-.38
Between once a week and once a month						
Math	.01	.20	.99	.34	-.04	-.24
Reading	.04	< .001	.99	< .001	-.29	.05
Science	.02	.20	.99	.01	-.10	-.35
Less than once a month						
Math	.02	.20	.99	.65	-.02	-.16
Reading	.02	.20	.99	.07	-.20	.04
Science	.02	.20	.99	.72	.01	-.22
Never						
Math	.04	.07	.99	.01	.07	-.65
Reading	.03	.20	.99	.12	-.13	-.35
Science	.02	.20	.99	.96	-.02	-.15

Table 2: *Summary of Multivariate Normality within Groups.*

School computer use frequency groups	Mardia's multivariate skewness	*p*	Mardia's multivariate kurtosis	*p*
Almost every day	.20	< .001	14.60	.24
A few times each week	.08	.15	14.35	.05
Between once a week and once a month	.10	.01	15.02	.95
Less than once a month	.08	.14	15.10	.76
Never	.13	.51	15.17	.76

Table 3: *Means and Standard Deviations of Primary Study Variables by School Computer Use Frequency Group.*

Variable	School computer use frequency group											
	Almost every day		A few times each week		Between once a week and once a month		Less than once a month		Never		Total	
	(*n* = 1,006)		(*n* = 1,112)		(*n* = 1,410)		(*n* = 1,061)		(*n* = 414)		(*n* = 5,003)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Dependent variable												
Math	484.47	89.56	490.37	95.18	500.89	89.02	488.52	87.51	460.21	86.28	489.26	90.59
Reading	493.96	91.25	501.82	98.30	514.62	93.13	505.33	94.44	478.68	92.90	502.68	94.71
Science	493.02	97.54	499.13	102.10	505.74	93.79	494.93	93.75	470.15	95.48	496.47	96.99
Covariate												
SES	.27	.90	.32	.91	.40	.87	.28	.84	.25	.90	.32	.88

Table 4: *Standardized Coefficient and Structure Coefficients for the Three Academic Achievement Variables.*

Variable	Standardized Canonical Coefficient	Structure Coefficient
Math	-.42	-.94
Science	-.36	-.93
Reading	-.30	-.91

Table 5: *Summary of Pairwise Comparison Groups with Adjusted Centroids Difference.*

Pairwise Group Comparison	Adjusted Centroid Difference	*SE*	*p*
Never vs. Almost every day	.26	.06	< .001
Never vs. A few times each week	.31	.06	< .001
Never vs. Between once a week and once a month	.39	.06	< .001
Never vs. Less than once a month	.32	.06	< .001
Almost every day vs. Between once a week and once a month	.14	.04	.001
Almost every day vs. A few times each week	.06	.04	.20
Almost every day vs. Less than once a month	.06	.04	.16
A few times each week vs. Between once a week and once a month	.08	.04	.04
A few times each week vs. Less than once a month	.01	.04	.89
Between once a week and once a month vs. Less than once a month	-.08	.04	.06

A preliminary analysis was conducted to test if SES was related to the set of academic achievement variables. Wilks Λ of .81481 was statistically significant (p < .001), which indicated that the covariate of SES did account for statistically significant variance in the set of academic achievement variables. In addition, the assumptions of homogeneity of regression and homogeneity of covariance matrices were each found tenable. Specifically, a preliminary analysis was conducted to check if there was any interaction between the type of school computer use frequencies and SES on the set of academic achievement variables. Wilks Λ for this interaction was .99683 and was not statistically significant (p = .198), indicating that the assumption of homogeneity of regression was tenable. Box's test was conducted to test the tenability of equality of covariance matrices assumption. Since Box's *M* is sensitive to rejecting homogeneity of covariance, a more conservative alpha level at .005 was applied to test the statistical significance (Huberty & Petoskey, 2000). Box's *M* test = 63.27 and was not statistically significant at .005 level, $F(40, 16{,}878{,}484) = 1.579$, $p = .011$. Although the sample sizes of the five groups were not equal (see Table 3), the log determinants of covariance matrix were approximately equal across groups (24.590, 24.555, 24.561, 24.480 and 24.542), with a pooled log determinate of 24.559, which further suggested the tenability of this assumption. Given the results from the above preliminary analyses, the MANCOVA assumptions were deemed satisfactorily tenable.

Next, a MANCOVA was performed to test whether school computer use frequency groups differ on the set of academic achievement variables after removing/adjusting for the influence of student SES. Wilks Λ = .984 was found to be statistically significant, $F(4, 4997) = 6.592$, $p < .001$, $\eta^2_p = .016$ (i.e., $\eta^2_p = 1 - \Lambda = 1 - .984$). The effect size indicates that knowing a student's school computer use frequency group accounted for 1.6% of the variance in the set of student academic achievement variables, after removing the effects of student SES. Structure coefficients and standardized coefficients for each academic achievement variable are shown in Table 4. The standardized canonical coefficients indicated that, in the order of strength, math, science, and reading each had contributed to the differences among the groups on the linear discriminant function, while the structure coefficients indicated that each academic achievement variable was strongly related to the linear function. Specifically, lower scores on the linear function reflected higher academic achievement, while higher scores on the linear function reflected lower academic achievement.

Follow-up pairwise comparisons were performed to determine how the groups' adjusted centroids differed. A Bonferroni adjustment of .017 ([19], p. 126) was performed for each pairwise comparison to protect against Type I error inflation. Pairwise comparisons indicated that the academic achievement of the students who had never used computers at school was found to be statistically significant lower than all other groups. Surprisingly, the academic achievement of students who used computers almost every day at school was statistically significantly lower than the students who used school computers between once a week and once a month (see Table 5).

Discussion

The present study was designed to investigate if students with high computer use frequency at school perform better than those who have limited use of it after controlling for their SES background. The results suggested that students who have never used computers at school have significantly lower achievement scores than those who use computers more frequently. This finding is consistent with the idea that student computer use at school has positive influences on academic performance. No significant difference on achievement was found between other moderate computer use frequency groups. Surprisingly, the students who used computers at school almost every day were found to have lower scores than the students who used computers less frequently at school (i.e., between once a week and once a month). One explanation is that low-achieving students were assigned to more frequent computer use than other student populations as a compensatory strategy, much as one finds that elementary school students who spend more time doing homework do less well in school [12]. In addition, students who use computers at school almost every day had the second lowest average SES scores among all the sample groups. These findings were unexpected and suggest that some unique characteristics exist in the students who use computers almost every day at school.

It is important to notice that PISA is a one-point-in-time cross-sectional assessment. While this design is appropriate for assessing academic achievement status, it is problematic for the inference of causal relations between variables measured at the same time point. Particularly, it is difficult to determine the direction of cause and effect. For example, it might be that computer use frequency creates achievement differences; it is also possible that students are selected to have certain patterns of computer use because of their achievement. A longitudinal study design that allows the examination of changes in achievement over time as a function of computer use frequency would provide better information about the causality.

Conclusions

It is crucially important to investigate the effectiveness of accessing or using computers in instructing students to improve their academic achievement because billions in federal funding has been spent for new computers, software, and teacher training, and politicians are proposing to input more money on expanding access to computers in schools in order to bridge the digital divide [17]. The present study adds supplementary information to the existing body of literature on the influence of computer use at school to students' academic performance. The noticeable low academic performance of students who had never used computers at school suggests computer access at school does improve students' learning. However, the weak correlation found in this study suggests the frequency of computer use might not be a good indicator of academic achievement after controlling for students SES. It was also found that students who use computers almost every day have lower achievement scores than those who use computers in moderate or low frequencies. These results suggest that simply increasing the educational input on computers during school may not produce the desired effect; instead, the quality of integrating computer use into effective instructional activities might play a more important role in influencing student academic outcomes. Future research on factors and characteristics that exist in this group of students are recommended in order to explain their low achievement performance.

This study provides important empirical findings by applying statistical methods with a proper treatment to a large scale database. However, this study was limited as it was based on a self-report of computer use at school. Thus, the reliability in this single item is in question since choices are subjective at best. An experimental design is recommended for future studies. This would then allow a more balanced design with respect to sample size and confounding variables, plus one could clearly define what is meant by frequency level. Despite this limitation, this study calls for the attention of incorporating effective instruction activities and the frequency of computer use at school to increase student academic achievements. Another advantage of this study was to use large national data for analyses. The national data set not only provided large random sample size which contributed to the representativeness of the sample, but also provided more accurate latent variables, therefore strengthening the reliability and validity of this study.

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