The Differential Effects of Computer Access Level on Student Achievement in the Early School Years

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A paper presented at the annual meeting of the American Educational Research Association, Montreal, April 1999.

As the cost of lightweight, notebook computers continues to decline, some school districts are beginning to experiment with the model of providing every student with their own notebook computer (Rockman et al., 1997). Typically, the rationale behind the model is an assumption that students will learn optimally when they have access to their own computer at any time and in any location. With ownership or unfettered access, the computer is always at students' disposal when they are ready to learn. This is not the case when they are sharing.

The purpose of this study is to examine the assumption that optimal learning occurs in classrooms where every child has access to their own computer. In particular, we studied a school district where a significant number of grade one to four classrooms, spread across the district, were given notebook computers in several pre-determined student-to-computer ratios. Our goal was to assess whether children in classrooms with one-to-one student-to-computer ratios achieved higher in language and mathematics than those in classrooms with higher student-to-computer ratios.

Theoretical Rationale

To date, no published studies have systematically examined the differential effects of various classroom student-to-computer ratios on achievement. Several studies have examined classrooms that had different student-to-computer ratios, including classrooms where all children had their own computer, but none of these studies showed a separate analysis by student-to-computer ratio.

In a recent study, Mann (1997) examined the impact of student access to computers in 55 New York school districts. He found that students in classes where there was a seven-to-one student-to-computer ratio achieved higher than in classrooms with the national average of nine-to-one and the New York State average of ten-to-one. Mann's report concludes that an increased access to technology supported and facilitated student achievement. In addition, these gains reached across schools and districts with different

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educational policies and socio-demographic backgrounds. This research is also considered extensive enough so that its results can be generalized beyond New York State.

In an earlier study with notebook computers, Gardner et al. (1993) attempted to assess the impact of high access to computers on learning. They provided portable notebook computers to over 235 students in nine schools in Northern Ireland to measure changes in their achievement in English and science. The researchers conclude that individual access to the portable computers resulted in higher levels of pupil motivation, harmonious and purposeful learning environments, and greatly accelerated information technology literacy among the pupils and teachers (Gardner et al., 1994). However, the authors claim that the impact of personal access to notebook computers on pupils' achievement was not significant, or at best marginal, over one school year. The authors do mention that the time period of one year was a major constraint for the experimental aspects of their research. As well, it must be noted that this study did not investigate differential effects of various classroom student-to-computer ratios on achievement. Rather, it focused on saturating selected classrooms with computers.

The Apple Classrooms of Tomorrow (Fisher, Dwyer, & Yocam, 1994) project pioneered the model of "saturating" selected classrooms across the country with computers for the purpose of studying their effects on students and teachers. In this decade long project, researchers studied classrooms where every student had their own computer—in some cases a notebook computer—and other classrooms where students shared computers. None of the studies considered the differential achievement of students according to level of access either; however ACOT researchers did report that overall writing, mathematics, and problem solving skills of students in ACOT classrooms were superior to their peers in regular classrooms.

The results of ACOT support the findings of Rockman et al. (1997), who studied 53 elementary, middle, and high schools that had large quantities of notebook computers. Some schools in the study had entire grade or class sets of notebook computers, while others had loaner sets of computers that teachers could borrow for their classrooms or only a few notebook systems in a classroom. Although the authors did not obtain separate achievement data by implementation model, they did report that each of the differing models yielded "encouraging outcomes that sustained the program and satisfied the schools" (p. iv). Additionally, the authors reported that across all models students collaborated more than they would normally expect, moved towards independent learning quickly, showed greater enthusiasm for schooling, and engaged more in problem solving. They note that "models which provided one-to-one and continuous access elicited the most praise and allowed the most time for developing integrated curriculum uses" (p. iv). They claim that students with full-time access to laptop computers apply more critical thinking skills, were more motivated and interested in core academic subjects and produce higher quality work, especially writing.

In a longitudinal study of student writing from grade three to the end of grade five, Owston and Wideman (1997) attributed, in part, the superior writing of students at the end of grade five to their unfettered access to computers, when compared to students who only occasionally used computers for writing. Students in one of the three computer-using classes had their own notebook computer toward the end of the second year for the duration of the study. Although a separate analysis of writing proficiency was not carried for the notebook computer class, anecdotal evidence from the teacher suggested that the notebook computers played a significant role in helping the students produce higher quality work. Each student having ready access to a computer was also considered a major contributor to superior writing in a recent study by Zakaluk and Haydey (1998). The researchers compared four classes of grade four students who used Apple eMate notebook computers half a day during a two-month intervention period to write biographies, to two classes of students who wrote biographies by hand. Because of the improved work quality, motivation, and positive attitudes of their students, teachers in the study wanted students to have full day access to the computers.

Earlier studies of student computer use were more ambiguous, particularly in the frequently studied area of word processing (e.g., Daiute, 1986; Gredja & Hannafin, 1992; Joram, Woodruff, Bryson, & Lindsay, 1992). None of these studies afforded students as ready access to computers as the more recent ones cited above. Therefore, one might speculate that the differences between the results of these two sets of studies might be explained, in part, by access to the technology. The salient question still remains as to what level of access students need to consistently benefit from computers. We investigate this question in this paper.

Method

Twenty-three classes of students in grades one to four located in seven schools in a middle income urban school district participated in the study (n=379). At each grade, classes were supplied with Apple eMate notebook computers in the following student-to-computer ratios: one-to-one, two-to-one, and four-to-one (except grade one where a one-to-one ratio did not seem feasible and grade four where only a one-to-one ratio was desired by the school). A comparison class that did not have any eMates was also selected from one of the participating schools at each grade. Teachers were provided with inservice training on the technical aspects of the use of the eMates prior to the start of the school year, and throughout the year, they participated in workshops to share curriculum integration ideas.

At the beginning and end of the school year all students wrote the writing subscale of the Canadian Tests of Basic Skills, a Canadian version of the popular Iowa Tests of Basic Skills. In addition, portfolios of students' language arts work were collected three times during the year: at Christmas, March Break, and in June at the end of the school year. These portfolios were scored using a holistic assessment of writing quality described by Pappas, Kiefer, and Levstik (1991) to provide measures of writing fluency. In the Pappas et al. (1991) procedures, evaluation of writing is separated into *message* qualities, which focus on the meaning and content of a text, and *medium* qualities, which deal with the form or surface features of the writing. In the present study, writing portfolios were rated on both dimensions using six point scales, with a score of 1 representing very little or none of the quality being assessed, and a score of 6 representing a high degree of proficiency for the quality being assessed. For message analysis, the following features were considered: general writing development (writing in the first, second, or third person), sense of audience, purpose for writing, story quality (overall meaning, unity, detail), story structure (setting, character, plot, outcome), lexical choice, cohesion (logical flow), and ability to share feelings. For medium analysis, the following features were considered: grammatical structure, spelling, usage, mechanics, and length. The rater was a retired language arts consultant with extensive formal training and experience in portfolio analysis. In an earlier study we conducted using the same rater, the inter-rater reliability was found to be .887, indicating a high level of rating reliability (Owston & Wideman, 1997).

In addition to these measures, one of three trained observers visited each classroom at least twice a month at different times and days to observe using a checklist based on the work of Gearhart et al. (1994). The checklist inventories such factors as classroom organization, symbol systems used by teachers and students, instructional intent, resources in use, and student focus and engagement. The researcher observes the class for one minute then checks, on a machine-readable sheet, the presence or absence of a list of characteristics. After a few minutes pause, the process is repeated. Up to ten observations can be made in a one-hour class. The observers were also asked to write field notes based on the observation session. Multiple observations at different times and days need to be made for each selected class. A copy of the checklist is provided in the Appendix.

Results

Analyses of writing scores

A 1 X 4 repeated measures MANCOVA was performed using the two student writing quality scores (medium and message) assigned to each students' writing portfolio for three different time periods as the (6) dependent variables (DV), the Writing subtest score on the Canadian Test of Basic Skills as the covariate, and the computer ratio grouping (no eMates in class, one eMate per four students, one eMate per two students, or one eMate per student) as the independent (categorical) variable (IV).

No univariate or multivariate outliers were found at $\underline{p} = .001$. The Box's M test ($\underline{p} > .001$) along with the examination of both the residual plots for the dependent measures and spread versus level plots of the variance of the dependent variables by group indicated sufficient homogeneity of the variance-covariance matrices for a MANCOVA analysis. Scatterplot analysis showed adequate linearity of the DV and DV-covariate variable pairs, and sufficient homogeneity of regression for MANCOVA was indicated by the lack of significance of the IV by covariate interaction ($F(6, 740) = 1.619$, $\underline{p} = .138$). High cell counts in the design ensured robustness of the analysis to violations of univariate and multivariate normality (total $\underline{N} = 379$). As Mauchly's test of sphericity indicated that the variance-covariance matrices of the orthonormalized transformed dependent variables were nonspherical ($\underline{p} < .001$ for both message and medium DVs), the Greenhouse-Geisser adjustment to validate the univariate F's was applied to all within-subject effects tests, in order to correct for inflated Type I error rates.

Using Wilk's criterion, the Writing CTBS subtest covariate was significantly related to the combined DVs ($F(2, 370) = 27.24$, $p<.001$), although the association was modest (partial eta squared = .152). The combined writing assessment DVs were associated with the computer ratio IV ($F(6, 740) = 2.32$, $p <.05$), but the effect size was very small (partial eta squared = .047). A significant multivariate main effect was also found for time (the within-subjects factor): $F(4, 1494) = 7.02$, $p <.005$. The time by computer ratio interaction for the combined DVs was also significant ($F(12, 1494) = 2.63$, $p<.005$). Once again, these two associations were very weak, with partial eta squared effect sizes of .018 and .021 respectively.

Univariate analyses of covariance showed a few significant effects of interest. A main effect for time was found for both the medium ($F(1.788, 668.7) = 12.33$, $p<.001$) and message ($F(1.807, 675.7) = 10.30$, $p<.001$) measures, although the effect sizes were very small (partial eta squared = .032 and .027 respectively). Figures 1 and 2 plot the estimated marginal means (after adjusting for the covariate) of the medium and message scores for each of the three testing periods broken down by computer ratio category. Means for all groups can be seen to increase slightly over the three testing periods. The computer ratio grouping also had a significant effect for both measures (medium: $F(3, 374) = 7.17$, $p<.001$; message: $F(3, 374) = 4.57$, $p<.005$). Effect sizes were minor (partial eta squared values of .054 and .035 respectively). Examination of the figures shows that the means for the four computer ratio groupings maintain some differentiation over time on both measures. However there is a significant computer ratio by time interaction for both dependent measures (medium: $F(5.364, 668.7) = 4.005$, $p <.05$; message: $F(5.421, 675.7) = 4.335$, $p<.05$). Again, effect sizes for both were small (partial eta squared values of .031 and .034 respectively). In the Estimated Means profile plots for the dependent measures shown in Figures 1 and 2, the interaction reveals itself in the slightly different patterns of mean score shifts over the three time periods for each of the IV groups, with the students in the 2:1 computer ratio group showing slightly greater gains in writing fluency over time than the others (.898 gain on medium scale, .852 gain on message scale), and the students in the control group showing the least gains in fluency over time (.454 on medium scale and .403 on message scale).

Insert Figures 1 and 2 about here

Dependent measure contrasts were made on the grouping effect using a simple contrast pattern in which each of the experimental groupings was contrasted with the control group. After correcting for inflated type I error due to multiple tests, only the contrast between the 4:1 and control groups proved significant for either measure (medium: $p<.001$; message: $p<.001$). The contrast estimates were -.672 and -.607 respectively, indicating that the 4:1 means were .6-.7 points lower on average on the 6 point scales than the control group. (It was not possible to run contrasts on the computer ratio by time interaction.)

Observational ratings

Table 1 gives the names and explanatory labels for the dichotomous variables derived from the observational scale used for assessing classroom activities, as well as percentage response rates by variable value for the control versus pooled experimental groups contrast (see discussion below).

Insert Table 1 about here.

The cases for the data analysis were the one-minute rating periods. In each period, observers coded for all behaviors and activities on the checklist scale that were observed. Several of the variables in Table 1 are derived from the more detailed rating scales by pooling the counts for several related observational categories into a superordinate coding. For example, the co_group variable was not directly observed; the count is the sum of the two subordinate categories that were rated, cooperative group work and collaborative group work. The collapsing of categories was necessitated by the statistical requirements for valid logistical regression of the observational data on the grouping variable. It partially eliminated problems engendered by empty cells and low cell counts in the variable matrix that had resulted in model overfitting and quasi-total separation of groups, making results uninterpretable. The other derived categories and their subordinate observation categories in this analysis are: co_pair - collaborative and cooperative work in student pairs; dir_inst - teachers providing information, questioning, answering questions, directing work, correcting and grading, testing, or reading to students; fac_inst – teachers monitoring work, assisting, conferencing, joint problem-solving; nonc_res – students using various non-computer based resources (texts, own work, etc.); comp_res – students using various computer resources – software, printers, word processors, etc.

Table 2 gives the means for the three continuous variables on which student activity in the classroom was rated once for each observational segment.

Insert Table 2 about here

Both the continuous and dichotomous variables were used as predictor variable inputs in a stepwise logistical regression on computer ratio grouping. The purpose of the regression was to determine to what extent the optimal combination of the variables discriminated between eMate ratio groupings (expressed as the regression equations' ability to correctly assign group membership for a case based on the observational variable values) and to determine what the relative contributions of the individual variables was to making that discrimination.

The model overfitting problem discussed above required further analysis adjustments beyond those already mentioned. In order to reduce the number of cells in the design further and so eliminate the overfitting, the three eMate using groups were collapsed into one, resulting in a dichotomous grouping variable (eMate versus control) which served as the outcome variable for the logistic regression. Given the somewhat weak but statistically significant eMate ratio by time interaction favoring the eMate groups relative to the controls, this seemed the best compromise from a substantive perspective, as it allowed for a search for any observational variables that significantly discriminate across the control-eMate dimension.

All the variables listed in Tables 1 and 2 were entered into an SPSS binomial logistic regression run using the conditional stepwise procedure, with the dichotomous grouping variable as the outcome or dependent variable. A test of the final model generated against a constant-only model was statistically reliable, Chi square (10, N=1157) = 208.554, $\underline{p}$<0001, indicating that the predictors, as a set, reliably distinguished between the control and eMate groups. The variance in group membership accounted for is modest but not trivial, with Nagelkerke's R^2 = .265. Prediction success was mixed, with 97% of the cases belonging to the eMate group successfully predicted, but only 25% of the cases belonging to the control group being correctly assigned. Due to unequal N, however, the overall prediction rate was quite high: 83%. The Hosmer and Lemeshow Goodness-of-Fit Test done on the final model indicated that it did not significantly differ from the perfect (observed) model (Chi Square = 7.8414, 8df, , $\underline{p}$=4491), indicating a good model fit.

Table 3 lists the variables entered into the final model in the reverse of the order of entry, and shows the (unique) significance of each term in improving the model fit when added with all other terms already in the model. R indicates the partial correlation of the predictor with the outcome (after adjusting for all other predictors). Given the coding used, a negative Beta for a significant term indicates that a case coded "yes" on that variable is significantly less likely to belong to the computer group. (Beta coefficient signs for each variable are identical to the sign of the corresponding partial correlation.) The odds likelihood ratios are in the column "Exp(B)."

Insert Table 3 about here

The most dramatic predictor of whether observations were made in an eMate or control class was subject coding for Language Arts. If LA were being taught in a class, that class was over three times as likely to be an "eMate class" than if it were not. Other variables that has a strong positive association with eMate classes included "medium length of expected response" (2.5 times more likely to be an eMate class); "teacher engaged in management and discipline" and "non-computer resources being used" (both 2 times more likely). The dramatic increase in odds signified by the Exp(B) of 6 for the computer resource in use is of little interest since this is an expected consequence of the fact that most control classes did not have computer resources to use. What is of interest is that computer resource use correlates so weakly with group membership (.18), and that use of non-computer resources is also associated positively with the eMate group. This reflects the fact that computer resources were only in use about 37% of the time in eMate classes.

Several variables are negatively associated with the eMate group: classes in which the teacher is facilitating individual, pair, or small group work, or engaging in direct instruction are about half as likely to have eMates. The same is true when the instructional intent of students' work is at a medium level of applying knowledge, and when the classroom is organized in groups.

Discussion

The significant result for the computer ratio by time interaction for the repeated measures Mancova and the univariate tests indicates that statistically reliable differences were found in the rate with which writing fluency as measured by the medium and message scales improved over time. Taken together with the means estimates, it appears that students in classes where there was a 2:1 student to eMate ratio showed the greatest improvement in their writing over time, and the control group students the least, with the other two eMate groups showing intermediate levels of improvement. As the effect sizes for the interaction are small, care must be taken not to over-interpret this result; it accounts for a very small portion of the score variance. But given delays in distributing hardware and teacher unfamiliarity with the machines that resulted in the eMates not being in regular use until late in the first term, this finding is encouraging.

The finding is also congruent with teacher reports of student writing accomplishments. For example, KL, a 1:1 ratio teacher, describes what she was able to achieve with her class:

> This year the students were able to publish numerous stories using their eMates and present them in various formats (picture books, anthologies, short stories, projects). The length of writing assignments increased throughout the year. In several incidents, students who had difficulty expressing ideas on paper felt more motivated to type them directly on their eMate.

Other teachers reported increased length of stories, neater more refined finished products, and students showing a strong pride of ownership as a result of using the eMates. LN, another 1:1 teacher, reported that she had students in grade 4 writing stories of "many typed pages in length" and that "they were willing to frequently go back and edit and revise their work."

A set of the observational variables proved to be a significant and substantively important, although modest, predictor of case grouping on the control-eMate dimension, accounting for over a quarter of the variance in grouping. Correlations of individual variables included in the optimal regression solution with grouping outcome were fairly low, but still of interest. Odds ratios indicate that several have a substantial relationship to group inclusion. The eMate classes were three times as likely to be engaging in Language Arts activities when observed. What is unclear is whether or not this reflects a greater overall rate of Language Arts involvement in these classes or is merely a demand characteristic of the observers' presence in the room (i.e., teachers desiring to impress or please the observer by having students use their eMates for language activities when they are present).

The greater engagement in management and discipline by eMate class teachers revealed in the analysis was more of an artifact of the 4:1 ratio classes than the 1:1 and

2:1 classes. The observed counts show that almost twice as much time was spent disciplining students in the 4:1 ratio classes as compared to the 1:1 ratio classes. Teacher reports at the end of the school year support this observation. For example, LS, a 1:1 teacher, describes what she observed when every student had his or her own laptop:

> It is amazing the concentration when each student has his or her own machine. In computer class where they must work in partners the noise level and the time on task are not at a productive level.

Contrast this to BR (4:1) who found that when every student didn't have a laptop it was more difficult keeping the students in the group who weren't using the eMate on task:

> Many kids were more focused when working with the eMate. During group activities, those not using the eMate at a particular time needed reminders to stay on task.

This situation might also explain the observed slight decrease in the amount of time teachers spent providing direct instruction and facilitating instruction with small groups and individuals compared to the control group.

As to the greater tendency of students to engage in work with a "medium" length of expected response, this may be indicative of a common feature of eMate-based assignments given in class. And the fewer number of group based activities seen in eMate classes may be a consequence of the greater amount of time given to working on eMates individually or in pairs in those classes.

It needs to be kept in mind that the relative weakness of the effects on achievement found in this study may be to some degree a reflection of the relatively short duration of the use of the eMates in these schools. There is considerable evidence that teachers need substantial amounts of time to learn about and explore approaches to using complex technology in the classroom (e.g., Owston & Wideman, 1997). Gardner et al. (1994) felt this constraint negatively affected outcomes in their yearlong investigation into notebook use in schools. While Zakaluk and Haydey (1998) noted greater work quality in their short-term trial of eMates, the eMate use was very intensive (1/2 of every day) and strongly focussed on writing, whereas in the present context eMate use was much more intermittent and incorporated many non-writing activities. In the next phase of this work, we will be examining the writing ability of the same cohort of students after they have been using eMates for writing for two schools years in order to uncover the longer-term effects of differential access.

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Appendix

Observation Checklist

Observer ______________________________
School/Grade __________________________
Date _________________________________

Factor	1	2	3	4	5	6	7	8	9	10
1. Primary Subject Focus										
Language arts										
Mathematics										
Other										
2. Classroom Organization:										
teacher-led										
independent work										
group/cooperative										
group/collaborative (jointly produced product)										
pair/collaborative										
pair/tutoring										
student-led										
3. Instruction and Support Roles:										
Directing instruction (for only teacher-led classrooms):										
explain/provide information										
question (for comprehension or examination)										
answer students’ questions										
direct students’ work (step by step)										
correct/grade										
test										
read to students										
Facilitating instruction (for only independent, cooperative, and collaborative work):										
monitor/rove to help students at work										
facilitate discussion										
conference										
joint problem-solve										
Management and Discipline:										
manage										
discipline										
Not present (with the group currently observed)										
4. Symbol Systems Serving Key Instructional Functions in the material the teachers make available to students:										
verbal										

numeric										
math symbols										
graphic										
chart										
diagram										
pictorial										
model										
map										
puzzle/pattern										
motor/action										
music										
objects										
5. Instructional Intent expected of students' work:										
low (emphasis on rote recall)										
medium (requiring inference or problem solution within a well-structured problem context)										
high (requiring inference and construction of a response in a less structured task context)										
Length of the Responses Expected of Students:										
repeat/copy (student replicates provided material exactly - e.g., spelling practice, cursive practice, keyboarding drill)										
select (multiple choice, true/false)										
short (no more than a sentence in length)										
medium (no more than a paragraph in length)										
long (multiparagraph)										
6. Symbol Systems Students Use in Their Work:										
verbal										
numeric										
math symbols										
graphic, chart										
diagram										
pictorial										
model										
map										
puzzle/patters										
motor/action										
music										
objects										

7. Resources in Use:										
Textual: textbooks (textbooks, assigned literature, workbooks/worksheets, tests)										
Print resources (library books, reference books, periodicals, reference/help sheets)										
materials (paper, file cards, blackboard)										
student's own work										
Hands on materials										
Computer word processing software										
Computer graphics software										
Computer spreadsheet software										
Computer other software										
Other technology: printer, scanner, probes, beaming, docking										
8. Students' Responses to the Activities:										
Appropriateness of students' behaviour (percentage of students who are on task)										
Students' focus and engagementment (on a 1-low to 5-high scale)										
Productive student-student interaction (percentage of students who are talking with one another about their work)										

Figure 1

Adjusted Means for Medium Scale

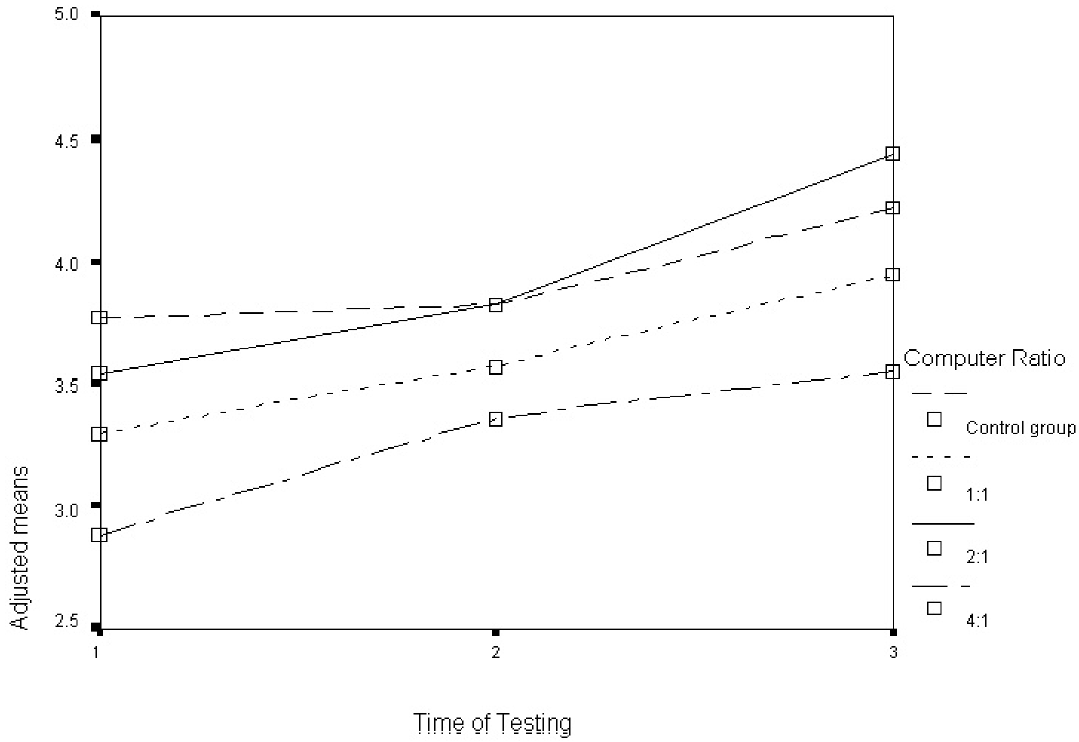

Figure 2

Adjusted Means for Message Scale

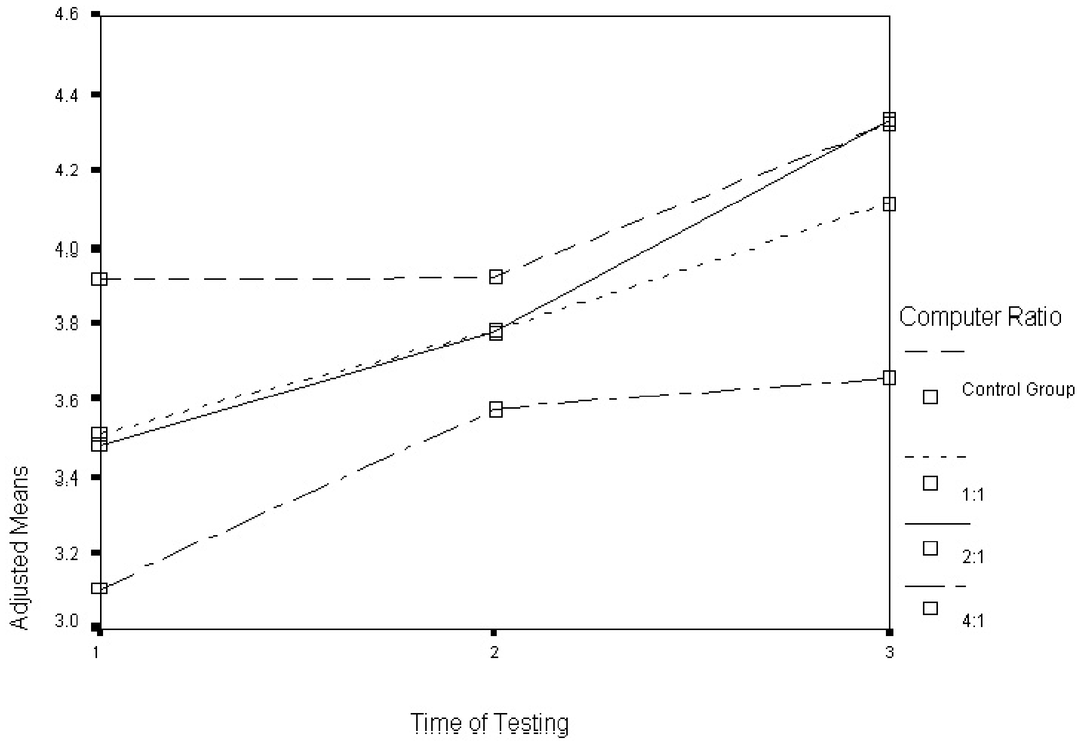

Table 1

Observational Variable Value		Emate usage: Control Col %	Emate usage: Emates Col %
Subject: Language arts [q1lang]	No	79.2%	44.9%
	Yes	20.8%	55.1%
Subject: Mathematics [q1math]	No	70.7%	85.6%
	Yes	29.3%	14.4%
Other subject [q1other]	No	73.8%	83.8%
	Yes	26.2%	16.2%
Instructional Intent: Low (receiving facts, comprehension) [q5low]	No	79.2%	76.3%
	Yes	20.8%	23.7%
Instructional Intent: Medium (starting to apply knowledge) [q5medium]	No	56.8%	65.1%
	Yes	43.2%	34.9%
Instructional Intent: High (analysis, synthesis, evaluation) [q5high]	No	84.9%	76.5%
	Yes	15.1%	23.5%
Expected responses: Repeat/copy (student replicates provided material exactly) [q6repeat]	No	81.1%	83.1%
	Yes	18.9%	16.9%
Expected responses: Select (multiple choice, true/false) [q6select]	No	86.1%	89.3%
	Yes	13.9%	10.7%
Expected responses: Short (no more than a sentence in length) [q6short]	No	79.8%	83.6%
	Yes	20.2%	16.4%
Expected responses: Medium (no more than a paragraph in length) [q6medium]	No	95.6%	83.3%
	Yes	4.4%	16.7%
Expected responses: Long (multiparagraph) [q6long]	No	91.8%	86.6%
	Yes	8.2%	13.4%
Classroom organization: Teacher-led & independent work [co_other]	No	39.4%	31.0%
	Yes	60.6%	69.0%
Classroom organization: Pairs [co_pair]	No	95.0%	93.0%
	Yes	5.0%	7.0%
Classroom organization: Groups [co_grp]	No	88.3%	92.4%
	Yes	11.7%	7.6%
Teacher directing instruction [dir_inst]	No	60.9%	67.5%
	Yes	39.1%	32.5%
Teacher facilitating instruction [fac_inst]	No	67.8%	71.3%
	Yes	32.2%	28.7%
Teacher managing and disciplining [man_disc]	No	76.3%	72.4%
	Yes	23.7%	27.6%
Students using noncomputer resources [nonc_res]	No	39.4%	43.1%
	Yes	60.6%	56.9%
Students using computer resources [comp_res]	No	87.4%	62.4%
	Yes	12.6%	37.6%

Table 2

	Emate usage	
Continuous Variable	**Control**	**Emates**
Appropriateness of students' behaviour (% of students who are on task) - whole class	92	92
Student focus and engagement (rated on scale of 1 to 5) - whole class	4.674	4.627
Productive student-student interaction (% of students who are talking with one another about their work) - whole class	18	21

Table 3

Term Removed	Log Likelihood	-2 log LR	df	Signif. of Log LR	R	Exp(B)
Q1LANG	-492.585	61.183	1	.0000	.2169	3.755
Q5MEDIUM	-468.776	13.566	1	.0002	-.1000	.542
Q6MEDIUM	-467.045	10.105	1	.0015	.0758	2.556
CO_GRP	-463.917	3.847	1	.0498	-.0412	.581
DIR_INST	-464.782	5.579	1	.0182	-.0557	.573
FAC_INST	-473.091	22.196	1	.0000	-.1308	.390
MAN_DISC	-467.580	11.173	1	.0008	.0883	1.986
NONC_RES	-465.712	7.438	1	.0064	.0688	2.043
COMP_RES	-484.887	45.788	1	.0000	.1761	6.094
Q9CINTER	-464.003	4.019	1	.0450	.0403	1.006