Learning with eMates in Etobicoke

Final Project Report

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Abstract

This study examines the assumption that optimal learning occurs in classrooms where every child has access to their own eMate laptop computer. Grades one to four classrooms in six schools of an urban school district were provided with laptop computers in three different student-to-computer ratios (1:1, 2:1, 4:1). Throughout the school year three samples of student writing were taken at equal intervals and classrooms were regularly observed. Writing samples were also collected from control classrooms in the same schools that did not have access to computers. A MANCOVA analysis of holistic ratings of writing samples revealed that by the end of the school year there were significant differences between the four groups in their development of writing proficiency ($p < .05$), with students in the 2:1 ratio classes showing the greatest average gains, followed closely by the 1:1 and then the 4:1 classes. The control group students demonstrated the least improvement.

A logistic regression analysis of the observational data indicated that in classes with eMates, teachers were less likely to be engaging in direct instruction and more likely to using a resource-based, project-oriented pedagogical strategy. They also spent more time managing student activities.

Initial plans were to study the progress of the first-year cohort of students over a second year as they worked in classes with the same student-to-computer ratios as they had previously. This proved impossible for two reasons: the low number of students who were placed in classes with the same ratio in both years, and the elimination of 4:1 ratio classes by the participating schools. Consequently a partial replication of the first year study was undertaken in year two without a 4:1 ratio group. Students in the 1:1 ratio classes showed an average 35% greater improvement in their writing over the year than those in the 2:1 classes, while those in non-eMate classes showed the least improvement.

Analysis of data from a questionnaire completed at the end of each year by the eMate teachers indicated that nearly all of the teachers considered eMate use educationally valuable and wished to continue it. Benefits noted included greater student motivation and on-task focus, increased length

of student writing, and an increase in students' ability and willingness to revise and edit their work. Teachers found that the technology facilitated the teaching of editing skills, and that its use promoted a shift away from directive whole-class teaching techniques towards more independent and cooperative student learning. In classes where eMates had to be shared, students were generally seen to be cooperating effectively, although some competition was also noted. A general preference for full-class sets of eMates was indicated; several teachers mentioned that maintaining two sets of classroom activities simultaneously (for those on and off the eMates) was burdensome and required more management time. Technical difficulties with the eMates and limitations in the available support (both pedagogical and technical) were also cited as drawbacks of the project.

Our results indicate that eMate deployment at either the 2:1 or 1:1 student: computer ratios can be effective in enhancing writing quality, although given the teachers' perspectives on their experiences, the provision of a full class set of computers would be appear to be preferable. While the eMates' impact was found to be relatively modest in the present project, the level of student writing improvement could very likely be increased in future implementations by deploying more reliable technology that makes use of a standard operating system known to teachers, and by providing a greater degree of technical and curricular support to the classroom.

Table of Contents

Introduction:

Computer Access and Student Achievement in the Early School Years

A recent international survey of computer policies reported that most developed nations are striving to provide every student with access to their own computer (Pelgrum & Anderson, 1999). Japan, for example, has a formal policy goal of reaching a one-to-one student-to-computer ratio in junior and senior secondary schools and a two-to-one ratio for elementary schools. In North America, as the cost of computers continues to decline, several states (*e.g.*, Texas and Ohio) have debated the notion of supplying all of their students with lightweight notebook computers (Chapman, 1998). Moreover, some school districts (*e.g.*, Beaufort County, South Carolina) have begun to experiment with the model of equipping every student with their own notebook computer (see Stevenson, 1999), following the lead taken by pioneering "laptop schools" such as Methodist Ladies College in Australia that has had one computer for each of its 2000 students and teachers since 1994 (see Stager, 1998). Typically, the rationale behind the model of one computer for every student is the assumption that students will learn best when they have access to their own computer at any time, in any location (Rockman et al, 1998). With ownership or unfettered access, the computer is always at the students' disposal when they are ready to learn. This is not the case when they are sharing with other students.

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. We focused on student writing competency as a proxy for achievement because word processing was the one application for which all teachers in the study planned on using the laptop computers. Our research goal was to assess whether children in classrooms with one-to-one student-to-computer ratios

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became more proficient writers at the end of two school years than those in classrooms with higher student-to-computer ratios.

Research on Student Access to Computers

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. Mann (1997), for example, 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 increased access to technology supported and facilitated student achievement. In addition, these gains reached across schools and districts with different educational policies and socio-demographic backgrounds.

In an earlier study with notebook computers, Gardner, Morrison, and Jaman (1993) attempted to assess the impact of high access to computers on learning. They provided notebook computers to over 235 students in nine schools in Northern Ireland to measure changes in their achievement in English and science. The researchers concluded 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, Morrison, Jaman, Reilly, & McNally, 1994). However, the authors reported that the impact of personal access to notebook computers on pupils’ achievement was not significant, or at best marginal, over one school year. 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.

Rockman et al (1998) generally support the ACOT findings in their two-year study of "pioneering" middle and high schools with laptop computers. They surveyed 144 teachers in the laptop schools and 450 students in the laptop schools and in non-laptop comparison schools. Some schools in the study had entire grade or class sets of laptop computers, while others had loaner sets of computers that teachers could borrow for their classrooms or only a few laptop systems in a classroom. Although the authors did not obtain separate academic outcomes data by implementation model, they did report that overall teachers believed that students' use of notebook computers led them to produce "higher-quality work, to show greater interest in school, and to better understand instructional content" (p. 49). Writing was the one academic skill cited to be most directly affected by computer use, with laptop-using students producing better quality work and writing more often. Additionally, the authors reported that laptop students demonstrated "greater evidence of applying higher-order-thinking skills to big-picture, strategic issues rather than to information gathering and procedural issues" than non-laptop students (p. xiii). Rockman et al concluded from their study that notebook computers are "the tool of choice for facilitating learning when this option is available to all students" (p. 1).

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.

Design and Method

Year 1. Students in 23 classes in grades one to four located in seven schools in a middle income urban school district participated in the study in its first year(n = 379). The schools were chosen by the school board on the basis of their perceived need for greater computer resources and their willingness to participate in the study. 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 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. These scores were used as a covariate in order to provide some control for differences between classes in students' writing proficiency. 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 assessment. In an earlier study 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 throughout the school year at different times and days to observe using a checklist based on the work of Gearhart, Herman, Baker, Novak, and Whitaker (1994) (see Appendix A). The checklist inventoried such factors as classroom organization, symbol systems used by teachers and students, instructional intent, resources in use, and student focus and engagement. The researcher observed the class for one minute then checked, on a machine-readable sheet, the presence or absence of a list of characteristics. After a few minutes pause, the process was repeated. Up to ten observations were made in a one-hour class. The observers were also asked to write field notes at the end of each observation session that elaborated on the checklist factors. At end of the school year, the participating teachers completed an open-ended questionnaire about their experiences and perceptions around eMate usage (see Appendix B).

Year 2. The initial plan for the second year of the study was to continue the student groupings of the first year in the second year, such that students who were initially in a class with four students for every eMate would be in a 4:1 class in the second year, and so on. This design would have made possible a two-year longitudinal assessment of the impact of the different computer ratios on writing. However, for a number of administrative and educational reasons such a continuance did not prove possible in the majority of cases. Frequently the educational needs of the child led to second year placements that resulted in their moving into nonparticipating classes or classes having a different student:computer ratio. In addition, new students who had not participated in the first year of the study were brought into study classes in the second year. As a consequence the number of students who were in classes having the same student:computer ratio over both years was too low to permit any statistical analysis of student writing quality by ratio grouping over the full two years. Instead, the second year writing quality measures were used to perform a partial replication of the first year study—partial because no four to one classes were included in the second year design, since principals had chosen to consolidate the eMate computing resources in the hands of fewer teachers., and because students had advanced a year so that the 21 classes in the study were either grade 2, 3, 4, or 5 classes. The writing portfolio assessment followed the same protocol as in year 1, and the same rater was employed. In addition, the open-ended questionnaire used with teachers at the end of the first year was again administered at the end of the second year.

Results

Year 1

Writing Score Analysis

A 1 X 4 repeated measures MANCOVA was performed using the two student writing quality scores (medium and message) assigned to each writing portfolio for the three different terms as the (6) dependent (outcome) variables (DVs), the student Writing subtest scores on the Canadian Test of Basic Skills as the covariate, and the student 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) of interest.

Data checks undertaken in conjunction with the statistical analysis indicated that, with the application of one statistical correction, the repeated measures MANCOVA analysis performed on the writing portfolio scores did not violate the test's statistical assumptions. (See Appendix C for a full description of the checks undertaken.) The Writing CTBS subtest covariate was significantly correlated to the combined DVs ($\underline{F}(2, 370) = 27.24$, $\underline{p} < .001$), although the association was modest (partial eta squared = .152) [1]. The combined writing assessment DVs were associated with the computer ratio IV ($\underline{F}(6, 740) = 2.32$, $\underline{p} < .05$), indicating that students in the different ratio groupings differed in their writing quality, 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): $\underline{F}(4, 1494) = 7.02$, $\underline{p} < .005$, revealing that on average, all of the students' writing improved over time. The time by computer ratio interaction for the combined DVs was also significant ($\underline{F}(12, 1494) = 2.63$, $\underline{p} < .005$), indicating that the four different computer ratio groupings differed in their rate of writing improvement. Once again, these two associations were very weak, with partial

[1] The partial eta squared effect sizes indicate the percentage of total variance in the outcome measures that can be safely attributed to (i.e., can be predicted from) the given independent measure. In this case, the partial eta squared for the covariate of .152 indicates that 15.2% of the variability in the combined writing scores is attributable to differences in the students' covariate scores (the CTBS Writing subtest scores).

eta squared effect sizes of .018 and .021 respectively. (As the writing measures used as DVs were scaled based upon what would be expected from a student at that stage in their schooling, one would not expect a substantial increase in these scores over time under normal conditions.)

Univariate analyses of covariance for each of the two writing measures 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 means plots of the means for the writing measures by computer ratio grouping[2], 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 ratio groupings, with the students in the 2:1 computer ratio group showing slightly greater gains in writing fluency over time than the others (2:1: .90 gain on medium scale, .85 gain on message scale; 1:1: .67 on medium scale, .62 on message scale; 4:1: .66 on medium scale, .55 on message scale), and the students in the control group showing the least gains (.45 on medium scale and .40 on message scale).

[2] These means have been adjusted to remove variation due to differences in the students' CTBS Writing subtest scores (the covariate).

Figure 1

Adjusted Means for Medium Scale

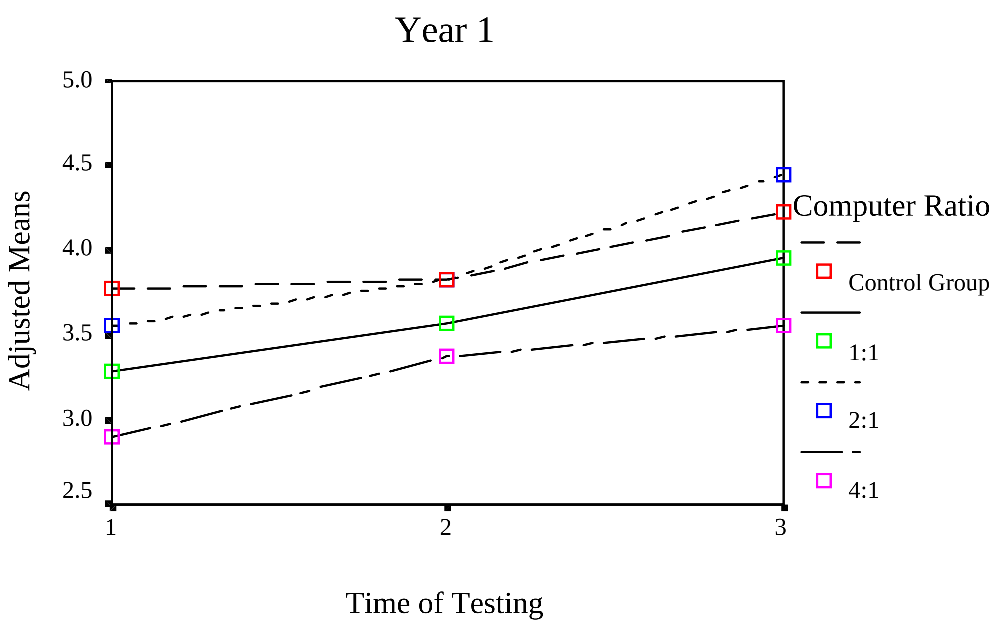
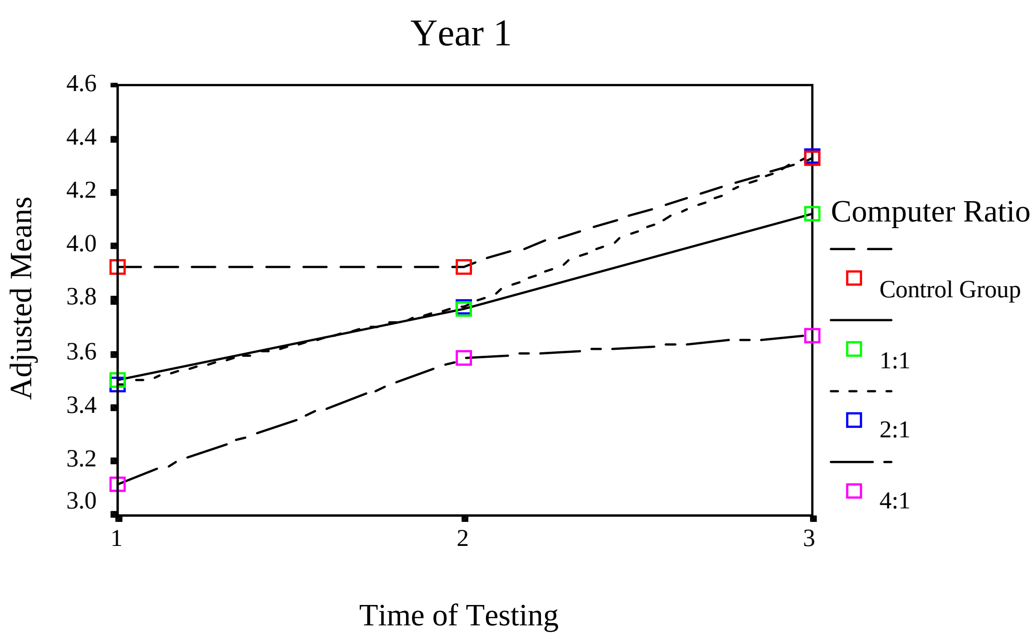


Figure 2

Adjusted Means for Message Scale



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: $\underline{p} < .001$; message: $\underline{p} < .001$). 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).

Table 1

Observed occurrence of classroom activity by group on dichotomous variables

Classroom activity variable		Group	
		Control group (%)	eMate group (%)
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) [q5medium] [q5high]	No	84.9	76.5
	Yes	15.1	23.5

Expected responses: Repeat/copy (student replicates provided material exactly) [q6repeat]	No Yes	81.1 18.9	83.1 16.9
Expected responses: Select (multiple choice, true/false) [q6select]	No Yes	86.1 13.9	89.3 10.7
Expected responses: Short (no more than a sentence in length) [q6short]	No Yes	79.8 20.2	83.6 16.4
Expected responses: Medium (no more than a paragraph in length) [q6medium]	No Yes	95.6 4.4	83.3 16.7
Expected responses: Long (multiparagraph) [q6long]	No Yes	91.8 8.2	86.3 13.4
Classroom organization: Teacher-led and independent work [co_other]	No Yes	39.4 60.6	31.0 69.0
Classroom organization: Pairs [co_pair]	No Yes	95.0 5.0	93.0 7.0
Classroom organization: Groups [co_grp]	No Yes	88.3 11.7	92.4 7.6
Teacher directing instruction [dir_inst]	No Yes	60.9 39.1	67.5 32.5
Teacher facilitating instruction [fac_inst]	No Yes	67.8 32.2	71.3 28.7
Teacher managing and disciplining [man_disc	No Yes	76.3 23.7	72.4 27.6
Students using non-computer resources [nonc_res]	No Yes	39.4 60.6	43.1 56.9
Students using computer resources [comp_res]	No Yes	87.4 12.6	62.4 37.6

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, problems 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 such as software, printers, and word processors.

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

Table 2

Observed mean occurrence of classroom activity by group on continuous variables

Classroom activity variable	Mean	
	Control group	eMate group
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	4.67	4.62
Productive student-student interaction (% of students who are talking with one another about their work) - whole class	18	21

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 proportion of variance in group membership accounted for is modest but not trivial, with Nagelkerke's $R^2 = .265$. The prediction success of the model 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. (Variables from tables 1 and 2 that are not in Table 3 had no predictive value and so were eliminated from the regression model). The column labeled "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 labeled " Exp(B)".

Table 3

Variables that predict whether observation was made in eMate or control class

Variable 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

The most dramatic predictor of whether observations were made in an eMate or control class was subject coding for Language Arts. If LA was being taught in a class, that class was over three times as likely to be an "eMate class" than if it were not. (Note that this does *not* mean that the raw number of times teachers were observed teaching LA was over three times greater in an eMate class (see Table 1), since the statistic is controlling for the eMate-non-eMate differences in the other observational variables.) 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 "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 the use of non-computer resources is also associated positively with the eMate group. This is possible because computer resources were only in use about 37% of the time in eMate classes. It may reflect a more project-oriented, resource-using focus to eMate classes, with less time being devoted to direct instruction—classes in which direct instruction was being used were twice as likely to be control classes.

Several other variables were negatively associated with the eMate group: classes in which the teacher is facilitating individual, pair, or small group work 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. No clear interpretation of these findings is evident.

Year 2

Writing Score Analysis

The same MANCOVA design was used for analysis of the second year data, with the exception of the number of levels used for the grouping variable, since there were no classes in year two in which a 4:1 computer to student ratio was employed. The same data checking procedure was undertaken, and the second year data set was also found (with the application of the Greenhouse-Geisser adjustment to univariate F's) to meet the assumptions for MANCOVA analysis.

The Writing CTBS subtest showed approximately the same significant but low level of correlation to the combined DVs as in the first year (partial eta squared = .150). The computer ratio grouping, however, no longer showed any relationship to the writing outcome measures ($\underline{F}(4,336) = .108$, $\underline{p} > .1$), indicating that there were no overall differences between the ratio groups in terms of writing quality. Students did improve in their average writing quality between the three testing periods, however, as shown by the main effect found for time ($\underline{F}(4,166) = 2.63$, $\underline{p} < .05$). And the within-subject multivariate tests did reveal a significant time by ratio grouping interaction ($\underline{F}(674,8) = 1.98$, $\underline{p} < .05$) showing that that the three computer ratio groupings differed in their rate of writing improvement. An in year one, these two associations were very weak, with partial eta squared effect sizes of .02 and .023 respectively.

The univariate analysis for each of the two writing measures (Message and Medium) indicated a significant effect for time on both measures assessed individually ($p < .05$). More importantly, the time by computer ratio grouping interaction was also significant for message but not medium (medium: $\underline{F}(3.5, 298) = 2.32$, $\underline{p} < .07$; message: $\underline{F}(3.8, 321) = 3.27$, $p < .02$). The lack of significance for the medium score relative to the first year of the study can almost certainly be attributed to the greatly reduced number of subjects in the second year, which reduced the statistical power of the design ($\underline{N} = 173$ vs. $\underline{N} = 370$). As in the first year, the effect sizes for the time by computer ratio interactions were quite small (Medium, eta squared = .03; Message, eta squared = .04) indicating that this interaction played a very small part in "explaining" the total variance in students' writing scores.

Figures 3 and 4 are graphs of the mean scores for the three consecutive testings in the second year intervals grouped by computer ratio, for the medium and message scales respectively. The means have been adjusted for the covariate CTBS Writing subtest.

Figure 3

Adjusted Means for Medium Scale

Year 2

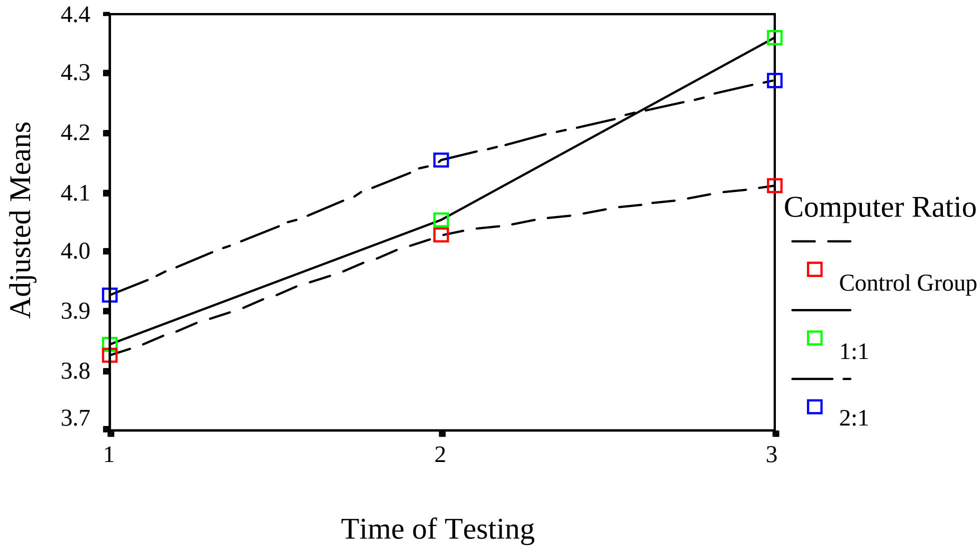
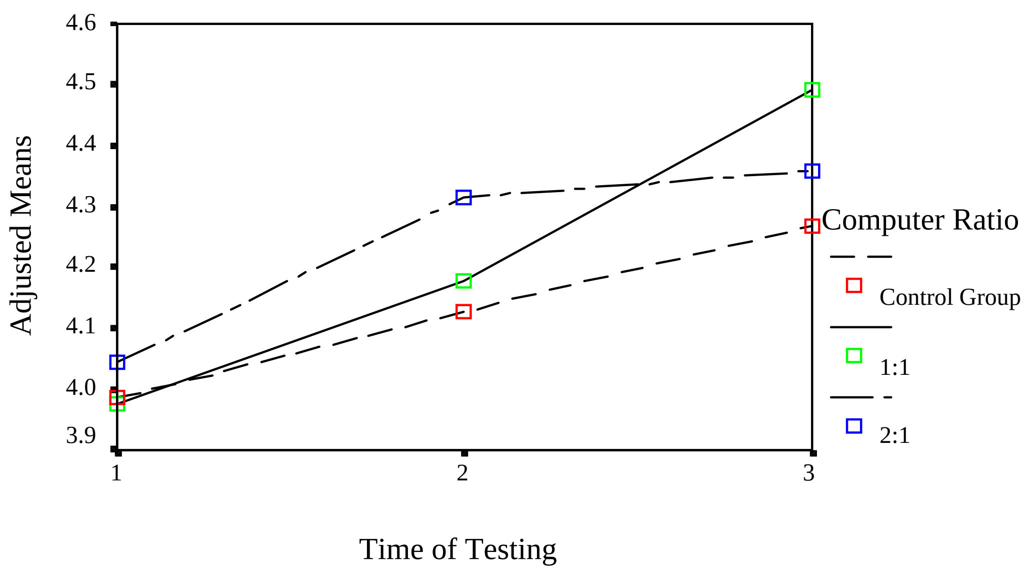


Figure 4

Adjusted Means for Message Scale

Year 2



Examination of the graphs reveal that on both the medium and message scales, students in the 1:1 ratio classes showed the greatest gains over the year in writing ability, while those in the 2:1 ratio classes and those in the control classes showed about the same level of improvement. On the six-point medium scale, students in 1:1 classes gained an average of .52 points, students in the 2:1 classes, .36 points, and in the control classes, .29 points. On the message scale, the gains were: 1:1 ratio, .52 points; 2:1 ratio, .32 points; and control, .28 points.

Teacher Perspectives on eMate use

The open-ended questionnaires completed by the participating teachers at the end of each year of the study were subject to qualitative coding and analysis. They proved to be a rich source of insights into how the teaching staff experienced the different stages of the implementation process, their sense of the eMates' impact on their teaching practices, and their perspectives on how students responded to the eMate deployment. As there proved to be very little differentiating the responses from first-year (*novice*) and second-year (*experienced*) users, the discussion that follows can be assumed to apply to both except where explicitly noted. Any significant distinctions between teachers having different student to computer ratios are also made explicit; where none are mentioned, responses were the same for all ratios. Where teachers are quoted, initials are used to preserve anonymity, and the student to computer ratio for that teacher's class is given in brackets following his or her initials. The teachers' perspectives are presented in a number of categories:

- their expectations and fears prior to implementing the eMates;
- their training experiences;
- their opinions about the ongoing support and resources for eMate usage made available to them over the study period;
- their views on the implementation process;
- the technical and operational limitations and problems encountered;
- the impact of eMate deployment on their teaching practices and curriculum;
- changes in student motivation;
- changes in the nature and quality of student work;
- shifts in patterns of student-student and student-teacher interactions;

- notable successes or failures;
- future eMate use in schools.

Expectations/fears

At the beginning of this study, some of the teachers were excited and hopeful about implementing the eMates in their classrooms. Others were nervous and apprehensive about utilizing this technology. Their concerns seemed to centre on their own knowledge of computers, their ability to use them with their students, and worries about their students' reactions to the technology. Several teachers expressed both hope and fear simultaneously, as BR(4:1) illustrates in the following statement:

> Initially I was excited but a little worried because I would be learning the technology of the eMate with the kids. I hoped to incorporate it into my program without making it like an add-on.

LR (4:1) echoes BR's ambivalence:

> I was excited when I found out that I would be participating in the project. I was also a little nervous and worried because I wasn't sure how I was going to fit it into an already packed program. I wasn't sure what to expect.

Those teachers using the eMates for a second year were generally free of these apprehensions :

> I participated last year so I was familiar with the project and it was free of any fear. Expectations were as I had supposed.... (LS(2:1))

Training

Generally, teachers found the training provided by the Board to be both sufficient and helpful. Some respondents did offer suggestions for improvements, such as providing for more experience sharing with other teachers during the training, and focusing the training more closely on their classroom interests and needs. A few teachers felt that the technical and operational aspects of the training were not comprehensive enough to meet their needs. In some instances where training and support were deemed insufficient the complaining teachers had not attended the training sessions. (Reasons for absence were not given.) Training sessions designed to meet the varied needs of teachers from different grades were not always perceived as useful, as noted in this remark by a combined grades one and two teacher:

> Actually [the skills taught in the] in-services were beyond the capabilities of grade 1 and 2 children in some cases, technically. (LS(2:1))

Support and resources

A failure on the part of the project staff to provide pedagogically useful curriculum resources for eMate-based activities was mentioned by several teachers. This was a concern for both novice and experienced users. JG(2:1), an experienced participant, stated about her second year:

> At first I thought that there would be a structured program and lots of guidance in this project and was a little disappointed when there wasn't. I would like to see the in-servicing and networking continue more in the second year and more in-class support.

KH1(2:1), a novice participant, expressed a similar belief: that "written materials (would be) exchanged or sent from a central source". Other respondents called for more lesson ideas and plans. One mentioned a specific need to learn more about the use of spreadsheets and graphing, a second about "docking" the eMates (the means used for data transmission and printing). It would seem that teachers expected more than just the distribution of eMates and provision of initial training. In as much as the eMate was seen as being a tool, these teachers' definition of 'toolness' became expanded to include resources once the computers were incorporated into the educational setting. They had the expectation that somewhere outside of the classroom there would be expertise available to aid them, providing classroom activities and/or technical assistance. The notion of "central source" (KH1(2:1)) and "structured program ... lots of guidance"(JG(2:1)), as stated above, was further evidenced by the comments of SP(2:1) and JP(2:1):

> I am not advanced in computers. I thought there would be more central office support in the school. I do not think my expectations were met.
>
> I would have found training, PRACTICAL ideas and TROUBLESHOOTING helpful... I found having to look up information in huge manuals a nuisance considering the workload of teachers.

A few other teachers mentioned that having support in the classroom to help them teach with the eMates was needed:

> In-class support; someone to show me math usage other than a teacher making simply a math worksheet and beaming it to others. (SP(2:1))

Another teacher was concerned that there was no time allowed to collaborate with peers:

> More time is needed to share with other eMate teachers, to discuss what worked vs. what didn't and creative ideas. (JP(2:1))

On the other hand, a few claimed to have successfully integrated eMate use without formal training or support, either through independent learning and/or with the help of students.

Implementation

As the teachers began to use the eMates with their students, they found that their anxieties slowly began to dissipate. HP(1:1), whose apprehension was noted earlier, remarked:

> Although I'm still learning, I feel a great deal more confident about the computer. I have learned a great deal (in-service, general use and from fellow teachers) and look forward to sharing my knowledge with the students.

Many of the teachers' initial fears about integrating the eMates into their programs were not borne out. For example, EM(4:1) found that she did not have to make drastic changes to her program:

> I fit the eMate around my program and tried to change procedures as little as possible to ensure consistency for the students – they were just using a different medium to do their writing.

In some classes, the integration process was even more fluid than expected. For example, LP(4:1) found that the eMates acted as a catalyst to stimulate new learning opportunities for her students:

> Once the project began, one lesson, one idea led to the next and children helped one another by being peer teachers.

There were a few exceptions to these positive outcomes, however. One teacher noted that competing demands on her time resulted in a less than optimal use of eMates:

> Time is limited, as always. There are huge demands curricularly. I did not feel I could do justice to the eMate study in light of the heavy program demands. I was right.

Technical limitations and problems

When an eMate broke down or wouldn't work properly, an immediate imbalance of computer resources was created in the classroom. In this situation, the teachers were rendered somewhat helpless because they could not implement the curriculum the way they had planned. They usually had to rely on a technical person to fix the problem, resulting in repair delays. BR(4:1) offers us a glimpse of her dilemma:

> Some days [using eMates] worked, [but] many times because of only having seven in the class and many technological 'glitches', the eMates sometimes became bothersome and tiresome for the children and me. Glitches included: printer problems, regularly I had to carry eMates to the other pod where Mrs. ____ was to use her printer as mine kept saying 'no printer connected' even though we checked it several times. Also eMates frequently 'froze' and needed to be reset. This became quite frustrating annoying for the children. [A technician] tried to help us but the printer problem kept occurring. Perhaps help 'docking' would have been useful but I did not feel confident after only one session. Also the way our Power Macs were distributed, I felt I could not tie one up just for eMates. We had 3 Macs to share in a 4-class pod. Less than ideal set up.

Technical difficulties also arose due to the differences between eMate technology and standard Windows or Macintosh-based computer environments, with which many teachers were already familiar. Facility with desktop computing did not readily translate into facility with eMate usage:

> ...I had no experience with laptops. Although I am fairly computer literate, I had difficulties dealing with software and hardware problems and teach lessons [sic] at the same time! (TM (1:1))

The range of technical difficulties encountered was broad. Some computers had to be replaced, others were stolen, printers ceased to operate, and connector cards broke down. Other experiences included computers freezing, blackouts, restarts required for the computers to function, glitches, and insufficient memory space. It was difficult to assess whether these were hardware or software problems. Here are some representative problems teachers reported:

> I found that several eMates would 'freeze or stall' and so they had to be restarted. (AS(1:1))
>
> Yes. I had frequent blackouts - I had to recharge often in order to clear them ...(LS(2:1,4:1))
>
> Some of the eMates became overloaded and I had to erase them so we could get more in. The children became quite frustrated when their eMate was behaving 'a little crazy' that day. (JG(2:1))

However, other teachers indicated that their technical difficulties were less serious or easily fixed:

> Sometimes they won't print but problems minimal. (SP(2:1))
>
> Nothing major. Solved on site - vanguard T's and other colleagues. (LH(1:1))
>
> Yes, I did have both hardware and software problems. Whatever my partner-teacher couldn't fix (she has worked with them for 3 years), I turned to our computer teacher. Hardware problems were sent out to be fixed. (TM(1:1))

eMate impact on pedagogy and curriculum

Many teachers found, not surprisingly, that they had to spend some initial time training students in eMate operations. This sometimes proved very time-consuming with first and second grade children. A few teachers stated that use of the eMates did not result in any significant changes or improvements in their teaching. One of these teachers responded:

> None - used eMates to supplement curriculum expectations. (JP(2:1))

But most teachers had a more favourable view of the effect that the introduction of the eMates had had on their teaching and curriculum. The comment of LS, whose class had a 2:1 ratio of students to eMates, is illustrative of this:

> I believe that if a teacher has a challenge and goals [for eMate use] that area will become enriched for the students - in our case writing formed a vehicle for response, reflection, interview, exposition, etc....

Asked about the amount of time eMates would be used in class on an average day, teachers gave a wide range of responses. In the second year, usage varied by class from 20-40 minutes to 11/2 hours per day with occasional half-day use if a special project was in progress. The average use time was about one hour per day.

Language Arts use : Many of the teachers made extensive use of eMates in their classroom writing activities. Students used eMates to create newsletters, publish stories, and do research reports. The deployment of eMates frequently led teachers to place a greater pedagogical focus on the editing and revising of student work. It was thought by these teachers that the eMates could facilitate this process and so they gave it greater emphasis in their classrooms. One teacher commented about eMate usage "I would aim to have the children become independent in editing at an early stage"

(JG(1:1)) . Another felt that the introduction of eMates allowed for a greater integration of the curriculum:

> [I am] able to teach more integrated strands of math, science and social studies curriculum. Programming including eMates in every way possible as a tool for work completion. (LW(1:1))

Mathematics use : Although the focus of the study was on language arts, we asked teachers about how they used eMates in mathematics too. In general, they played a far less significant role in mathematics education. Many teachers such as SP(2:1) and BR(4:1) reported that they did not find it easy to use the laptops to teach math:

> I have not used the eMate very much for math. Only transformations in the geometry unit and the use of the calculator were covered. Spreadsheets were attempted but students quickly became frustrated.
>
> I found I did not use it as efficiently for math as I may have with older students. Primarily as a "tool" to record problem solving work. I feel children at this age need to use concrete materials rather than eMate to develop understanding.

As BR's comments suggests, eMate use in mathematics was most successful with older students in grades three and four. Two teachers of such students found that their charges were more motivated to learn math concepts using eMates. Some of the concepts they were able to teach with eMates included division, motion, geometry, graphing, Venn diagrams and symmetry.

Student impact: Motivation

Virtually all of the teachers, regardless of the eMate ratio in their class, noticed positive changes in the attitudes and motivations of their students as a result of the implementation of eMates in the classroom:

> Students were very interested and motivated. The eMate was almost an incentive to do well. (HP(1:1))
>
> Students tried to think of as many possibilities for using eMates. (SP(2:1))
>
> …more eager to use the eMate therefore more eager to write stories - length not deeply affected. (JP(2:1))
>
> Students were very excited to get to use their own eMates. Many chose to work on the eMate during free choice after work was done. Many felt a sense of accomplishment in an area they had limited exposure to beforehand. (AS(1:1))

One teacher stated that “students with short attention spans and difficulties seemed to spend more time when using the eMate.” Several others mentioned that eMate usage could be employed as a reinforcement to encourage the completion of other schoolwork.

Very few instances of lack of interest or off-task behaviour were reported by teachers in their questionnaires. One teacher who was in her second year of using eMates noted that “students had less interest in eMates this year”. A tendency for students in one grade five 1:1 ratio class to lose focus was noted:

> [Students had]difficulties staying focused on the task and wanted to ‘play’ with other parts of the software. (TM1(1:1))

Most respondents, however, indicated that students were more on-task working on eMates than when doing traditional seatwork. Descriptors such as quiet, focused, intent, co-operative, busy, shared and mentored, occupied, and attentive were used. One teacher’s comment was particularly revealing of classroom practices:

> Students were easy to manage because they were focused on their computers. However, students that tend to act out, act out no matter what. The only difference was that the acting out was delayed a bit. I sometimes found it difficult to get students’ attention once they began their assignments because they were so absorbed in their task they didn’t want to be interrupted. (TM1(1:1))

Student impact: Work quantity and quality

Language Arts: Several teachers found that when students wrote using eMates, their stories were longer and greater in number. For example, TG (1:1) and LN (1:1) both witnessed increases in productivity:

> Length of stories has increased. Neater, more refined finished products, due to showing pride of ownership.
>
> I have students in Grade 4 writing stories of many typed pages in length. They are willing to frequently go back and edit and revise.

The lack of a requirement for rewriting would free up student time that could be used for further writing:

> Stories are much longer and students don’t mind editing. Productivity has doubled as rewriting time is used to write new stories. (LJ(1:1))

One teacher commented upon an educationally important shift in the students' attitudes towards writing resulting from eMate use:

> By having eMates as a writing tool, overall writing in class increases for the children - they perceive themselves as writers writing for several purposes and audiences. (LS(2:1,4:1))

Other improvements cited by teachers included the development of editing concepts and skills, increased proofreading accuracy, and the 'neater, more polished" appearance of the final product. The use of eMates afforded teachers the opportunity to teach editing concepts and skills with more clarity, and students the ability to edit with greater ease:

> I found more opportunities for teaching punctuation and other structures in editing. (JG(2:1))
>
> EMates make it easier for students to revise and edit so this is a good motivation. (SP(2:1))
>
> Less laborious for students to correct their own work. (JP(2:1))
>
> Some children were able to edit and discover mistakes in their work much easier when it was on the screen or printed out. Therefore less mistakes were found in their work. AS1(1:1)

A few teachers, while noting greater writing motivation, either found no change in overall productivity or a decrease in output, usually due to students' lack of keyboarding skills:

> For my strong writers, using the eMate was a thrill. Their story length did not increase nor did their number of stories. My weaker writers struggled and also did not like having to type - they were weak in keyboarding ...(TM1(1:1))
>
> My children have opportunities to write everyday with or without the eMates. For those children who write longer stories, I would find those stories in their own handwriting. (JG(2:1))
>
> Productivity increases when children have paper and pencil - less delay, slow down/ to transcribe writing onto eMate takes longer, less is produced. (LS(2:1,4:1))

When keyboarding improved, it impacted story length:

> The more comfortable they got with the eMates and the more keyboard familiarity they acquired the longer their stories became. (AS1(1:1))
>
> Volume increased in length of writing once students finished the Almena typing program. (LW1(1:1))

There were fewer comments about increases in the quality of students' writing. Some teachers reported that the overall quality of their students' work did improve as they were able to access the various tools available on the eMates such as spell-check, editing, and storage. A few teachers described an aggregation of writing benefits that were made possible by the eMates. For example, KL (1:1) describes what she was able to accomplish 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.

There also appeared to be more than one eMate success story with ESL students, as SG1 (1:1) and LN (1:1) discovered:

> I saw a more significant change, especially in ESL children showing a greater interest.
>
> I find ESL and communication students experience more success with the eMate. They know that they have resources right there for spelling. For students who occasionally are disorganized and cannot find assignments in their desk or bag, the logically organized overview is very helpful.

Students' levels of technical proficiency in eMate operation had a direct relationship to the efficiency with which students worked:

> Students who felt more comfortable working with the eMates finished tasks and assignments much sooner and therefore spent less time. (AS1(1:1))
>
> Time was a problem. For slow workers, the eMates did not speed them up. Sometimes it seemed it slowed them down. Mastering the use of the stylus and other functions interfered at times. My students who are on task in any situation benefited because they were able to manipulate the eMate with ease. (TM1(1:1))

The need for students to acquire eMate operational skills before they could pursue independent work was mentioned by a few teachers. As one put it:

> eMate helps students to focus and stay on task. Once the base skills are established they can work somewhat independently. Until then many step-by-step group activities are needed so the teacher is not torn in 30 directions! (LJ(1:1))

There were a few teachers such as LR (1:1) and LH (1:1) who felt that the eMates did not help improve the quality of their charges' reading or writing at all:

> The quality of the work was quite good but I don't think this was related to the eMates.
>
> Little impact. Without major support from the teacher the quality was wanting.

Teacher-student interactions

A large majority of the teachers reported a shift in their roles in the classroom and in their interactions with students as a result of eMate use. The greater level of motivation students exhibited during eMate-based activities reduced the amount of teacher time spent dealing with discipline problems, and seemed to encourage teachers to employ a less directive pedagogy:

> This year the children are much more self-directed, as though each task is a personal project and exploration. (LS(2:1))
>
> Students were highly focused and interest levels were high when learning new functions, therefore less discipline problems. (AS(1:1))
>
> I am making them more responsible for their writing and the mechanics involved in using the eMate. There is less waiting for them in the writing process and so my approach to them is more relaxed. (JG(2:1))

Some teachers said that they developed higher expectations for student work as a result of using the eMates. Other teachers reported that with eMate use they found themselves relating to their students in a less directive, deeper, and more collaborative manner. For example, one 1:1 teacher stated that she was able to "get more in depth" with her students when they were working independently with the eMates. Another 1:1 teacher said that she felt she was able to treat her students more as "expert partners" as a result of the eMates. Teachers in some instances went well beyond traditional role norms for interaction with students, relying on them for assistance in resolving technical and operational eMate difficulties they either could not or did not have the time to resolve:

> ... students were teaching me mechanics...I had students in September write instructions 'How to Use an eMate'... [It was a] co-operative learning class - students were mutually supportive. (KH(2:1))

In general, it appears that the lower the student/eMate ratio, the more time teachers had to focus on the individual student and the greater the opportunity there was for a shifting of the locus of control for learning from the teacher to the student. For example, SP and JC illustrate how this shift seemed to take place in their 2:1 classrooms:

> I find that I am making more time for individual conferences with students as they are writing longer works.

> I had to depend on them to work more independently. I placed more responsibility on their shoulders for decision-making.

Not surprisingly, grade level seemed to also play an important part in determining the level of autonomy granted to students. Some teachers of younger students thought that the eMates had limited utility for their classes. BR (4:1), LP (4:1) and LH (1:1) state:

> I am not totally sure that the use of eMates in Grade 2 is a valid use of the equipment. Children enjoyed them and learned how to do many neat things but only having 7 in the class often made things [more] difficult and more time consuming than without them.
>
> The project seems suited to higher grade levels than grade one. Most of my ideas I created alone as workshops were geared more to Grades 2, 3, and 4.
>
> As much as I enjoyed having this tool, I believe there are students who would benefit more from the class programs if their time was not fractured by this imposition. Students in Grade 6 / 7 would have the foundational requisite math and language skills much more consolidated than the Grade 3 / 4 students that I currently have.

Student-student interactions

There was a near-total consensus on the part of the teachers that eMate use had a positive effect on student behaviour and social interaction in the classroom. Words like sharing, fostering independence, feelings of usefulness for students, co-operation with others, respect for others' work, peer coaching and helping were not uncommon in their discussions of students' interrelationships. As one teacher put it in a typical comment:

> The children learned to share and to be patient with each other. They always had respect for the integrity of the work of their partners. They also helped each other eagerly when something went wrong. (JG(2:1))

Another remarked "I've noticed students helping others who are not necessarily their social peers" (SP(2:1)).

Teacher statements about student interactions emphasized co-operation as opposed to competitiveness and this was attributed to the presence of the eMate in the classroom:

> Students were eager to help each other when using the eMates and when printing out assignments. Many grouped together in small groups to share expertise and around the classroom knowledge. (AS1(1:1))

In fact, most eMate teachers in this study, regardless of their ratio, found that their students worked more cooperatively with the eMates than without them. TG, a 1:1 teacher, noticed the following:

> [An increased sense of] maturity and a sense of responsibility among friends and peers. Pride of ownership – willing to share work with one another.

A 2:1 ratio teacher had the following to say about the cooperation seen in her class:

> More talk, more help and appreciation for the help - co-operate out of necessity but also happily. Occupied with the type of task - so pleasantries abound. For independent learning, the children often chose to work in pairs. (LS(2:1))

JG, a 2:1 teacher describes a slightly different type of cooperation as well as an element of respect for other students they had to share their eMate with:

> The children were respectful of their partner's work and never interfered with that. They also were aware that someone else was waiting to use the eMate.

In a few classes, certain students emerged as peer mentors:

> [Students were] much more helpful. Some computer leaders emerged who were always willing to help teach others and train in new areas - this positive attitude encouraged others. (LW1(1:1))

The 4:1 teachers indicated that their students worked more cooperatively in groups once the eMates arrived than they did prior to having them. There was also greater student role definition in the 4:1 classes; some students took on the role of eMate experts while others were more passive about the technology. In some 4:1 classes, the eMates were described as a "status symbol" because not everybody had one. BR was of the opinion that her children learned to collaborate and solve problems as a result of having a 4:1 ratio in her classroom:

> Because of only having 7 eMates, much of the work was group oriented. Kids learned to cooperate and solve e-mate problems by working together. Some kids were able to take on a leadership role as 'e-mate' expert. Kids worked together well…students worked much more cooperatively in groups when using the eMate.

Another 4:1 teacher, LP, seems to corroborate BR's observation that a 4:1 ratio affected the sharing and team building skills developed by students:

> The children loved using them and they served to be a status item, especially with ratio of 4:1. They wanted to learn and eagerly helped peers. …The children managed well with sharing-taking turns. Good concepts for our social skills focus on team building.

A few others, while noting certain benefits from eMate use, were not so sanguine about some of the effects of a 4:1 ratio in the classroom. Contrast the comments of LS, a 1:1 teacher, who describes what she observed when every student had his or her own laptop, with the observations of BR in her 4:1 class:

> 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.
>
> 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.

Remarks like those of BR corroborated our quantitative findings. It will be recalled that the analysis of the observational data showed a significantly higher degree of teacher time being spent on classroom management and discipline in the 4:1 classes. The 4:1 teachers also noted increased difficulty with project design and coordination and commented that more time was necessary to complete projects.

Notable successes and failures

When asked if they had any notable successes with eMate use in their classes, teachers focused on both the quality and appearance of the student work produced and the students' mastery of keyboarding skills and eMate operation. A few provided lists of projects they felt were successful, such as that offered by TM:

> Successes included my lessons on geometry (angles), French vocabulary, geometric translations, flips, and turns, writing poetry, fairytale writing, letters for Remembrance Day, invitations, and using it as a checking tool for calculations. (TM(1:1))

Accounts were also given of students either at-risk or with learning factors that limited their learning/writing ability, and in every instance cited the outcomes were positive:

> Tourette's syndrome child in Sept. 98 - very poor fine motor skills - 1 hour/day working on eMates and completed Almena touch typing course - strong progress in fine motor - student can produce neat and legible work now. (LW1(1:1))
>
> A student with dyslexia in my class has greater success recognizing letters on the keyboard and his work is more legible. (LJ(1:1))

> Students with very poor penmanship who were reluctant to write were happy to use the eMate - loved the presentation that the eMate allowed them to have with their work. (JP(2:1))

There were no mentions of specific failures.

eMate ratio issues

The differences teachers noted in the relative ease of curriculum development and implementation across the different ratios have been previously discussed. Those teachers with 2:1 and 4:1 classes often mentioned that it took greater time and effort to prepare, deliver and monitor what were essentially two simultaneous sets of teaching activities—one for those using eMates, and another for those working without. Teachers with 4:1 classes in particular had to spend more time and effort coordinating class work as more students would be engaged in off-computer activities, increasing the difficulty of teaching and supervising.

It also seemed that some of the 4:1 teachers cited a lack of eMates as a limitation to a greater extent than the 2:1 and 1:1 teachers. They lamented the recurring technological glitches that could take one or more of the precious eMates out of action.

Future eMate use

Nearly all the teachers in the study felt that the eMate program should continue. Most of those who had been at a 2:1 or 4:1 ratio explicitly stated a preference for having a full classroom set of eMates in the future.

Most responses favouring continued use cited the educational benefits they had observed as their main rationale. Some dealt specifically with the advantages eMate use was thought to offer in helping students develop certain skills, increase productivity, and deliver prescribed curriculum:

> I am able to integrate and accomplish a fairly good degree of the standards of the stringent new curriculum. Daily practice also allows students to develop their touch typing speed in a strong workable level. (LW1(1:1))

> Yes I would [continue their use]. I really think they facilitate publishing various forms of writing so productivity goes up. (SP(2:1))

Others cited observed changes in student attitudes and behaviour as a justification for continued use of the technology:

> Yes. I find it to be a beneficial tool to encourage proofreading, improving concentration and pride in one's work. (KH1(2:1))
>
> Yes, the children will benefit from what they enjoy using. (LS(2:1,4:1))
>
> I would like to continue working with them. This year I taught grade 3 and found the eMates to have played an important role in raising student confidence levels using computers. (AS1(1:1))

For another teacher a socio-economic factor was also considered to support eMate use:

> Yes - students thoroughly enjoyed using them - good opportunity. Inner city school children who do not have access to technology at home are given more exposure with the eMate. (JP(2:1))

One teacher who did not wish to continue using eMates found them too much of a burden in her first years of teaching:

> As a new teacher I felt totally overwhelmed by the new curriculum and the many other challenges that come up in the first few years of teaching. I think I would feel more comfortable with the eMates once I have gained more confidence with my teaching. (TM1(1:1))

Another respondent commented on the educational limitations of the eMate technology from his perspective:

> I think the eMate may not be the most reliable lap-top to use. The page cannot be viewed at one glance and it frustrated the children to scroll down and up to see the rest of their text or to space their text. (LS(2:1))

Discussion

Our data analysis indicates that the use of eMates during the writing process by students in grades one to four had a positive impact on the standard of the writing produced. Students in classes where eMates were deployed had a significantly greater rate of improvement in the quality of their work as judged by an assessment of their writing portfolios on two broad dimensions: message quality (the meaning and content of the text) and medium quality (the form and surface features of the writing). In the first year of the study, students in classes with a student to eMate ratio of 2:1 showed marginally greater gains than those in the 1:1 and 4:1 groups (these two groups had equivalent gains); those not using eMates showed the least degree of improvement. Students in the 2:1 classes showed about twice the rate of gain over the year on both the Message and Medium scores relative to the control classes, with their improvement averaging .87 points on the 6-point scales.

In the partial replication undertaken in the second year of the study, the three computer ratio groupings investigated (no-eMate controls, 1:1, and 2:1) again differed significantly in the their rates of writing improvement. Students in 1:1 classes showed the highest gain (.52 points on both Medium and Message scales over the year), while those in the control classes evinced the least improvement, averaging a gain of .3 points.

While these figures may seem to indicate important differences in writing improvement between the groups favouring those classes with more eMates, caution in interpretation is necessary in order to avoid making unjustified inferences from the data. It will be recalled that the effect size statistics indicated that only 3-4% of the variance in student writing scores was due to the differences between groups in the writing improvement rate. And because the limitations of statistical analysis prevented any calculation of the significance of the difference in growth rate between each pair of groups, we cannot be certain whether the 4:1 group, for example, was significantly different from the control group in their rate of improvement. All that can be stated for certain is that there are significant differences between the different ratios in their rate of improvement, and then a considered judgment must be made about the differences from an inspection of the adjusted group means and their shifts over time (see Figures 1-4). On the basis of this inspection, there is strong support for claiming that students who use eMates for writing do show minor but significant improvements in writing quality relative to those who do not, and that of those students, those in classes with greater access to eMates (1:1 and in some cases 2:1 classes) generally show a slightly greater level of improvement than those with less ready access.

Analysis of the observational data showed that observers were far more likely to find language arts being taught in an eMate-equipped class than in a control class. This may be an artifact of the teachers' prior knowledge of the observation schedule, since this knowledge might have led eMate-equipped teachers to slot in eMate-based language arts activities for those times when observers were expected to be present. The two most readily interpretable findings from the observations were that eMate-using teachers were about half as likely to be observed engaging in direct teaching, and that their classes were about twice as likely to be observed using various forms of non-computer resources. Together these differences indicate that the eMate teachers engaged in more resource-based, project-oriented, non-direct pedagogy—an encouraging development. Perhaps partly because of the use of this more logistically complex form of teaching, eMate teachers were about twice as likely to be observed engaging in classroom management and disciplinary tasks. And a large part of the increase in management time in eMate classes can be attributed to the demands placed on teachers in 2:1 and 4:1 ratio classrooms to organize and monitor subsets of students engaged in different activities and negotiate the inevitable conflicts that arise whenever students have to share resources. This explanation is supported by the comments made by teachers of 2:1 and 4:1 classes in their questionnaires—implementing split-class activities was found to increase their logistical and management burdens.

Nearly all of the teachers who used eMates in their classrooms thought it worth the effort involved. They made considerable use of eMates in their language arts teaching, especially for writing tasks. eMates were less often employed in mathematics instruction. In general, eMate use was perceived to have a considerable positive impact on student motivation, engagement, and work focus. This subjective perception was not reflected in the regression analysis of the observational data, however; no predictive distinction between control and eMate classes was found for either the "appropriateness of student behaviour" or "degree of student focus and engagement" variables, and they did not form part of the regression model distinguishing the two groups (see Tables 2 and 3).

But this is not to say that some distinctions along these dimensions did not exist. Since the observational data for all of the eMate ratio groups had to be collapsed together for the regression analysis, any existing distinction between the 1:1 ratio classes and the control classes could well have been drowned out by less favourable data for classes at the other two ratios. A secondary analysis of the relevant uncollapsed data, independent of the larger regression analysis, tends to support this hypothesis. On the five-point observational ratings of “student focus and engagement”, a crosstabulation by student - computer ratio indicated that classes with 1:1 and 2:1 ratios were significantly higher in observed student focus and engagement, with the 4:1 classes being less engaged than the control classes. An identical pattern emerged in a crosstabulation of the ratings of “appropriateness of student behaviour”. Further research would be needed to confirm these findings.

Teachers typically reported that as students became comfortable and proficient in using the eMates, the length of their written work increased, and some noted an improvement in composition quality, although this was not universally found. A few teachers remarked that because eMate use made editing easier for students, they came to place a greater emphasis on teaching students about editing and revision, and to have higher expectations of their charges in this regard. Several teachers also noted that their students exhibited a greater degree of responsibility and cooperation, especially in higher-ratio classes where the sharing of resources had to be negotiated.

While classroom eMate ratios did have some impact on writing quality and classroom process, there were several other unrelated factors affecting the eMate experience. These included the background of the students, the support for technology in the school, and the individual pedagogy of the teacher. For example, the ability to successfully implement the eMate in the classroom was largely a function of the approach of the individual teacher. Judging by the teachers’ own comments, if a teacher was resourceful and creative in adapting her lesson to a 4:1 ratio or to a breakdown of equipment, the number of eMates in the classroom did not necessarily have to adversely affect students’ learning. What appeared to be as important was the teachers’ ability to adapt to the situation. Nonetheless, given the perceived lack of curricular, pedagogical, and technical resources in the present project and the intensive time demands on teachers today, it seems probable that the likelihood of success for 2:1 and even 4:1 classes could be appreciably enhanced by increasing the level of technical assistance available and by developing a bank of eMate-based activities that teachers could readily access.

Still, providing an entire class with a full set of eMates has certain advantages. There was a clear trend in the teachers' comments favouring the 1:1 ratio. It was thought to increase students' on-task focus, reduce the complexity of lesson development, and liberate teachers from some class management concerns. In light of both the greater achievement demonstrated by students in 1:1 ratio classes in the second year and teacher preferences, we suggest that when eMates (or comparable devices) are deployed, every effort be made to equip classes at this level. At the very least, the 4:1 ratio should be avoided, as it required the greatest degree of management time and afforded very little in the way of writing improvement.

Technical and operational problems had a substantial impact on the eMate experience for some teachers and students. As the eMate line is now discontinued, the question of whether to further disseminate that particular technology is moot. But we recommend that school boards looking to bring inexpensive, portable computing tools into the classroom should give considerable weight to the question of whether the technology under consideration is compatible with the existing desktop operating systems already deployed in target schools. The eMate's lack of compatibility with existing systems forced already computer-literate teachers to learn a new operating system and sometimes led to technical problems. Many if not most teachers now have at least some ability to use either the Macintosh or Windows operating system, and their skills should be leveraged by implementing low-cost sub-laptops based on the system they currently know and use in school. Doing so will heighten the laptops' compatibility and interoperability with existing school networks and peripherals and reduce training and support costs.

Finally, there is the larger debate about the value of bringing computers into the classroom at all. The present research provides evidence that even inexpensive digital tools used primarily as an aid in the writing process with young children can have a positive if modest effect on writing quality over the course of a single year of schooling, especially when all students in a class are provided with on-demand access. 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 by these students. 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 (half of every day) and strongly focused on writing, whereas in the present context eMate use was much more intermittent and incorporated many non-writing activities. Very young students, such as those focused on in this study, are likely to require a longer period to develop proficiency in keyboarding and system operation—delays which several teachers noted impacted the level of some students' work. What remains to be seen is the cumulative impact of the continued use of such tools over large segments of a student's academic career.

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Appendix A

Observation Scale

Learning with eMates in Etobicoke Project (LEEP)

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)										
6. 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)										
7. Symbol Systems Students Use in Their Work:										
verbal										
numeric										
math symbols										
graphic, chart										
diagram										
pictorial										
model										
map										
puzzle/patters										
motor/action										
music										
objects										
8. 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										
9. Students’ Responses to the Activities:										
Appropriateness of students’ behaviour (percentage of students who are on task)										
Students’ focus and engagement (on a 1-low to 5-high scale)										
Productive student-student interaction (percentage of students who are talking with one another about their work)										

Appendix B

Teacher Questionnaire

eMate Project 1999

Name: ____

School: ____

Grade: ____

Student to Computer Ratio: 1:1 2:1 4:1 (Please circle)

Did you participate in the eMate Project last year? Yes No

Please take your time to carefully think about and answer these questions. Where ever possible, illustrate your answers with examples from your classroom. Use the back of this questionnaire or attach another sheet if you need more space for your answers.

1. Compared to other classes you've taught at this grade, how was your class this year (circle one):

   (a) above average (b) about the same as others (c) below average

2. Once you found out that you would be participating in the project, what were your initial hopes, fears, and expectations? Have they been borne out?

3. Was the training and support offered for the eMates sufficient? Are there additional areas where you feel more training is needed?

4. Did you have any hardware and software problems this year and how were they resolved?

5. What impact did the eMates appear to have on the following aspects of student work and behaviour (give illustrations):

   a) student attitude and motivation____

   ____

   ____

   ____

   ____

   ____

   b) productivity in writing (length of stories, number of stories, etc.) ___________

   ____

   ____

   ____

   ____

   ____

   ___

   c) overall quality of work in language ___________________________________

   ____

   ____

   ____

   ____

   ____

   d) understanding of math concepts____

   ____

   ____

e) overall quality of work in math

f) development of social skills

g) overall time students spend on task

h) student behaviour and discipline

6. What changes, if any, did you make in your curriculum and teaching as a result of having eMates in your classroom?

7. What changes, if any, have you noticed about the way you interact with students?

8. What changes, if any, have you noticed about the way students interact with each other?

9. Are there any notable successes or failures you've had as a result of students working on eMates? Please illustrate. ____

____

____

____

____

____

____

____

10. Would you like to see the eMate programme expanded, curtailed, dropped, or changed in any way? ____

____

____

____

____

____

11. If given the opportunity would you like to continue to use eMates in your class? Please explain your answer.____

____

____

____

____

12. Do you have any other comments that you feel would be helpful in assessing the eMate project?____

Thank you!

Appendix C

Data Check

No univariate or multivariate outliers were found in the data at the $\underline{p} = .001$ level. 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-covariate interaction ($F(6,720) = 1.46$, $\underline{p} = .188$) . High cell counts in the design ensured robustness of the analysis to violations of univariate and multivariate normality (total $\underline{N} = 370$). Mauchly's test of sphericity revealed that the variance-covariance matrices of the orthonormalized transformed dependent variables were nonspherical ($\underline{p} < .001$ for both message and medium DVs), indicating that the pairs of levels of the within-subject variables did not have equivalent correleations. Consequently the Greenhouse-Geisser adjustment was applied to the univariate F's for all within-subject effects tests, in order to correct for the resultant inflated Type I error rates.