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ABSTRACT

A three-year study examined the efficacy of microcomputers in the teaching of writing in the regular school classroom and combined experimental and observational methods to develop a model of effective application of computers to the eighth-grade writing skills situation. Divided into control, mixed, and experimental classes, 281 students in six classes using computers were compared with 231 students in nine classes using paper and pencil and 212 students in nine classes in a mixed treatment, using computers as well as paper-and-pencil. Results showed that a computer was needed for each individual student during every class meeting to maximize the value of using word processing. In the fully computerized treatment, students demonstrated greater use of high-level editing than in the paper-and-pencil or mixed treatments, and students who used computers developed more positive attitudes toward revision, drafting, and learning to use computers than those who had only brief or no exposure. Results suggested 14 design criteria to weigh in effective computerization of writing classrooms, and writing instruction was most effective in brief, immediately applied "mini-units" rather than in longer lessons. Student work was initially slower and more asynchronous among members of a class, and teaching was most effective using process-based and cooperative learning strategies. Student use of printers was key to increased feedback from others, leading to increased revising and editing of their work. The model illustrates the contributions of computers, printers, lessons, and learning environment to the development of mature writing skills. (One figure and four tables of data are included; 40 refrences are attached. (KEH)

WRITING WITH COMPUTERS:
ACCOMMODATION, ACHIEVEMENT, AND ATTITUDES

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Abstract

WRITING WITH COMPUTERS: ACCOMMODATION, ACHIEVEMENT, AND ATTITUDES

This three-year study examined the efficacy of microcomputers in the teaching of writing in the regular school classroom. Researchers used a combination of experimental and observational methods to develop a model of effective application of computers to the eighth-grade writing skills situation. Divided into control, mixed, and experimental classes, 724 students in six classes using computers (N = 281) were compared with students in nine classes using paper and pencil (N = 231) and nine classes in a mixed treatment -- using some computers as well as some paper-and-pencil (N = 212) for their classwork. Following a one-semester pilot study, all students had the same lessons with the same teacher using process-based writing instruction. Analyses focused on (1) criteria affecting the accommodation of computers within a standard writing skills classroom, including impacts on room design, student learning, and the teacher's writing lessons, (2) improvements in student writing achievement, especially higher-order revisions, and (3) changes in student attitudes toward writing resulting from use of computers. Results showed that a computer was needed for each individual student during every class meeting to maximize the value of using word processing. In the fully computerized treatment, students demonstrated greater use of high-level editing than in the paper-and-pencil or mixed treatments, and students who used computers developed more positive attitudes toward revision, drafting, and learning to use computers that those that had only brief or no exposure. Results suggested fourteen design criteria to weigh in effective computerization of writing classrooms, and writing instruction was most effective in brief, immediately-applied "mini-units" rather than longer lessons. Student work was initially slower and more asynchronous among members of a class, and teaching was most effective using process-based and cooperative learning strategies. Student use of printers was a key to increased feedback from others, leading to increased revising and editing of their work. Replication of these results from semester to semester adds strength to these conclusions. The model illustrates the contributions of computers, printers, lessons, and learning environment to the development of mature writing skills. We concluded that the positive benefits of computers occur because they accelerate the cycles of creative effort and feedback. This study unequivocally demonstrates positive benefits to full computerization of the middle-school writing classroom.

WRITING WITH COMPUTERS: ACCOMMODATION, ACHIEVEMENT, AND ATTITUDES

Public schools are incorporating microcomputers in curricula at a rapid rate and great expense, but their role in the classroom remains problematic (Becker, 1988; Chen & Paisley, 1985; Eastman & Krendl, 1987; Fiske, 1988). Although innumerable articles, books, and speeches urge educators to show foresight by adopting computers for teaching (Williams & Williams, 1984), few cite reliable evidence of their value to learning and their impact on students (Hawisher, 1989; Hillocks, 1986; Kurth, 1987; Becker, 1988). In fact, some studies researching the application of computers to ordinary in-school lessons demonstrated little improvement in student skills (Duling, 1985; Wetzel, 1985), while other studies have apparently shown notable improvements -- at least for some students or for the teaching of some skills (Eaton, 1986; Flinn, 1985; Hillocks, 1986; Krendl & Fredin, 1985; Kurth, 1987). Which students benefit and which skills improve seem the crucial questions.

Criticism of the quality of student writing at all levels persists throughout the United States, and writing has been targeted by federal and state educators for improvement. As late as 1989, Hawisher reviewed the literature and noted the absence of definitive conclusions about the use of computers in teaching writing. Beyond generally increasing learning time (Vockell, 1987), researchers agree that using word processing can improve the quality of student writing (Monahan, 1984, 1986; Parson, 1985; Wheeler, 1985) by removing some physical and psychological barriers to revising that come from the arduousness of handwriting and recopying (Diaute, 1983; Eastman, 1986; Halpern & Liggett, 1986). The benefits of using computers also include increasing student motivation and improving student attitudes toward writing (Kurth, 1987; Lepper, 1985). Positive or negative attitudes toward writing developed early in school years generally persist, and many educators assert that learning to write using a computer can alter in positive ways students' understanding of the writing process, as well as their ability to use the self-editing process so essential to

skilled writing (Parson, 1985; Rodrigues & Rodrigues, 1986; Schwartz, 1983). In order for students to realize any of these potential benefits, they need extended opportunities to use computers for writing. However, recent surveys show that word processing occupies less than 10 percent of all in-school use of computers, and less than 5 percent of computer time at the middle-school level (Becker, 1986).

Vockell (1987) has attributed the computer's benefits to its effect on **academic learning time**, defined as "the amount of time a student spends attending to relevant academic tasks while performing those tasks more successfully" (p. 72, based on Caldwell, Huitt, and Graeber, 1982). The amount of academic learning time directly affects academic success, though not all time allocated for students to learn automatically qualifies as academic learning time. Class and study time qualify as academic learning time only if learners are successfully engaged in relevant tasks; time spent on preparation, set-up, word processing mechanics, or accomplishing trivial tasks does not increase learning time and may, in fact, decrease it. Vockell and Schwartz (1985) found using computers to teach writing an effective teaching strategy because computers increased the time college students involved themselves in their learning. In studies where no gain from using computers was found, Vockell (1987) attributes the negative effect to the absence of a net gain in academic learning time. This may have been because the tasks were educationally worthless, the teaching inappropriate, or the students lacking in the abilities or skills prerequisite to achieving the desired objectives. These researchers viewed the opportunity for more time for writing as a clear contributor to writing improvement, but expected that time was not the whole explanation for the computer's impact on learning to write better.

Most empirical studies of the computer in the classroom to date have focused on either older students (high-school and college level) or the very young (primary grades), and most have examined the use of computers for teaching computer literacy or drilling in arithmetic and spelling (Becker, 1988). Relatively few studies have looked at the teaching of writing (Becker, 1988; Chen & Paisley, 1985; Lieberman, 1985). Those studies reporting positive results in the area of writing skills usually

examined a small number of students, and the projects often occurred under special learning circumstances, such as in small summer workshops for exceptional students or special classes for those with physical problems or learning disabilities. Although such studies have considerable value, they fail to tell teachers and administrators about ordinary classrooms and ordinary students engaged in learning the traditional curriculum materials. They also fail to explain the mechanism accounting for the computer's impact on learning writing. In addition, few studies have focused on the teaching of writing at the middle-school level, a crucial time for learning writing skills and reinforcing attitudes, and they have not settled the question of "how many computers is enough?" Many classroom teachers acquired a few computers, but found themselves unable to demonstrate benefits in student writing.

RESEARCH QUESTIONS AND HYPOTHESES

In order to close these gaps in the chain of evidence, this study examined the efficacy of using computers in the standard classroom to teach eighth-grade writing skills. We wanted to learn whether using a computer regularly in the classroom would improve students' writing more than using paper and pencils/pens -- the usual way middle-school students practice writing skills, and if so, what aspects of the computer, classroom, and lessons mattered. Theory suggested that students would do more revising and correcting of their own writing -- especially revisions involving more complex structural changes in their writing -- when they had access to a computer as their primary writing means, compared to using paper and pencil or occasionally using a computer. We wanted to know if daily access to a computer would have an impact on eighth graders' attitudes toward writing and toward computers. And we wanted to know what design and teaching factors would affect the teacher's and students' accommodation of computers in a regular writing skills classroom. For this portion of the three-year study, we tracked the introduction and evolution of classroom setup to isolate the decision-making criteria influencing effective room and lesson design. Applying the theory that academic learning time must be increased to result in improve learning (in this case,

writing), we expected to amplify the concept of academic learning time, identify factors encouraging or inhibiting increases in learning time, and develop a model explaining their relationships.

Specifically then, based on previous research in the area of writing skills and computers (Diaute, 1983; Eastman, 1984; Halpern & Liggett, 1986; Monahan, 1986; Wetzel, 1985; Wheeler, 1985), we expected that the writing skills classroom could accommodate the physical presence of some computers with adjustments under the control of the classroom teacher and school principal, but that full computerization of student workplaces would require rethinking of the classroom environment. We also expected that introducing computers for teaching writing skills would have a modest impact on lesson plans, changing the format of the lessons but not the substance. Theory suggested that students using computers ought to write somewhat better by the end of the semester than noncomputer students (as measured by holistic evaluations of actual class papers while controlling for prior writing level). In particular, we expected that students using computers would demonstrate more use of both lower-order editing (additions and deletions for clarity) and higher-order editing (structural revisions and major coherence changes) than noncomputer students (Halpern & Liggett, 1986; Hollingsworth & Eastman, 1988; Parsons, 1985; Rodrigues & Rodrigues, 1986; Schwartz, 1983). In the area of attitudes, given the consensus within previous studies on the appealing and motivating aspects of computers (Becker, 1988; Kurth, 1987; Lepper, 1985), we expected computer students to exhibit more positive attitudes toward writing and toward computer use in the classroom than noncomputer students or those with a mixed treatment. Logically, it seemed that students using computers some of the time would fall between the two extremes.

Previous researchers have defined two orders of editing and revising (higher-order and lower-order) based on an alteration's impact on an entire piece of writing. Higher-order revisions depend on the writer's ability to "re-see" the writing in terms of the intended audience and purpose. Based on previous research (Becker, 1988; Lepper, 1985), we expect poorer writers to attempt more writing assignments when they had access to computers. In addition, based on assumptions about the advantages of computers over handwriting (Diaute, 1983; Krendl, 1985; Lieberman, 1988), we

expected that students using computers to have fewer errors in their final drafts of end-of-semester papers than the students using paper and pencil (relative to the number of errors each student had in the first draft).

THIS PROJECT

Grants from the State of Indiana through the Center for School Improvement and the Consortium for Computers and Higher Technology Education and Monroe County Community School Corporation over a period of three years gradually computerized an eight-grade writing-skills classroom in a public middle school enrolling about 850 students in grades seven and eight. Computers and associated equipment were installed in a regular classroom used solely for teaching eighth-grade composition. Other computers located in the school's Media Laboratory served for teaching computer literacy, data base applications, and subject matter applications in other classes. The project began with 10 computers, half Apple IIe and half Radio Shack, and then added more Apple computers each year. By 1989, the classroom had 25 self-contained computers with disk drives (22 Apple IIes and three Radio Shack TRS-80 IIIs), 25 word processing programs (AppleWorks and Scriptset), six dot matrix printers (four Apple Imagewriters and two Radio Shacks), and six intelligent switches connecting four computers to a printer. Initially, the computers were set up on small rectangular tables with individual chairs around the classroom's perimeter, while the room's center contained the usual table-arm student seats.

Altogether, 724 eighth graders participated in this project during the spring of 1987 and academic years 1987-88 and 1988-89. All were assigned to one teacher's writing skills classes, and intact classes (average size of 30 classes was 24 students) were randomly assigned a treatment. During the first three semesters of the project, three daily classes (50 percent of the students) used computers to learn writing as much as possible (though much work had to be done by hand as there were too few computers) and the same teacher's remaining three daily classes (50 percent) used only paper and pencil for their work. Finally, when the classroom was fully computerized, each student (in six

classes for each of two semesters) had a individual computer, and the regular arm-table seats were replaced with large tables carrying computers and printers. Irrespective of treatment, all were taught the same writing lessons each semester by the same teacher to keep teaching style and lessons as constant as possible. Parents were informed of the project by means of letter students took home, and virtually all students were allowed to participate in the research aspects of the project. The first semester (spring 1987) served as a pilot project for the study's remaining two years, permitting pretesting of lesson plans, questionnaires, equipment, and word processing programs, and replication across two semesters.

METHOD

Four outcomes of the project were examined: the factors influencing **computer accommodation** in the classroom and the impact of computer use on **writing lessons**, on students' **writing achievement**, and on the students' **attitudes toward writing and computers**. Wherever possible, the study employed multiple methods of evaluation and measures of effects to cross check the trustworthiness or reliability of the results.

Students in all 30 classes in this study received identical instruction in **process-based writing**, including prewriting, drafting, sharing, revising, and editing (Bechtel, 1985; Calkins, 1986; Hollingsworth & Eastman, 1988; Lindemann, 1982; Moffett & Wagner, 1983). All students learned and practiced **prewriting strategies**, such as brainstorming, listing, clustering, questioning, timed writing, looping, and cubing (Calkins, 1986; Cowan, 1983; Elbow, 1981; Hollingsworth & Eastman, 1988; Rico, 1983). It was observed and reported that some students preferred to engage in prewriting on the computer while others preferred to use paper and pencil for prewriting and the computer for drafting. Students were encouraged to return to prewriting strategies at any stage in the course of writing any assignment. They were encouraged to use the computers during class time and at home if available. Cooperative activities were encouraged to foster peer aid in the mechanics of learning computers and in revising writing (Cohen, 1986; Johnson & Johnson, 1985).

All 30 classes studied the same writing and revising processes and skills during each 19-week semester. Each student had about 28 graded writing assignments, ranging from imaginative stories to factual reports to business letters to persuasive essays (see Hollingsworth & Eastman's Teaching Writing in Every Class). Topics for specific assignments varied just slightly by semester but not by treatment; 14 of the assignments were major papers for a large number of points. Prior computer familiarity was assessed with a 5-item close-ended questionnaire (see the Appendix) administered early in the semester.

Assessments of **computer accommodation** were based on observations in the classroom by four researchers, extended discussions with the classroom teacher, interviews with the school principal, and interviews with and informal feedback from the student. Every semester, the equipment arrangement, room setup, computer procedures, lesson plans, student assignments, and testing questionnaires were reevaluated and participants reinterviewed. We looked for factors altering the computer's impact on both the classroom situation and the lessons.

Both the quantity and quality of student **achievement in writing** was assessed by comparing the number and quality of papers handed by each student, grouped for better, middle, and poorer initial writers in the computer, mixed, and noncomputer classes. Three eighth-grade language arts teachers served as paper evaluators, judging initial (start of the semester) and final (end of semester) papers for each student. They were given training in holistic paper evaluation (using a five-step model and sample papers), counting first and final draft errors, and calculating lower-order and higher-order revising and editing changes between first and final drafts of a single paper. A major or **higher-order edit** was defined as a change involving organizational or structural alterations, such as adding or deleting sentences or moving paragraphs, determined by comparing first draft to final draft; a minor or **lower-order edit** was defined as a change involving grammar, style, or appearance, such as reordering words, fixing a run-on sentence, creating paragraphs and indentation, and simple adding or deleting of words or phrases.

Following the pilot, two papers per student in each of 18 classes were evaluated in detail. (Six additional classes were observed without quantitative measurement.) Judging was blind with papers from different classes intermixed. (Since some students printed their papers on home computers or retyped them at home, appearance was not a reliable clue to treatment.) The same paper evaluators were used in all semesters, and altogether 1,078 student papers plus hundreds of first drafts were evaluated for this study. Discounting the pilot, comparative paper data (both initial and final papers) were available for 377 out of 422 students; editing and error data on a final paper were available for 358 students. We compared computer, mixed, and noncomputer classes using the holistic scores for writing achievement on the final paper while controlling for initial writing level using the diagnostic initial paper scores (applying paired t-tests for repeated measures). As a second measure, for some classes we compared the computer, mixed, and noncomputer classes on their final papers using the students' standardized English Competency Test scores (administered statewide in the seventh grade the previous year) as a control (applying t-test for repeated measures). We found no significant differences between the two measures when used as estimates of prior writing level.

At the start and end of each semester for two years, **attitudes toward writing and computers** were assessed with a 38-item Likert-scale questionnaire (using a five-steps from Strongly Agree to Strongly Disagree). A copy of the questionnaire appears in the Appendix. Six experimental, six mixed, and six control classes were compared using t-tests for repeated measures and analysis of covariance (in effect, controlling for individual pretest scores). Questionnaire items related to students' (1) attitudes toward writing in general, (2) attitudes toward computers in general, and (3) attitudes toward using computers for learning writing in school. Additional items addressed attitudes toward gender roles and computers, cooperative learning processes in the writing classroom , and parents' familiarity with computers (2 items asking whether a parent used a computer at home or at work).

RESULTS

During the semester, students were required to rewrite, revise, and edit their writing and to turn in all drafts of every paper, however prepared (handwritten, home typed, or computer printed). Average class size was 24 with no significant differences between the sizes of computer, mixed, and noncomputer classes or their prior writing level. Nearly all students had some self-initiated previous practice in typing, and all who attended an Indiana school had completed an 8-week state-mandated unit on computer literacy (emphasizing BASIC) during the seventh grade. There was no significant difference among treatment groups on parents' use of computers at home or at work.

In the computer treatment in this study, each student had a personal Apple or Radio Shack computer at his or her regular workplace in the classroom (see photographs in the Appendix). In mixed classes, students moved around from table-arm seats to computer tables, sharing a computer or working alone as they preferred. Keyboarding skills and use of disks proved no obstacle to use of the computers at any time in this project. The 5-item questionnaire about prior computer experience established that all but 3 percent of the students had worked with computers at home, at school, or at a friend's house before beginning eighth-grade, and that 95 percent of the students came to their writing skills class with some knowledge of computers.

The pilot study in the spring of 1987 provided valuable insight into the mechanics of the computerized writing classroom. Although computers were installed too late that semester to have measurable impact on the students' writing or attitudes (more than half the semester had passed by the time the equipment was working so no net increase in academic learning time occurred), we were able to observe the students' reaction to word processing, printing, and the computerized writing room environment and solve several small problems before the main study began. The pilot demonstrated that the computerized classroom requires different norms and different sanctions than most other classrooms. For example, students cannot chew gum or eat candy in the room because of carpeting and expensive equipment; all coats, books, and papers must be stored in specific places to leave computers and printers unencumbered; many containers for trash paper disposal are needed.

The penalty for lack of attention to task became removal from a computer for the day with the requirement that assignments be handwritten. The pilot also showed that the teacher needed to make several advance preparations before the students faced the computers. For example, written instructions for using disks, setting up a file, saving a text, and printing a text need to be conspicuously posted at every computer or distributed in laminated plastic sheets (to make them hardy and easy to locate). Lessons needed to be prepared in mini-units for immediate application. If the teacher wants students to save and print both first and final drafts of papers (as recommended in grading process-based writing), then a system for individual naming of sequential files needs to be determined.

The pilot also showed that most students were able to follow the word processing instructions with volunteer aid from other students, leaving the teacher free to work with individual students about their writing. However, the students did find the Radio Shack word processing program (Scripset) more confusing (and occasionally more obstinate) than the Apple program (AppleWorks), and most students soon announced a decided preference for the Apple computers. Most had used Apples in their seventh-grade computer literacy class, and there was transference from that experience. Most students willing to work on the Radio Shack computers were those who had prior experience at home or at a friend's house with that brand.

Accommodating Computers in the Classroom

After three years of assessing classroom computer use, several generalizable conclusions emerged regarding equipment and the computerized writing classroom environment. Evidence supporting these claims comes from the quantitative assessments of writing achievement and comparative attitudes described in the next sections, as well as from interviews with teachers, the principal, and students. Photographs from the project's 1988-89 phase included in the Appendix also support these claims. All conclusions have stood up through three years of observing, testing, and working with multiple classes in a computerized writing classroom.

First, **sufficient numbers of computers are needed for all students to work simultaneously and individually.** This arrangement is much to be preferred to doubling up or staggering use of fewer computers. Having individual computers permits students to start and complete a project at the same time. This (a) minimizes repetition of assignment and word processing instructions, (b) finishes each learning task when it is time to begin the next new lesson and is convenient for grading, and (c) fosters cooperative learning and peer teaching. Moreover, only when all students have computers are improvements in higher-order editing measurable (see Table 1), probably as a result of substantially increased academic learning time.

Second, **all computers should be of the same brand and model.** Standardization provides (a) unity in computer and printing instruction and (b) encourages peer aid with word processing mechanics, allowing the teacher to concentrate on teaching writing, not directions for using word processing commands. In practice, the classroom teacher called out AppleWorks instructions in response to student questions, and then had to stop and think what the comparable process was in Scriptset. Since many of these processes are reversed, confusion readily occurs. For example, in one program, there is an Enter key, in the other, a Return key; in one the user presses the Control key, in the other the Ampersand.

Photographs A, H, and J in the Appendix show Radio Shack computers with built-in disk drives and accompanying printer in the foreground and Apple IIe computers with separate disk drives and printer on the right in the background. In this project, the Radio Shack computers functioned poorly as word processing machines; both the software and hardware created problems. Scripset, for example, proved slower and more cumbersome to use than AppleWorks. Just to clear the screen, for example, the following sequence is required in Scripset: Shift/Up Arrow; Ampersand/D; Ampersand/Down Arrow; Yes; Enter. The Radio Shack computers and disk drives available for this project were nearly ten years old and were much less reliable in saving files than the newer Apple computers. These older machines were slow to call up a directory and agonizingly slow to initialize (format) disks. In addition, the Scripset program had been modified to the point

where the school's computer expert was no longer sure just what the proper instructions for word processing in Scripset should be. In contrast, the Apple IIe computers, disk drives, and printers and the AppleWorks word-processing program proved dependable and appropriate for this kind of student use. Newer Radio Shack units would probably prove quicker and more reliable, but the important point here that one system is quite enough for a classroom teacher to handle.

Third, **regular table-arm seats should be replaced with groupings of four or six computers around hexagonal or rectangular tables holding a printer and associated electrical and switching equipment.** Most classroom are too small to accommodate two seats for each student. Diagonally positioned rectangular or hexagonal tables will hold 24 or more computers and six or more printers in the usual size classroom. Power poles can be installed to carry electric current down from the ceiling when below-floor installation of cables is not possible (as when floors are concrete or otherwise rigid). As several photographs show, this arrangement (a) minimizes crowding, (b) maximizes student working space for spreading out papers and books, (c) speeds the printing of drafts and start of revisions, and (d) facilitates smooth transition from one kind of activity to another kind of work without interference by the furniture. The students are not then required to move around to change activities, a positive benefit in minimizing room noise. Photographs A, B, C, D, and J show the layout of the computer tables in the classrooms. Photograph I shows a closeup of one power conduit, a metal container for cables dropped from the ceiling (needed because cables could not enter from below the floor in this room). Each metal conduit is marked "Caution: Electric Current" not because any imminent danger exists, but because it is prudent to discourage students from removing the metal conduit covers and exposing the cables. In this classroom, a separate power conduit was installed for each table of computers.

In the design of the classroom, we found nine criteria had to be weighed before the electric wiring is finalized to arrive at an **optimal room arrangement** for computer use. The tables need to be (1) far enough apart to allow 2' behind each student chair for chair movement and passage room (see Photograph C). They need to be (2) angled so that all students can see a projection screen and

blackboard without moving themselves or their chairs (see Photograph D). They need to be (3) aligned so that none are against walls and the teacher can walk in a figure-eight pattern around the room (figure-eight walking patterns minimize retracing of steps as in Photograph F). They need to be (4) aligned so that most screens are visible to the teacher, half from one side of the room, half from the other side, with no blind spots. Symmetrical positioning (5) minimizes clutter (see Photographs A, D, and J). In addition, (6) some arrangement must be made to store student coats to keep them from crowding space around the computers, and (7) empty tables and chairs need to be available for group work activities and visitors (see the far right background of Photograph A). Regarding the electronic equipment itself, (8) no computers should be positioned against a wall with windows because outside light causes poor visibility on monitor screens. Printers (9) should be located at the end of the tables farthest away from the teacher's usual lecture positions to cut down on noise (see Photographs A and D).

Perhaps most important, however, is the need to **alter students' expectations about the "normal" environment of the writing classroom.** Replacing the traditional table-arm seats with computer-oriented groupings visually asserts that using computers is the normal, everyday method of working in this classroom. Having two seats for each student -- one table-arm chair and a straight chair at a computer table -- overcrowds most classrooms and sends a mixed message: It implies that one set is "regular" and the other somehow "special." A mixed message distracts students from the real focus of the class: writing.

Also, every computer/printer grouping should have a readily available trash container as large amounts of trash paper are generated; waste paper includes endless miles of strip-edging from fan-fold paper as well as whole sheets of scrap. Having a stapler and a box holding the appropriate computer disks on each table--rather than centrally located--also minimizes unnecessary moving around. Having a separate disk for each student eliminates ready opportunities for students to fiddle with others' work. The focus of the writing classroom should be on producing writing, facilitated by accessible materials, the proper tools, and the appropriate furniture for comfortable writing.

Finally, one important observation was that easy **access to printing** is as crucial to students as user-friendly word processing programs. In this study, students printed and reprinted their work, modifying and improving it each time. The value of this process to achieving "distance" from the writing and the ability to "see" needed improvements and thus to revise should not be overlooked. Students repeatedly told us that their work appeared different to them in ways they hadn't predicted when printed on paper, compared to the way it looked on the computer screen. Students reported that they always saw things they wanted to change. Many took the hard copy home for out-of-class editing and commented that they received more valuable revising aid from parents and other adults when they had printed versus handwritten drafts. The process of printing was as important to revising and editing as seeing changes immediately on the computer screen. Therefore, teachers need to encourage printing in their attitudes (for example, by not penalizing students for using up paper for reprinting) and by having at least one printer for every four students.

Accommodating Computers in the Lessons

On the writing side, **using computer keyboards will be slower for students at first than handwriting.** Teachers must expect to hear complaints that "computers take too long" (compared to handwriting) and, especially at the start of the semester, to find many noncomputer students turning in their assignments noticeably sooner than students using computers -- much to the vocal dismay of the computer students. Students usually want rapid closure on assignments, and at first the computer seems to get in the way (largely because of poor keyboarding skills). It is important for the teacher to make clear that rapid completion is unimportant (unlike in typing classes) and that taking longer is not penalized, as long as the student works steadily. However, vocalized complaints about the computer's slowness evaporate as soon as the students see a printed page of their own work. Once (1) they begin to print, they become enthusiastic proponents of the computer and devote much more attention to their work's appearance than they did when work was handwritten, striving to make printouts look professionally "published." Moreover, (2) as the students get experience with

word processing, they get faster, eliminating much of the initial keyboarding disadvantage. Eventually, (3) many students discover the ease of revising on the computer and favor the ease of revising and editing that computers give them. However, students who have actually used a computer for writing in school report some caution in their attitudes regarding computers compared to students who haven't used a computer as much; all students reported (see Table 4) that using a computer made schoolwork easier, but those who had used one in this study for word processing were slightly less sanguine about the process.

Using computers for teaching writing skills also affects the design of writing lessons. Some lessons (such as those incorporating wholly new skills or producing major projects) necessitate all or most of a class period, irrespective of whether students use computers. However, the computerized classroom lends itself to the use of mini-lessons within ongoing writing units. **Mini-lessons** (Calkins, 1985) are brief 3- to 5-minute teaching periods, occurring before or in the middle of an assignment, that focus students on a particular skill or process that will then be graded. Because revising their work is comparatively easy on a computer, students using computers tend to show more effort in incorporating these mini-lessons in their ongoing work (presumably learning more than paper and pencil students).

Over the course of a semester, however, teaching with computers generally **takes slightly more time.** Lessons will have to be adjusted for nonsyncronous computer use (especially in mixed equipment classes), and assignment deadlines need to be flexible to accommodate individual differences in typing and composing skills. In addition, it may be necessary to reduce the total number of writing assignments given in a semester, but the depth of each individual assignment can increase in the computer class. A further outcome of using computers is the necessity of developing supplementary activities that are both fun and rewarding for those students who finish before others and who might otherwise interfere with classmates' files and involve themselves in other classroom annoyances. Overall, students using computers to write will end up writing longer papers than those restricted to handwriting. This occurs in part because it upsets students to find a first printout looks

shorter than they expected. In response, they rethink their work and usually will write more to make the paper longer, meanwhile revising, often making higher-order edits. Students will also fiddle with the appearance of their papers, seeking symmetrical and attractive titles and notes similar to those of published work.

Using computers will aid in concentration on assignments. This facet of the computer has positives and negatives. On the positive side, students will tend to focus tightly on their writing, attending to a single activity longer than they might without computers. At the same time, the class period will pass so quickly that clear and frequent warnings of the period imminent end will be needed to get files saved and materials cleaned up by the end of class time.

As a teaching aid, **the computerized writing classroom should have an overhead display of a master computer's projection screen** visible from every seat in the room. Although similar lessons can be taught using a blackboard or handouts, displaying writing processes on an overhead screen, demonstrating just the way the students will be using them, has distinct advantages. What the teacher shows on the large projection screen corresponds exactly with what the students see on their own screens, making the outcome of multistep processes on the computer, such as blocking and moving, inserting and deleting, underlining and centering, and so on, immediately apparent to students. Technological innovations such as the liquid crystal (LCD) overhead display which connects to a standard computer make this next step in efficient teaching and learning possible as reasonable cost.

Writing Achievement

In this study, the computer students averaged significantly higher scores for overall quality, creativity, and higher-order editing on the end of semester papers than the mixed or paper-and-pencil students. We measured writing level two ways -- by a standardized competency test score and by holistic evaluation of writing samples by participating teacher/evaluators -- but found no significant difference between the results on average or when students were grouped by prior writing level. Table 1 compares computer, mixed, and paper-and-pencil classes using average scores for (1)

holistic evaluations, (2) creativity evaluations, (3) error rates (controlling for number of errors in initial draft), (4) number of lower-order edits, and (5) number of higher-order edits. The significant differences give evidence of substantially more higher-order revision in the computer treatment compared to paper-and-pencil. The effect did not occur in the mixed treatment, supporting the conclusion that students need individual computers for writing in order to make measurable gains in learning revision within a single semester. Using a computer also seems to foster creativity in writing, even when essays from identical assignments are compared.

Table 2 shows that even mixed-treatment students wrote significantly better irrespective of initial writing level (high, middle, or low). In the paper-and-pencil classes, only the initially poorer writers (as measured by holistic writing scores on a beginning-of-semester paper) improved significantly, whereas even some computer use led to higher qualitative writing scores for the mixed treatment classes, as measured by blind evaluations by teacher/evaluators. In addition, when the number of graded assignments completed was compared by treatment group (see Table 3), it was found that the initially poorer writers in the mixed classes completed more work (only 7.9 items missing on average per class versus an average of 9.2 items missing in the control classes).

No differences in error rates or lower-order editing practices among groups emerged in this study. Appleworks and Scripset, the word processing programs used by students, lacked spelling checkers or other self-correction programs, and such programs might be desirable to foster students' ability to "see" the need for polishing their writing.

Attitudes Toward Writing with Computers

As is typical of short-term attitudinal research, most of the 24 items on the student survey asking about attitudes toward writing and computers remained stable during one semester. No significant differences existed among classes in the attitudinal pretest, and most attitudes remained unchanged at the semester's end when analysis of covariance took into account the individual's pretest score. As Table 4 shows, however, some significant attitudinal changes occurred that differed

by treatment. Students in the computer classes developed somewhat more positive attitudes toward revising ($p > .05$) and toward drafting their papers on computers ($p > .03$) than students in the mixed or paper-and-pencil classes. Moreover, students in the computer classes expressed more liking for learning by means of computers ($p > .00$) and for cooperative interaction with classmates in the learning process ($p > .02$). At the same time, computer students expressed slightly less enthusiastic (though still positive) attitudes toward the assertion that "computers make schoolwork easier." This suggests that an extended experience with relatively primitive word processing (Appleworks compared to, say, Word Perfect or Word Star) generates some reality correction. Perhaps the more one works with computers, the more visible their shortcomings.

DISCUSSION

Based on this study's results, and consistent with previous research, we concluded that two overall conditions -- motivation and academic learning time -- lead to writing improvement. However, six sets of more specific factors, including computers and printers, also contribute cumulatively and probably in rank order to increasing both motivation and academic learning time, thus affecting how quickly and how well students learn to write.

Figure 1 illustrates some relationships among the factors affecting student writing. The model recognizes that students have learned to write over the decades and centuries of civilization without modern methods of computer technology. Nonetheless, we assumed that better methods and equipment can increase the two key elements of the process -- motivation and academic learning time -- by speeding up the learning process, perhaps ultimately increasing the total amount of learning (of writing skills) for most children.

Thus, our model of influences on learning writing begins at the bottom with the students' **individual differences** in cognitive development and communication ability, which naturally affect their motivation and capacity to take advantage of academic learning time (bottom of model in Figure 1). Then, we assert, **teaching** makes a difference, and process-based instruction in writing

fosters learning better than the more traditional teaching of skills (grammar, punctuation rules, and so on), though both eventually become important to learning writing. These factors are reinforced by the **classroom environment**, the main elements of which are expectations about writing and reinforcement of the teacher's lessons (or contradictions of them -- as when the teacher claims to desire revision but complains about excessive use of printer paper). Other elements in the classroom environment include the attitude of other students and the attitude of school administrators as implied by the condition of desks, equipment, displays, and so on.

Another crucial element in increasing motivation and academic learning time is how student work appears to others. Tidy-looking typed or printed student papers get more attention from classmates, parents, and teachers than handwritten work, thus **presentation** becomes important in getting help in learning to write (both through direct criticism and recognition for writing). Since few schools provide typewriters for writing classes, the electronic printers associated with computers that aid students in achieving easy-to-read and even professional-looking papers. Then **computers** have a direct role to play. They foster concentration and focus on task certainly, and they contribute the ability to see writing immediately on a screen, without the labor and slowness of handwriting. Computer screens show changes in writing instantly, encouraging students to revise and edit, as demonstrated in this study. On a cognitive level, writing on a computer helps students distance themselves from their words, making alterations (especially higher-order revisions) relatively uncomplicated.

Finally, the style of **learning** among students and between students and machines contributes to motivation and academic learning time. Considerable evidence shows that cooperative learning strategies (in which students teach each other -- for example, by commenting on each other's papers) encourages better writing. Interactive computer software might also contribute to better writing by increasing motivation and academic learning time, though whether writing software has reached that level of sophistication is problematic.

For scholars, the question then becomes HOW printers and computers have these effects. Vockell claims that academic learning time (as opposed to social or interpersonal learning) only takes place during short periods of time among long periods of non-learning. We accept increased time as a partial explanation, but we concluded that computers and printers have the additional effect of increasing feedback. Printed papers encourage constructive peer and adult criticism, and computers make revising papers easier, probably even encouraging certain types of self-editing and revising, such as spelling checks and block movement, and encouraging presentation improvements, such as consistent indenting and spacing, thus increasing motivation by making a degree of professionalism attainable. Based on the results of this study, we concluded that computers are important to learning to write because they **accelerate the cycles of creative effort and feedback**. Thus the study adds to scholars' theoretical framework as well as provides practical classroom applications.

In sum, this study thus shows how computers can improve student writing in an eighth-grade writing skills class and improve student attitudes toward the writing process. It suggests that full computerization of the writing skills classroom is a worthwhile and achievable goal for schools. The study shows that modest changes in writing curricula and classroom management strategies will accommodate computers. At the same time, we found that the computer's effects in learning writing are limited and difficult to detect with gross measures of lower-order editing and errors. In surveys and interviews, many students will continue to assert that handwork is faster than using a computer and report this as a negative aspect of computer use, while simultaneously claiming to prefer learning writing by means of computers largely because of their innate appeal and their perceived job relevance. Our rudimentary model illustrates some relationships between computers/printers and the student, the teacher, and other aspects of the writing classroom, accounting for the computer's positive impact on writing by its tendency to increase feedback as well as academic learning time. Finally, we enumerated the criteria for designing a writing skills classroom, based on our prototype classroom, to provide a framework for teachers adopting a writing with computers curriculum.

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Table 1. Comparison of Computer, Mixed, and Paper-and-Pencil Students by Quality of Writing, Errors, and Revisions

Average Score++	Holistic Scores	Creative Scores	Errors**	Lower-Order Edits	Higher-Order Edits
COMPUTER CLASSES	4.0*	3.4*	.5	5.1	4.9*
MIXED CLASSES	3.2	3.0	.3	6.8	1.6
PAPER & PENCIL CLASSES	3.2	3.1	.3	5.8	2.0
Significance	p>.03	p>.04	p>.00	p>.10	p>.00

**Errors calculated by subtracting the number of errors in the first draft from the number in the final draft.

++The Ns of groups analyzed varied somewhat across variables, ranging from a low of 115 cases to a high of 136 cases per treatment.

Table 2. Comparison of Computer and Paper & Pencil Students' Holistic Writing Scores, Fall 1987, for High, Middle, and Low Prior Writing Level

	Holistic Scores		Significance
	Initial Paper	Final Paper	
MIXED CLASSES			
High (3.5-5.0)+ N = 8	4.31	4.75	.04*
Middle (2.1-3.4) N = 28	2.98	3.64	.00*
Low (.01-2.0) N = 18	1.69	2.30	.00*
PAPER & PENCIL CLASSES			
High N = 8	4.18	4.18	N.S.
Middle N= 30	3.01	3.28	N.S.
Low N = 19	1.68	2.47	.00*

+Students were divided into High, Middle, and Low groups based on initial diagnostic paper score (unrelated to semester course grade).

Table 3. Comparison of Average Number of Assignments Not Completed for Computer, Mixed, and Paper-and-Pencil Classes, Fall 1988, Fall 1987 and Spring 1988

	Papers Not Completed	
	Computer Classes	NonComputer Classes
Writing Level**		
TOP WRITERS	.8	.6
MIDDLE WRITERS	2.3	2.3
POORER WRITERS	7.9*	9.2

*Writing level was determined by score on diagnostic initial paper (not necessarily related to course grade which is affected by achievement).

Table 4. Comparison of Attitudinal Differences Among Computer, Mixed, and Paper-and-Pencil Classes, Controlling for Pretest Attitudes

	Significant Questionnaire Items				
Treatment	Revising Papers	Drafting Papers	Learning Computers	Commenting by Students	Schoolwork by Computer
COMPUTER CLASSES N = 137	2.08*	3.32*	1.83*	2.70	2.44*
MIXED CLASSES N = 129	2.28	3.06	2.05	2.71	2.36
PAPER-AND-PENCIL CLASSES N = 146	2.27	3.06	2.05	2.93*	2.27

Figure 1. Model of Factors Contributing to Writing Achievement