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How Exemplary Computer-Using Teachers Differ From Other Teachers: Implications for Realizing the Potential of Computers in Schools

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In a recent study of teachers who had reputations as being expert computer users, researchers at the Bank Street College of Education identified teachers who used computer software to provide intellectually exciting educational experiences (Sheingold & Hadley, 1990; Hadley & Sheingold, 1993). In the Bank Street study, the exemplary practitioners directly addressed curriculum goals by having students use a wide variety of computer software, including simulations, programming languages, spreadsheets, database programs, graphing programs, logic and problem-solving programs, writing tools, and electronic bulletin-board communications software. Over time and with experience, the teachers became enthusiastic about seeing their students exploit intellectual tools for writing, analyzing data, and solving problems; and they became more comfortable and confident about using computers themselves. Sheingold and Hadley (1990) provided a portrait of computer use that other teachers might aspire to and attain in their own teaching practice.

Although the teachers in the Bank Street study constituted a broad cross-section of teachers in different regions and demographic and socioeconomic climates, they were selected because they had reputations as expert computer-users. Such a design enables us to learn in detail about exemplary teachers, but makes it difficult to assess how exemplary teachers came to use computers differently from other teachers. It is not known whether the nominated expert teachers differed from others in terms of their personal background, their beliefs about and philosophy of education, or the characteristics of their work environment that may have fostered the growth of exemplary teaching practices. It is important to investigate these differences because they will help us understand the barriers that exist for extending the practices of exemplary teachers to others.

If, for example, the major difference between exemplary and typical computer-using teachers is that exemplary teachers have more years of experience in using computers in their teaching, we can relax because we know that eventually better practices will diffuse to more teachers. Or, if the major difference between exemplary and typical teachers is organizational—for example, if exemplary teachers receive support from their building and district administrators—then the

development of additional expertise among computer-using teachers is something that administration and policy can influence. However, if the major difference is something less easily changeable—for example, if exemplary teachers believe far more strongly than do typical teachers in organizing classrooms around exploration and discovery-based learning—then the task of extending best practices to a wider population of practitioners will be far more difficult. Similarly, if exemplary teachers practice their craft mostly in classrooms with academically talented students or students from better educated families, then the effort to extend their practices to less favorable circumstances remains problematic.

The Bank Street study shows that exemplary teachers exist. But to more accurately assess the relative frequency with which such teachers exist in different places and work environments, a survey design is needed that incorporates the full range of computer-using teachers, including both those who would be nominated as exemplary users and those who are more conventional in their use of computers in their teaching. Only through such a comparative design can we learn how to provide interventions that will expand the practices of the best teachers to others.

An Approach to Studying Exemplary Computer Users Through Data from a Probability Sample Survey

In 1989, an international survey (the I.E.A. Comp-Ed survey) collected information about the patterns of computer use in elementary and secondary schools in 20 countries (Pelgrum & Plomp, 1991). As a participant in that international effort, the Center for Social Organization of Schools at Johns Hopkins University conducted a national probability sample survey of teachers and administrators in roughly 1,400 schools in the United States.

In the sampled schools, questionnaires were completed by the principal, by the school-level computer coordinator (or the staff member most knowledgeable about computer use), and by a probability sample that included both computer-using and non-computer-using teachers. About 69% of the principals, 76% of the school-level computer coordinators, and 79% of the teacher sample responded by mail. Most of the remaining coordinators and teachers participated in an abbreviated telephone interview, so we actually have some data on 94% of the sampled respondents. The teachers who were included were those who taught elementary grades 3 through 6 and, in middle schools and high schools, those who taught mathematics, science, English, or computer education. The teacher sample was somewhat smaller than the samples of computer coordinators and principals (N=1,029 teachers sampled; 817 questionnaires completed; 140 more interviewed by telephone). Schools and teachers that were expected to use computers more intensively were oversampled in comparison to those expected to be less active computer users, so all statistical analyses necessarily used weighted cases in order to reconstitute the sample as representative of all schools and teachers in the population.

This national probability survey was fielded at the same time as the Bank Street College study, but, as one would expect from their different designs, the national probability survey described a very different pattern of teaching practices involving computers. Across the United States, as of 1989, only one teacher in six among secondary school math, science, and English teachers used computers in a substantial way—either, as phrased in the survey, “throughout the year” or “intensively, but only for certain units” (Becker, 1991). At the elementary level, most teachers reported having students use computers for their classes, but a majority of those teachers had only one or two computers accessible to their class. Even frequent use by a class that had only one or two computers could not translate into substantial experience for an individual student.

Moreover, in contrast to the Bank Street finding that software productivity tools were used extensively by teachers reputed to be exemplary, such programs played only a minor role in the national survey, except for word-processing in high school English. For example, only 1% of computer-using math teachers said that their students used spreadsheets on more than five occasions during the year. And only 11% of computer-using English teachers had students use spelling checkers regularly.

Even in terms of the teachers' goals for using computers, the typical survey responses from the national sample were not inspiring. The majority of surveyed computer-using teachers indicated that their major goal in using computers was to help students master basic facts or skills. Among secondary math teachers, 58% said that one of their three most important goals for using computers was "for student mastery of computation skills," while only 16% gave "understanding numerical relationships" as a goal of computer use. And more than twice as many elementary teachers chose "basic skills" as a goal than chose "applying math," or "improving writing skills," or "understanding math and science."

This pattern of responses to the national survey raises a real question: How rare are the kinds of teachers nominated as exemplary in the Bank Street study? To address this question, we can define a set of criteria similar to that used to nominate exemplary teachers in the Bank Street study, and then examine our data to see what fraction of our national sample of teachers fulfill those criteria. Then, using other data about the schools and teachers in our national survey, we can assess how the background and teaching environment of this select group of teachers differs from those of the remaining computer-using teachers. Such differences will help us learn how difficult a task it will be to extend the practices of exemplary teachers to others. That is the primary function of the following analysis.

Method: Identifying the Exemplary Computer-Using Teachers

From the many questions in the subject-specific teacher questionnaires administered in the U.S., eight sets of questions were selected from the mathematics, science, English, and elementary questionnaires. The survey questions that were examined indicated (a) the teacher's goals for computer use, (b) the frequency with which students used computers, (c) the saliency of the computer approaches used for the major learning activities in the class, (d) the amount of experience students had with using certain types of software, and (e) the general functions that computers played in the class.

For each group of teacher-respondents, 12 to 15 standards were selected—these standards were answers that an exemplary teacher in a given subject might be expected to provide. In the case of English teachers, for example, one standard was that improving writing skills was one of their most important goals of computer use. Another was that computers did not primarily serve as a reward to students for completing other work. A third was that computer activities mostly or nearly always directly supported other work done that day in class. A fourth standard for English teachers was that when students were given an assignment to complete a story from a prompt, computers were used at least 25% of the time.

The set of standards selected—indeed, the particular questions asked in each questionnaire booklet—differed by subject and between elementary and secondary teachers. But the standards suggest a classroom environment in which computers were both prominent in the experience of

students and employed in order that students grow intellectually and not merely develop isolated skills.

Based on the standards described, a pilot index score was calculated for each teacher. The pilot index scores were then correlated with each of about 25 other answers from the same set of eight questions. Using these correlations and considering the teaching practice that each answer represented, between six and eight additional items were added to the original pilot indices to build a more complete index for each teacher group. Table 1 lists the components of the final index for each of the four groups of teachers and indicates whether each component was in the index by definition or because of its positive correlation with the pilot index.

An index arrays people along a continuum, from low to high. In the absence of any independent data on the teaching success of teachers with different index scores, an arbitrary cut-off index score to separate exemplary computer-using teachers from more typical ones. After examining dozens of teacher questionnaire booklets for each teacher group, the general criterion decided upon was that the exemplary teacher must meet at least a bare majority of the index standards for that teacher group. Thus, a teacher classified as “exemplary” could actually fail to meet nearly one-half of all of the standards being used for his or her teacher group (subject-matter). The Appendix demonstrates how this works for one subject area by presenting each of the components of the index created for the mathematics subject-matter teachers and the standards used for that subject area.

Of the 516 math, science, English, and elementary teachers who completed U.S. subject-specific questionnaires or telephone interviews and who were all to some extent computer-using teachers, only 45 teachers met a majority of the standards for their group. Among the math teachers, 11 did so, as did 9 science teachers, 13 English teachers, and 12 elementary (grades 3-6) teachers. Because those teachers happened to be somewhat overrepresented in the sample compared to an equal probability sample, the actual proportion of computer-using teachers in the U.S. who would meet the majority-of-standards criterion is only about 5%. When we also include in the denominator the teachers who do not use computers at all, the proportion of exemplary teachers among all teachers of the studied subjects and grade levels is only 3%.

Distinctions Between Exemplary Computer-Using Teachers and Other Computer-Using Teachers

In the remainder of this article, we shall examine how the 5% of computer-using teachers whom we judged as exemplary differed from the other 95% of computer-using teachers in those same subject areas and grade levels. We will look at three types of differences among teachers: (a) differences in the school and classroom environment in which they worked (including the clientele they served), (b) differences in the teachers’ own backgrounds and experiences, and (c) differences in the ways they carried out their teaching practices and in their perceptions concerning teaching and computer use.

By examining the teachers’ computer-use practices (other than the ones used to define “exemplariness”) and their perceptions of their teaching tasks, we can begin to see how computers have affected them as teachers. By examining their backgrounds and experiences, we can document which teachers have more successfully mastered the challenges of using computers effectively. And by examining their school and classroom environments, we can learn more about the conditions that facilitate the blossoming of exemplary computer-use practices.

Differences Between Exemplary and Other Computer-Using Teachers' Work Environments

Our research started with the following question: What is it about a teacher's teaching environment that might facilitate the development of exemplary computer-use practices? This question was operationalized as a more empirically addressable one: How does the teaching environment of exemplary computer-using teachers differ from the teaching environment of other computer-using teachers in the same subject? We especially want to identify those differences that are alterable through re-allocation of resources.

Table 2 presents a summary of this analysis. Table 3 provides more detailed results for five aspects of the teachers' environments, incorporating the following school-level and classroom-level variables:

- The nature of the student body served.
- The experience and level of expertise with computers of all teachers at the school.
- School policies and practices regarding alternative uses of computers.
- Allocation of resources for computer coordination and staff development.
- Resources available to the teacher and teaching requirements.

For each of these five aspects of the teacher's environment, specific variables that were studied are shown in Table 3 in order of decreasing difference between the environments of exemplary teachers and those of other computer-using teachers (i.e., starting with the variable showing the greatest difference).

In addition to actual means or percentages for exemplary and other computer-using teachers, the size of the difference between them is summarized using the standardized mean difference, which is comparable to an effect size statistic in an experimental design. This statistic is the difference between the mean for the exemplary teachers on the variable in question (or the percentage of that group having some characteristic) and the mean for other computer-using teachers, divided by the two groups' pooled within-group standard deviation. Table 3 also gives a rough indication of effect sizes for teachers of specific subjects (math, science, and English), and for elementary-level teachers. In the table, + and – signs are used in various quantities to denote where the factor may be particularly important (see note to Table 3). Although the difference implied by even one + sign is quite large, the number of cases of exemplary teachers in any one column (math, science, etc.) is quite small—fewer than 15 persons in every case—so the likelihood that any one difference was obtained by chance is substantial. Where two or more columns contain + signs, or where there are multiple + signs for a single column, the likelihood is much greater than the differences reported for this sample (or subsample) are true for the population at large.

Both Table 2 and Table 3 illustrate that although the teaching environments of exemplary computer-using teachers differed in many ways from the environments of other teachers, there were also important similarities. For example, exemplary computer-using teachers were as likely to be found in low-income districts and low socioeconomic-status schools as they were in other schools. A second example shows that, although classroom-located rather than lab-located computers may be more easily integrated into important teaching/learning activities, exemplary

teachers were as likely to use computers in lab settings as were other computer-using teachers.

Generalizing from the results of many variables examined for their correlation with the presence of exemplary computer-using teachers, four characteristics of the teaching environment seem to make exemplary computer-users more likely to be present: (a) the existence of a social network of computer-using teachers at the same school; (b) sustained use of computers at the school for consequential activities, that is, where computers are used to accomplish a goal other than learning, for example, writing and publishing, industrial arts, or business applications; (c) organized support for computer-using teachers in the form of staff development activities and a full-time staff member in the role of computer coordinator; and (d) acknowledgement of the resource requirements for effectively using computers, for example, smaller class sizes and funds for software acquisition.

Social Networks of Computer-Using Teachers

Teachers spend most of their working lives out of sight of other adults. If they are to successfully incorporate a new and complex resource like computer software into their teaching practice, they must have access to other people from whom they can learn, either experts who have already mastered the resource or a community of teacher-learners who pool their efforts and share their exploratory findings. Thus, it is not surprising that we would find that exemplary computer-using teachers are more likely than other computer users to be working in a school with many other computer-using teachers. It is also true that exemplary teachers may themselves create (rather than just be created by) an environment in which many teachers use computers. Nevertheless, it is instructive that of the 51 separate teacher environment variables examined (see Table 3), the one with the largest difference between exemplary and other computer-using teachers was simply the total number of teachers at their school who used computers. Exemplary teachers were in schools that had nearly twice as many computer-using teachers (13 versus 7, on average). The absolute number of computer-using teachers in their environment was even more closely related to the presence of exemplary teachers than was the proportion of teachers who are computer users. Among the teacher groups studied, only mathematics teachers were as likely to become exemplary computer-using practitioners regardless of the number of other computer-using teachers at their own school. Science and English teachers seem especially dependent on the presence of other computer users in order for them to develop high quality practices involving computers. (see Table 3, panel 2.)

It helps if the other computer-using teachers are also competent users. Exemplary teachers practiced in schools where nearly twice as many teachers were thought (by the survey informant) to be expert at using instructional programs and where twice as many were reported to be expert at programming, compared to reports from schools of other computer-using teachers (see Table 3, panel 2). In general, the environments of exemplary teachers are more computer-active. At the schools with exemplary computer-using teachers, there were more computers present per capita (Table 3, panel 5), and a larger fraction of school computers were obtained in the previous two years, which suggests a more vibrant interest in computer use (Table 3, panel 2).

Computer Use for Consequential Activities

A nearly universal characteristic of school is “busy work,” for example, worksheets and homework assignments, quizzes and tests, all of which are assigned so that students can practice and demonstrate skills mastered and knowledge remembered. Worksheet activity is symptomatic of the fact that, in school, students demonstrate learning mainly by taking paper and pencil tests rather than by accomplishing something or producing something for the real world outside of the classroom. In that sense, skill mastery and remembered information are significantly different in school than in real life, where people’s activities are valued for the consequences that they have for others—an audience, a clientele, a customer base, or colleagues. Although most computer work mimics traditional school work, with computer-based drills, tutorials, educational games, and programming exercises dominating most students’ time on school computers, computers do make possible activities that may imitate real life (as in simulation games), or even may be a part of it. Writing for an audience is one computer activity that could have real consequences, for example, using computers to write class and school newspapers or to do the design and paste-up work related to publishing volumes such as the school yearbook. Other consequential computer-based activities are those involved with occupational preparation. In the two high school subject areas of industrial arts and business education, computers are generally used as tools to accomplish tasks necessary in the performance of productive work.

Several results shown in panel 3 of Table 3 suggest that exemplary teachers work in environments where some thought has gone into making computer activities consequential. The evidence about using computers for writing is one indication of this. Exemplary teachers were twice as likely to be present at a school where the school’s computer coordinator reported that students had used word processing to complete school assignments for three or more years (60% versus 30%). Moreover, they were more often present at schools where computers were often used to produce the school newspaper or the school yearbook. It was not just the emphasis on word processing instruction that made a difference here but also the use of computers for actual writing in classes. In schools where the principal’s computer priorities were stated in terms of word processing or keyboarding skills, exemplary teachers were not particularly likely to be found; but they were disproportionately present where the principal’s priorities involved the use of computers for writing.

A further indication of the relation between consequential computer work and exemplary teaching practice comes from a survey question about how school computers were generally used throughout the school. In schools where exemplary teachers were identified, the amount of computer time going to occupational preparation subjects was 2.5 times as great as in other schools. In contrast, the fraction of computer time devoted to computer education activities, math and English, and, most strikingly, recreational activity was smaller than at other schools (see Table 3; panel 3). Recreational uses of computers often reflect an absence of systematic plans and purpose for this expensive resource. Not only was a smaller fraction of computer time spent on recreational activity in schools with exemplary teachers, but those schools also found it less necessary to establish rules limiting the amount of game playing on computers.

Resources Allocated to Support Effective Computer Use

Over the past 10 years, American schools have spent a large fraction of their discretionary funds on purchasing computers and software for their teachers and students. Computers, though, are not only expensive but also complex to use. Funds spent to create computer laboratories or to buy new software can easily be misspent unless substantial resources are also expended to make their use effective. One of our most consistent findings was that exemplary teachers work in school districts that had invested heavily in staff development and on-site staff support for computer-using teachers.

There were large differences between the 5% of computer-using teachers classed as exemplary and the other 95% on nearly *all* of the measured variables relating to school and district support for computing (see Table 3; panel 4). Exemplary teachers were much more likely to be found in schools where there was either a full-time staff member designated as a computer coordinator (with limited teaching responsibilities) or a district-level coordinator who directed school-level computing activities. Fully 37% of exemplary teachers worked in such situations compared to only 10% of other computer-using teachers. Moreover, exemplary computer-using teachers were much more likely (40% versus 17%) to have begun using computers initially at the suggestion of their school-level computer coordinator or a district coordinator or administrator rather than to have to started on their own initiative or because of suggestions from school administrators or teaching colleagues.

Third, exemplary users had greater access to formal district staff development activities than did other computer users. Two staff development activities were especially significant: (a) instruction in using computer applications such as word processors, spreadsheets, and grade book managers and (b) formal training in using computers with the specific subject matter that the teachers taught. Fourth, exemplary computer-using teachers were more likely to be present at schools where teachers were able to borrow school computers for home use. As shown in Table 3, 46% of exemplary teachers reported that teacher borrowing privileges have existed for three or more years compared to 34% of other computer-users.

In summary, the survey findings indicated consistent associations between the presence of exemplary teaching practice using computers and substantial investment in support and training of personnel. As with all correlational research, the direction of cause-and-effect is a question that must be examined carefully. However, the lack of association between district socioeconomic status and the presence of exemplary teachers suggests that districts choosing to invest larger fractions of available funds in staff development and support engender more sophisticated and accomplished computer-using teachers.

Resources and Requirements for Effective Teaching Using Computers

Classroom teaching is sometimes viewed as an activity in which resources for serving individual clients are brought to bear against a population of individual clients to be served. The more resources and the fewer clients, the more the individual teacher can accomplish. Such an individualistic notion about classroom teaching is certainly an oversimplification. Much research

on class size has shown that small classes do not result in substantially higher achievement. And a smaller number of classroom computers might be used more effectively with groups of students in a collaborative activity or by the teacher in a demonstration mode than if each student used a separate computer. In fact, one strong correlate shown in Table 3 concerns the practice of teachers using computers to demonstrate concepts to a whole class. This practice was reported much more often in schools where there were exemplary computer-using teachers than in schools where there were typical computer-using teachers.

Nevertheless, compared to other instructional media, such as books or chalkboards, computers primarily serve one individual or a pair of students at a time. In a classroom setting, computers may not be practical unless there is a sufficiently favorable ratio of students to computers. Yet, we know from past studies (e.g., Becker, 1986) that for the better part of the last decade teachers have often attempted to use computers in settings where students outnumbered computers by as much as 10 or 20 to1.

When the teaching environments of exemplary computer-using teachers were contrasted with other computer-using teachers, it was clear that exemplary computer users practiced in a much more resource-rich situation. They had fewer students per computer in their classroom (or wherever they used computers), they had more software available to them (by a large amount), and most significantly, perhaps, they had smaller classes. In fact, their classes were 20% smaller on average, which equates to four fewer students per classroom. Moreover, in a regression analysis that incorporated the 20 variables with the largest effect sizes listed in Table 3, class size had the largest independent predictive effect discriminating between exemplary and other computer-using teachers. Amounts of software available was also among the six variables surviving the backwards elimination regression procedure (see Table 2).

Whether it was smaller class size that caused exemplary computer use or whether exemplary teachers more successfully claimed the right to smaller classes, these findings emphasize that effective teaching with computers may be costly not only in terms of hardware, software, training, and human support but may require the costliest element of all—more teachers.

To summarize, differences in the teaching and school environments of exemplary computer users and typical computer-using teachers were examined. Based on these analyses, it could be argued that school and district administrators have the capacity to increase the number of teachers engaged in more efficacious teaching practices involving computers, although this strategy is not without substantial expense. The data suggest, for example, that school district administrators could improve how computers are used by (a) ensuring that relevant staff development activities, on-site computer coordination, and computer resources are all allocated to individual school sites in measures large enough to enable a community of computer-using teachers to develop (even if that means staging, over a period of years, the provision of these resources across all schools in the district); (b) directing that inservice instruction of teachers, curriculum development, and student computer time be prioritized so as to foster consequential uses of computers, for example, writing for an audience or using computers to model real occupational environments; and (c) forming instructional classes and organizing access to computers so that computer-using teachers have favorable ratios of students to computers and relatively small class sizes.

Personal Background and the Teaching and Computer Experiences of Exemplary and Other Computer-Using Teachers

What of the teachers themselves? If exemplary practice occurs largely among a group of teachers who differ in background and preparation from that of most other teachers, it may be harder to extend exemplary practices across large numbers of teachers, no matter how optimally administrators allocate resources. Table 4 contains the data from our analysis of the individual differences between exemplary computer-using teachers and the other computer users in our national sample.

Table 4 shows that there were substantial personal differences between the 5% of computer-using teachers classed as exemplary and the remaining ones. Not all of these personal differences are unalterable. Some of them are, like those of the preceding section, amenable to change by systematic administrative effort. Other differences suggest the need to recruit people into teaching who have background more like those of the exemplary teachers in the sample.

Alterable Variables in the Teachers' Backgrounds

The two largest differences in Table 4 are alterable. First, exemplary computer-using teachers spent more than twice as many hours personally working on computers at school than did other computer-using teachers. Of course, one might perceive their greater time investment in using school computers not as something affected by administrators' actions but deriving instead from greater personal interest in using computers. However, if personal interest was the reason exemplary teachers used school computers more, one would expect the differences to be at least as strong for computer use at home. But, in fact, there are only small differences in home computer use between the exemplary and the other teachers. This suggests that the time investments these two groups of teachers made in using computers were differentiated as much by the opportunities they each had to use computers at school as by their personal interests in using computers per se.

The second largest difference in Table 4 is that the exemplary teachers had more formal training in using and teaching with computers. (Table 3 indicated differences in the availability of district-organized staff development activities for the school staff; the results reported in Table 4 concern the teachers' own training experiences.) Teachers in the survey responded to questions about how they learned five different computer-related skills (or whether they had learned the skill at all): (a) how to integrate software into existing lessons in the subjects they taught, (b) how to organize class activities to allow for computer use during class time, (c) how to write computer programs, (d) how to use word processing programs, and (e) how to use other computer applications. Exemplary teachers reported having formal training in more areas than did other users. This was particularly true for secondary mathematics and elementary teachers, who had training in more than twice as many areas as the other computer users.

Teaching Experience and Experience Using Computers in Teaching

Other personal characteristics in Table 4 that distinguish between exemplary and other computer-using teachers are what might be called general experience variables. To some extent, developing expertise in using computers in teaching comes with time and experience—time spent using computers and time spent learning to teach well. Sheingold and Hadley (1990) concluded in their study that at least five years of computer use are required for teachers to develop computer expertise.

In the survey, exemplary users, on average, had taught their subject for three years longer than other computer users, and they had used computers for about one year longer (4.0 years versus 3.2). These are not big differences, but the effect sizes, +.41 and +.37, are substantial. The differences in experiences between exemplary and other users were particularly great for mathematics teachers. Math teachers who used computers for six or more years were 20 times more likely to be classed as exemplary. However, experience by itself did not ensure effective instructional practices using computers. Of the typical computer-using teachers (the non-exemplary ones), 10% had used computers in their teaching for more than five years, compared to 26% of the teachers classed as exemplary. But experience does help.

Interestingly, among the English teachers in our survey, the relationship between teaching experience and exemplary status was reversed. The younger (less experienced) English teachers were more likely to be exemplary. Also, among English teachers, the exemplary computer users had learned significantly more about using computers through self-instruction than through formal training, and they spent much more time using computers at home than other users. Computer use in English classes is also a more recent phenomenon than in math, science, or elementary classrooms. Taken together, this suggests that district and school support for developing exemplary computer-use practices in English teaching is particularly lacking—or it least it was in 1989 when this survey was conducted.

Differences in the Teachers' Own Educational Backgrounds

Not all important distinctions between exemplary computer using teachers and other computer-users are likely to be erased simply by giving teachers more training, more experience, and greater access to computers. Two aspects of the teacher's own schooling—how much formal schooling they had had (measured in degrees and credits) and whether they majored in education or the liberal arts and sciences—distinguished the exemplary from the other computer-users in our sample.

Although most teachers in the sample had received college credits beyond the bachelor's degree, exemplary teachers had accumulated significantly more credits and degrees than had the other computer users. For example, three-quarters of the exemplary math teachers and more than half of the exemplary science teachers had 30 credits beyond a master's degree, compared to less than 10% of other math and science computer users.

Additional degrees and credits are accumulated by teachers with more teaching experience and

thus may be a proxy for the effect of experience. On the other hand, the credits are likely to have included some experience in using computers, and thus the experience that the credits reflect may also produce more expertise in using computers. But there is a third explanation. More education also may reflect greater long-term interest in occupationally relevant knowledge and thus be the result of prior differences in interests that may not be readily transferred to other teachers. The exemplary teachers previously may have had a greater interest in and understanding of effective teaching and learning processes. Thus, their expertise may not have been simply a result of their having taken more graduate courses. Simply forcing teachers to take graduate credits may not produce exemplary-level expertise in using computers.

Their choice of major as undergraduates also distinguishes exemplary and other computer-using teachers. As shown in Table 4, 63% of the exemplary teachers majored in math, science, the social sciences or the humanities. Only 40% of other computer using teachers in the same subjects did so. (Most of the rest majored in education, not liberal arts.) This indicates not only that a greater interest in effective teaching and learning may differentiate the best computer-using teachers from the others, but also that a deeper interest in academic subject matter differentiates exemplary teachers from others. Teachers lacking a deep interest in learning the subject matter they teach might be unlikely to develop effective and exemplary practices using computers in their classes.

Teacher Gender

Once we knew that roughly the same proportion of elementary and secondary teachers in our sample were classed as exemplary, we did not expect to find gender differences between the exemplary and the other teachers. Nevertheless, although males comprised only one-fourth of the other computer-using teachers, nearly one-half of the exemplary teachers were male. Males were particularly overrepresented among exemplary science and English teachers.

The background and activities of male teachers differed sharply from the female teachers, and these teachers help explain the male's disproportionate representation in the exemplary teacher category. The male teachers had, on average, more advanced degrees and credits; and, as shown above, further education is associated with a greater likelihood of being a teacher identified as an exemplary computer user. Fifty-eight percent of the males while only 37% of females were math, science, or liberal arts majors; again, those majors rather than education majors were also more likely to be exemplary computer users. However, the greatest difference between male and female teachers revealed by these data was in the amount of time that they spent using computers. We previously showed that time spent using school computers was the largest discriminator between exemplary and other computer-using teachers. The male teachers in this study used school computers for about twice as many hours per week as the female teachers did (2.7 hours versus 1.4 hours). But the differences are even greater for nonschool (primarily home use). The male teachers spend 2.5 times as many hours per week using computers at home as the female teachers did. When all time spent on computers was combined, the male teachers spent nearly four more hours per week using computers than did the female teachers (6.9 hours versus 3.0 hours).

Like other female full-time workers, women teachers typically have more demands on their time than males do. In spite of cultural changes in the allocation of household and child-care responsibilities between males and females, females still have more nonwork-related obligations. Also, more males than females in our culture have patterns of personal interests that are

technical, mechanical, and numerical, which is consistent with having a deep interest in working with computers. These differences in interest are reflected in the ways males and females use free time. Thus, to the extent that time spent is itself a determinant of more exemplary use of computers for instructional practices, males will continue to be found disproportionately among exemplary teachers, as defined here.

Nevertheless, our explanations involving male teachers' stronger educational credentials and greater time-involvement with computers do not fully account for the gender differences we found. Using a multivariate analysis procedure (logistic regression) that held constant the graduate education, undergraduate major, time spent using computers both in school and away from school, and breadth of formal training for using computers in teaching, we found that the gender of a teacher was still among the stronger independent predictors of exemplary computer-using teaching.

Perceptions and Practices: How Using Computers Has Affected Exemplary Teachers and Other Teachers

The previous sections have demonstrated how exemplary computer-using teachers differ from other computer-using teachers in background, in teaching and computer experience, and, more usefully in a policy sense, in the school and district resources that define the environment in which these teachers work. But what are the consequences for schools of having exemplary computer-using teachers on their staff? Does it go any further than having teachers with a more systematic, varied, and intellectually respectable pattern of using computers in their own classroom instruction?

Effects on Curriculum Coverage: Differences Between Exemplary and Other Users

Our survey was not designed to measure how computers changed teaching practices, but by contrasting the teaching practices of exemplary computer-users and other computer-using teachers, we can get some ideas about the potential of computers to change instruction and classroom organization, that is, if all computer-users behave like the small number of exemplary users in our study.

Panel 1 in Table 5 shows that the teachers classed as exemplary computer users reported that they changed their coverage of curriculum topics more than the other teachers did. Four times as many exemplary computer users as others (47% versus 11%) reported that they introduced new topics in their course as a result of computers. Five times, (38% versus 7%) reported having de-emphasized or dropped certain topics in a class as a result of using computers. And nearly twice as many (66% versus 39%) reported that they emphasized certain topics more than they had before. In terms of the standardized difference or effect size statistical measure we used in these analyses, differential change in content coverage is by far the largest of any effect-size statistics calculated between exemplary and other computer users.

Of these results, the most striking is the statistic about the exemplary teachers having downgraded the salience of some curriculum content in exchange for computer activities that may have enabled more in-depth concentration on other content. One of the most difficult

barriers to curriculum reform has been the reluctance of teachers and other regulators of curriculum to drop existing content. Our survey suggests that computers may actually be an effective vehicle for getting rid of weak or outdated content in academic curricula.

Differences in Organizing the Class for Student Computer Assignments

Many studies of classrooms (e.g., Goodlad, 1984) show that most students' time is spent either listening to the teacher present a lesson to the whole class or working alone but doing the same work as other students. Computer work provides the possibility that students will not all be doing the same thing at the same time. In many settings, the goal of teachers and administrators is to have enough computers so that student computer work can be individualized, thus enabling students to do work tailored to their own learning needs. Most commonly, this is accomplished by having students use a computer-based integrated learning system or other method for automatically sequencing students through a series of software exercises.

Our survey found, though, that exemplary computer-using teachers did not individualize their computer assignments more than other computer-using teachers did. In fact, they were somewhat less likely to report that they used software that allowed students to proceed at their own pace through a sequence of computer activities (see Table 5, panel 1). On the other hand, they also were less likely to have students do the identical computer assignments. Instead, exemplary computer-users emphasized more small-group work, with each team of students working together and using different software. Their responses also suggested that they were more flexible in deciding which software different groups of students would use, and they were more likely to give students a choice in selecting software. We don't know from this survey, however, whether these differences in the social organization of computer use reflect the teachers' own long-standing teaching practices or are the result of their learning about how to maximize the benefits of using computers.

Computer-Use Problems Faced by Exemplary and Other Users

Although computers have been a major preoccupation of school teachers and administrators over the past decade, computer use in schools is still at a nascent stage. Compared to the resources required for electronic technology to clearly and substantially make a difference in how all students experience schooling, current patterns of computer use reflect the comparatively minor investment made in hardware and software. Therefore, it is not surprising that both exemplary and other computer users reported that not having enough computers and not having enough instructional software were among the major problems associated with using computers in their teaching practice. Still, the exemplary teachers did not believe these problems were as severe as the other teachers did (Table 5, panel 3). Perhaps this was because they have somewhat better student-to-computer ratios and they have substantially more software available to them.

However, the presence of expert computer-using teachers does not mean that problems will go away. In fact, more problems will arise from the greater demands that exemplary computer-using teachers make on resources and from their greater expectations about the utility of computer resources. Exemplary computer users reported quite a few problems to be more important for

their own teaching practice than did other computer-using teachers. Specifically, not having enough space to locate computers appropriately, having computers that were too limited because they were either out of date or incompatible with other equipment and software, having software that was not pedagogically sound, and having difficulty keeping computers in working order. Exemplary teachers simply had higher standards and greater perceived needs than did the other computer-users.

In addition to these more global problems, exemplary teachers reported having encountered a greater number of other specific problems in their computer use during the year than did other computer-using teachers (Table 5, panel 4). More exemplary teachers than other teachers reported occasions when computers they were expecting to use were already being used by other teachers or were broken; and more exemplary teachers reported finding software that did not teach as well as they expected, that was not as interesting as they expected, that was harder to use than they expected, or that was just plain missing. In addition, more of them complained that they hadn't had a chance to try out software that they intended to use. Every category of problem incident was reported more frequently by exemplary computer-using teachers than by other computer-using teachers.

To gain a final perspective on the problems of exemplary and other computer-using teachers, we asked respondents to prioritize several alternative computer-related investments of school funds: Teachers were asked, "Suppose your school administration annually made money available (for example, $5,000 per teacher) for improving computer-based learning. Which two of the following ways would you like to see this money spent in order to improve your own instructional uses of computers?" As shown in panel 5 of Table 5, the choices included such items as having an aide to assist in supervising students using computers, paying for a coordinator to provide expertise and assistance, and paying for extensive inservice training in using computers. Although there were differences for nearly every item between the proportion of exemplary computer users and the proportion of other teachers choosing that item, the largest differences were related to computer hardware. Whereas most typical computer-using teachers wanted more computers in their classroom, exemplary teachers were more likely to want to use the money to pay for a computer to use at home. Exemplary teachers were also more likely than others to choose the item about inservice training and were less likely to choose the item about buying more software. Thus, while typical computer-using teachers saw their highest priority as merely acquiring more hardware and software for their classes, the more knowledgeable and successfully practicing computer-using teachers recognized that equally important problems remain unsolved, in particular, time for using computers at home and more opportunities to learn how to use computers in their teaching.

Summary and Conclusions

This article has identified some important distinctions between the teaching environments, personal backgrounds, and teaching practices of a small group of computer-using teachers whom we have classified as exemplary and another group of more typical computer-using teachers. To reiterate, exemplary teachers were not recognized as such on the basis of hard evidence that their students' computer use resulted in higher test scores or greater intellectual competence. Instead, our attribution of exemplary teaching practice was an assumption that important academic outcomes will result from systematic and frequent use of computer software for activities that involve higher order thinking (such as interpreting data, reasoning, writing, solving concrete, complex, real-world problems, and conducting scientific investigations). The questionnaire

responses of teachers operationalized this assumption as a single dimension, and a somewhat arbitrary cut-off point was established (based on a case-by-case examination of borderline questionnaires) in order to distinguish the small fraction of computer-using teachers who appeared to have adopted this approach to using computers in a major way from the much larger number of teachers whose use of computers was either less intensive or more traditionally focused on knowledge and skill acquisition.

Our subsequent analyses assume not only that computer software used in an exemplary way works in the sense that as a result of its use students do learn to think better, write better, and problem-solve better, but that optimal use of computer resources for maximizing student outcomes will occur when computers are used in these ways. These assumptions are not arbitrary; they are based on a large body of literature in cognitive theory and in research on human learning and its application to groups of students in school settings (e.g., Chipman, Segal, & Glaser, 1985; Resnick, 1989; Idol & Jones, 1990). The critical thought and careful observation that constitutes this work appears plausible and well-reasoned, but it nevertheless lacks on its behalf substantial systematic empirical evidence based on concrete outcomes measured across comparison populations of students taught using different instructional approaches.

Given these assumptions about the optimal goals and methods of computer use in the major academic subjects, the distinctions we uncovered overwhelmingly favor the exemplary teachers. That is, exemplary teachers teach in an environment that helps them to be better computer-using teachers; they are themselves better prepared to use computers well in their teaching; and, in fact, they have allowed computers to have a much greater impact in how and what they teach. At the same time, exemplary teachers make greater demands on available resources and face problems that other computer-using teachers are less likely to face. This in turn presents administrators with problems they could otherwise avoid, for example, having to keep equipment and software available and in working order.

One of the most important results of these analyses is that nearly all of the advantages that exemplary teachers have in their working environments—that they teach where many other teachers also use computers, that their districts provide relevant and broad-ranging staff development activities, that they have access to computers at school and have the time to use them personally, and that they teach smaller classes—are extensible to other computer-using teachers. It might have been otherwise. We could have found that exemplary computer-using teachers disproportionately taught at elite private schools or at public schools serving wealthy communities, or that they disproportionately taught high-achieving and high-ability students in gifted programs. But that was not the case. Exemplary teachers in our study taught in a representative range of communities, schools, and classrooms; but they taught in schools and districts where resources had been used to nurture and support the kind of teaching practice we classified as exemplary.

On the other hand, the exemplary computer-using teachers in our survey were not simply typical teachers who liked computers. In particular, they had had significantly more well-rounded educational experiences than the other teachers had had; and, unexpectedly, were disproportionately male. To the extent that exemplary teaching practice using computers depends on a teacher having strong personal interest in computing activities (interests which in our culture have, at least until recently, been highly correlated with gender), having a liberal arts background, or a greater personal commitment to lifetime learning, it will be more difficult to extend the practices of these teachers to others in the profession who do not share those deep interests and backgrounds.

Regardless of whether the critical advantages of exemplary computer-using teachers are inherent or extensible to other teachers' practices, it will take money to make computer-based education become a more widespread effective teaching practice. It will take money to provide staff development to create a critical mass of computer-using teachers through which the ideas conducive to exemplary teaching practice will germinate. It will take money to staff schools with support personnel who have sufficient expertise and stature to provide the intellectual resources and technical support other computer-using teachers will need. It will take money to provide teachers with computers for home use and, even more importantly, to provide them with time at school to develop computer-based lessons and plans that can be used in the most profitable ways. It will take money to reduce class sizes. It will take money to solve the many new problems that extensive and inventive use of computer facilities will itself provoke. Finally, it will take money to recruit more people into teaching—who have both a potential talent for classroom teaching and a personal interest in using interactive technologies such as computers.

If producing exemplary teaching practices using computers is so expensive, one must ask if it will it be worth it. There are other ways for schools to spend money to improve their capacity to develop competent learners and thinkers. For example, they might invest in smaller classes for teachers (but not specifically so that they can use computers), in systematic and ongoing inservice training and supervision (on topics other than computer use), in larger salaries to recruit smarter teachers (who may not particularly like computers), in restructuring to give teachers fewer class hours and more planning time (not specifically for the use of computers), or in innovative print-based curriculum materials. Almost all proposed improvements to educational practice call for similar types of expenditures whether or not computer-based learning approaches are contemplated.

Our research has demonstrated that certain conditions make exemplary computer-using teachers more likely to be present. Research is now needed to specify the relative cost-effectiveness of alternative investments: between reducing the class size of computer-using teachers and providing a school-level computer coordinator, between investing in staff development activities and providing more time for teachers to develop their own plans on how to best use computers, and between loaning teachers computers for home use and providing them a richer mix of software for school use. Our survey work indicates that all of these factors may have advantages for improving computer-based teaching. But this survey provides only a rough gauge. We need carefully designed experiments to produce the kind of evidence useful for administrative decision-making.

Furthermore, we must begin to produce systematic evidence that the kinds of teaching practices that we assume here to be exemplary (i.e., the focus on writing, problem solving, and inquiry- and discovery-based learning) do result in the kind of improvements in student competencies that cognitive science research has implied is possible. Much of that research has proceeded as a study of individual learners, whereas schooling proceeds in a social setting involving dozens of simultaneous learners taught by teachers with limited amounts of time to plan learning tasks and assess their consequences. Although it seems correct to encourage schools and teachers to focus on the kind of learning outcomes that produce more adult competencies, schools may not be successful doing this, even with the best computer software and with lesson plans and teaching strategies designed to best exploit this software. Thus, we need to know not only how teachers are coming along in developing exemplary teaching practices but also how students are coming along in attaining competencies that these practices (and this article) now only assume.

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APPENDIX

Standards for the Selection of Exemplary Computer-using Secondary Mathematics Teachers

To measure exemplary teaching practice among mathematics teachers who use computers, a pilot index was created by scoring 13 responses that seemed likely to be related to exemplary practice. Then, 8 more items were added that were substantially correlated with the pilot index,

either for high school teachers, middle schools teachers, or both. The items were all questionnaire responses concerning the teacher's teaching practice in a single mathematics class in which computers were used. The class had been selected at the beginning of the questionnaire based on the time-schedule and the teacher's use of computers in different classes. Specifically, the subsequent questions applied to the first class taught on Mondays in which computers were used at least occasionally. For the pilot index, one point was scored for each of the following conditions:

1. If "mastery of computational skills" was NOT one of the three most important goals for using computers in math teaching."
2. Similarly, if "reward for completing other work" was NOT one of the three choices. (The remaining six choices—"understanding numerical relationships," "learning to apply mathematics," "motivating interest in math," "teaching about computers," "challenging the brightest student," and "remediating deficiencies of some students."—were all plausibly selected by exemplary teachers and, therefore none was initially selected as a criterion: Subsequently, though, a positive response to "learning to apply mathematics" was selected because of its high correlation with the pilot index.)
3. If the response concerning frequency of use of computer use in that class was ANY of the following three choices: "nearly every day," "throughout the school year, but not every day," or "intensively, but only for certain units."
4. If 25% or more of the activity of making graphs or charts of data was done using computers.
5. Similarly, if 25% or more of the activity of graphing equations was done using computers. (No other application was initially selected, but four others—"solving word problems, estimating, interpreting graphs and charts, and solving equations or proofs—were drawn in using the correlation rule.)
6. If students used computers for any one content area in mathematics (out of 13 given) for five or more days during the year.
7. If a typical student used tutorial software six or more times during the year.
8. Similarly, if the student used spreadsheet programs six or more times during the year.
9. Again if the student used mathematical graphing programs six or more times during the year. (All three other types of software inquired about in the questionnaire—drill-and-practice, programming languages, and word processing programs—were subsequently added to the expanded index if the respondent indicated each was used by students six or more times during the year.)
10. If computer activities were identified as being only supplementary or for enrichment either "never" or "sometimes" (and therefore not "mostly" or "nearly always").
11. If the computer programs used were tools like spreadsheets or graphing programs "mostly" or "nearly always."
12. If computer programs were used "mostly" or "nearly always" for instructional programs that directly supported work done that day in class.
13. If the teacher reported using software "most weeks" to demonstrate a math concept or how to solve a math problem.

Based on correlations of other responses with the pilot index score, eight other items were added, as described under conditions 2, 5, and 9, to make an expanded index.

With the expanded index of 21 components, a score of 11 (a bare majority of possible points) was selected as a cutoff for considering a teacher an exemplary computer user. Actually, an examination of the individual questionnaire booklets and the full range of questions answered suggested that a higher cut-off would be more accurate. However, using that more rigorous definition would have produced only two math teachers (with scores of 16 and 17) in the exemplary category, and that small number would have rendered it impossible to make statistical comparisons. For the other categories of teachers (science, English, and elementary), a bare majority cutoff seemed reasonable considering the individual teacher responses.

Using the less rigorous initial cutoff score of 11 produces a total of only 11 mathematics teachers out of 107 computer-using math teachers in the survey who would be classed as exemplary. Of those 11, 8 were high school (rather than middle or junior high) math teachers, and the 3 middle school teachers barely classified as exemplary, having scores of 11 and 12. Applying the sampling weights, we estimate that, nationwide, only about 3-4% of computer-using secondary math teachers would be classed as exemplary users of computers for math instruction, even using the less stringent criterion of a bare majority of possible index points rather than the more stringent criterion of passing a holistic judgment based on their entire set of questionnaire responses.