# Identifying Teacher, School and District Characteristics Associated with Elementary Teachers' Use of Technology: A Multilevel Perspective

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## Abstract

Over the past decade, investment in technology for schools has increased at a dramatic rate. Although policy makers are eager to understand how technology in schools is impacting student learning, we believe that a critical preliminary step toward assessing the impacts of technology on teaching and learning, requires the examination of the varied uses of technology in schools as well as the contexts that are likely to affect the use of technology in the classroom as a teaching and learning tool. Previous research examining technology use has focused on teacher characteristics and has neglected to explore the potentially alterable, organizational characteristics that may be impacting the adoption and use of technology in the classroom. In light of this argument and using survey data collected from 1490 *elementary* classroom teachers in 96 schools in 22 Massachusetts districts, this research examines how technology is being used by elementary teachers, and examines the school and district organizational characteristics that are associated with increased use of technology as a teaching and learning tool. In addition to examining technology-use as a multi-faceted construct, using multilevel regression techniques this study provides evidence that schools' organizational characteristics are associated with teachers' use of technology in the classroom. Organizational characteristics such as districts' and schools' leadership practices and emphasis on technology, the type and amount of technology-related professional development available to teachers, as well as the amount of technology-related restrictive policies were found to be associated with the four measures of teachers' use of technology examined in this study. Individual teacher characteristics such as constructivist beliefs, higher confidence using technology and positive beliefs about the efficacy of technology were each found to be associated with increased use of technology in the classroom.


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## Introduction

In a society that has become increasingly reliant on technology, it is not surprising that technology has become part of the permanent landscape in our schools and classrooms. In recent years, federal initiatives for which spending on educational technology increased from $21 million in 1995 to $729 million in 2001, have served to decrease the student-to-computer ratio from 9:1 to 4:1 over the same period (Glennan & Melmed, 1996; Market Data Retrieval, 1999, 2001). Both teachers and students report using technology at unprecedented levels; in 2001, the U.S. Census Bureau's Current Population Survey reported that American children between ages 9-17 use computers more than any other reported subgroup of the American population (92.6 percent) (A Nation Online, 2002). Similarly, data from NAEP reveals that 85 percent and 78 percent of teachers report using a computer to create instructional materials at home and at school, respectively, and that about half of all teachers use computers for administrative record keeping at school as well as at home (U.S. Department of Education, 2000). Additionally, NCES reports that about half of all teachers use email to "communicate with colleagues" and about a quarter of teachers communicate with parents via email (2000).

Despite these large expenditures, this increased access, and almost universal use by school-age children and their teachers, several observers have questioned the extent to which technology is impacting teaching and learning. In particular, some argue that there is insufficient evidence that access to educational technology has increased test scores (Oppenheimer, 1997; McNabb, Hawkes & Rouk, 1999), has had a positive impact on instruction (Stoll, 1999; Healey, 1998), or is being used effectively as an instructional tool (Cuban, 2001). While there is, understandably, a strong desire among policy makers to examine the impact of technology on student learning, we believe that as a critical preliminary step, it is first necessary to understand *how* technology is being used and *the contexts* that are likely to affect the adoption and use of technology in the classroom as a teaching and learning tool. Similarly, in order to effect policy changes, we believe that it is necessary to generate an understanding of the organizational characteristics that are associated with the use of technology in the classroom. Since technology-related decisions that can impact practices within the classroom are typically made *outside* of the classroom, it is important to examine potential technology-related policy levers that exist at the school and district level. Overall, examining the characteristics of schools and districts associated with increased technology-use has the potential to lead to a greater understanding of the organizational practices, policy differences, and differences in student populations that explain teacher-to-teacher and school-to-school differences in how technology is being used as a teaching and learning tool.

In light of this argument, this research examines how technology is being used by elementary school teachers, and examines the school and district characteristics that are associated with the use of technology in the classroom. We begin by discussing previous research that examines technology use among teachers, and the methodological as well as substantive advantages to examining the ways in which organizational characteristics impact technology-related classroom practices.

***Prior Research Examining Types of Technology Use and Teacher Characteristics***

In recent years, seminal work by Becker, Anderson, Ravitz, and Wong (1998, 1999) and work by Mathews (1996, 2000) have helped define types of "technology use" in classrooms and schools. Research by Becker and his colleagues found that teachers' and students' use of technology is both varied and widespread (Ravitz, Wong, and Becker, 1998; 1999; 2000). For example, in their nationally representative sample, 71 percent of teachers in Grades 4 through 12 reported requiring their students to use a computer at least once in some way at some point during the 1997-1998 school year. Their work also found that almost 75 percent of the teachers who reported not using technology *with* their students, reported using technology themselves for non-instructional purposes. In fact, the most frequent use of technology across all subject areas was not instructional use, but "professional uses of technology related to their day-to-day needs" (Becker, 1999, p. 31) such as preparing handouts for class at least weekly (66 percent of all teachers). Other frequent non-instructional uses of technology included use for record keeping and student grading, with almost half of all teachers reporting this type of use on a weekly basis.

Although the work by Becker et al. found "technology use" to be a multi-faceted phenomenon, the majority of their research focused on teachers' use of technology to deliver instruction. In their study, Becker and his colleagues (2000) found that "constructivist-oriented teachers use computers in more varied ways, have greater technical expertise in the use of computers, use computers frequently with students, and use them in more powerful ways" (p. 55) and that teachers who report feeling comfortable with technology and have a positive philosophy towards computers will make more frequent use of computers both in their own work and with their students.

Becker et al. also examined the relationship between technology use and other teacher characteristics. These characteristics included teachers' subject area, teachers' access to technology, scheduling practices, as well as measures of teachers' perceptions about school culture. Becker et al. found that academic teachers who work in secondary schools that schedule longer blocks of time (e.g., 90-120 minutes) for classes "were somewhat more likely to report frequent student computer use during class (19 percent vs. 15 percent), even though they met with their classes on perhaps half the number of days as teachers who taught traditional 50-minute periods" (Becker & Anderson, 2001, p, 3). School environment was measured in a number of ways including the extent to which teachers' reported feeling pressured (either self-imposed or externally imposed) to cover large amounts of curriculum. Here Becker found that those teachers who do not try to teach a large number of separate topics but "a small number of topics in great depth" are twice as likely to have their students use computers in class (29 percent vs. 14 percent, respectively) as are those teachers who report pressure to cover a large amount of curriculum.

Similarly, Mathews' study (1996, 2000) which examined 3,500 K-12 teachers' survey responses from Idaho found that "technology use" is not a singular concept. Mathews' research examined teachers' use of technology for the preparation of class materials, for reporting attendance, for word processing, for tutorials that explain concepts/methods, and for drill and practice. Using ordinary least squares regression to examine technology use, Mathews found that predictors vary in their ability to predict the many different technology uses that are

observed among teachers, confirming the hypothesis that there is no single measure of generic "technology use". For example, Mathews' found teachers' education level to be a powerful predictor of teachers' use of technology to prepare instructional materials, record attendance, and perform word processing, while the number of students in the class was a strong predictor of technology use to record and calculate grades, and for drill and practice. Mathews' work was the first to use regression models to predict deconstructed measures of how teachers use technology as a professional tool.

Both Becker et al. and Mathews demonstrate the refinement of measurement that is possible in assessing teachers' use of technology and their statistical models show that context variables differ in terms of their relationship to each of the defined technology uses. A commonality across the work of Becker et al. and Mathews is the absence of contextual measures taken at the school or district level. Their research focuses on the teacher characteristics that potentially influence technology use, but neither study includes other potentially alterable variables at the school or district level that may be affecting the adoption of technology in the classroom by teachers. Although Becker and his colleagues' work does include some measures of school culture, these are measures taken at the teacher level and are not aggregated to create school or district averages. The research presented here seeks to extend the work of Mathews and Becker et al. by including organizational characteristics measured at the school and district level in models of technology use. Knowing that teachers are influenced by the structure of the system in which they work, we seek to examine technology use using a multilevel or hierarchical approach.

### *Examining Teachers' Use of Technology Using a Hierarchical Approach*

Over the past two decades, researchers have become increasingly aware of the pitfalls of examining organizational data using traditional analyses such as ordinary least squares analysis or analysis of variance, and of the need to analyze education-related processes using a hierarchical or nested approach (Robinson, 1950; Cronbach, 1976; Haney, 1980; Burstein, 1980; Bryk & Raudenbush, 1992; Kreft & de Leeuw, 1998). As far back as 1976, Cronbach wrote the following:

> The majority of studies of educational effects – whether classroom experiments, or evaluations of programs, or surveys – have collected and analyzed data in ways that conceal more than they reveal. The established methods have generated false conclusions in many studies (1976, p.1)

A hierarchical approach is recommended because education systems are typically organized in a hierarchical fashion; students are nested within classrooms, classrooms within schools, and schools within districts. At each level in an educational system's hierarchy, events take place and decisions are made that potentially impede or assist the events that occur at the next level. For example, decisions made at the district level may have profound effects on the technology resources available for teaching and learning in the classroom.

Given that decisions to make technology available in classrooms are typically made at the school or district level, it is important to examine the school system as a hierarchical organization within which technology use occurs, and to identify alterable characteristics at the

school or district levels that could positively affect the use of technology as a teaching and learning tool. A hierarchical approach to analyzing the factors that are associated with increased technology use requires the analysis of individuals within groups, and groups within larger organizations, and has a number of advantages over more traditional approaches. The advantages of the hierarchical approach include the following (Bryk & Raudenbush, 1992; Goldstein, 1995; Kreft & de Leeuw, 1998):

- the approach allows the examination of technology use as a function of classroom, teacher, school and district characteristics;
- the approach allows the relationship between characteristics such as school socioeconomic status or the availability of technology-related professional development, and technology use to vary across schools;
- the approach "borrows strength" from the relationship between structural characteristics and technology use in other schools in order to create a better understanding of the processes that impact technology use;
- differences among teachers within schools and differences between schools can be explored at the same time therefore producing a more accurate representation of how organizational effects impact technology use in the classroom.

Recognizing this importance, the purpose of this study is to examine elementary teachers' use of technology from a multilevel perspective. Using data collected as part of the Use, Support, and Effect of Instructional Technology (USEIT) Study, this research applies hierarchical linear modeling techniques to examine the ways in which elementary teachers' use of technology is impacted by the characteristics of their schools and districts. Using a two-level model, this research examines technology use as a function of teacher characteristics at level-1, and as a function of school and district leadership characteristics and technology-related policies at level-2. Based on these findings, implications for school and district technology-related policies and practices are explored. Prior to examining these issues, we provide a brief overview of the USEIT study and the measures used in the hierarchical models. Throughout the present work, the term technology refers specifically to computer-based technologies and includes personal computers, LCD projectors, and Palm Pilots.

## USEIT Study Data

Data from the USEIT study were analyzed to examine the organizational characteristics that are associated with technology use. The USEIT study, which was conducted in 22 school districts in Massachusetts, was designed to examine how educational technologies are being used by teachers and students, which factors influence these uses, and how these uses affect student learning. In the spring of 2002, surveys were administered to gather data about district technology programs, teacher and student use of technology both in and out of the classroom, as well as information about the factors that influence these uses. In total, survey responses were obtained from 120 district-level administrators, 122 principals, 4400 teachers, and 14200

students in elementary, middle, and high school.[1] The USEIT sample design allows students, teachers, principals and district-level administrators to be linked to each other.

This paper presents analyses based on survey responses from 1490 elementary classroom teachers in 96 schools from grades kindergarten through Grade 6. Special education teachers are not included in the sample. Approximately 86 percent (1276) of the elementary teachers included in the sample report teaching all subjects, and the remaining 14 percent report teaching English, mathematics, science, or social studies in some combination. Ninety-three percent of the sample was female. The majority of teachers surveyed were veteran teachers with approximately 58 percent reporting that they had been teaching for more than 10 years at the time the survey was administered. Only 3 percent of the elementary teachers reported having been teaching for less than one year. Approximately 83 percent (1236) of the teachers surveyed reported having Internet access in their classrooms, and 38 percent reported having access to three or more desktop computers in their classrooms. Almost 14 percent of the teachers reported that they do not have access to desktop computers in their classrooms, and of this percentage about half have access to computers in either a lab/media center or in the library. Only about 4 percent of the sample reported not having access to either desktop computers or laptop computers in their classrooms, lab/media centers, or libraries.

The USEIT study was designed to focus on a broad range of issues related to teacher and student use of technology, and included several survey items that focused specifically on the ways in which teachers are currently using technology and the factors that influence these uses. In the analyses presented here, a subset of survey items from the student, teacher, school principal, and district technology director are used to provide insight into the policies and practices that influence the adoption of technology as a teaching and learning tool in the classroom.

## Outcome Measures: Defining Teacher Technology Use

Despite a substantial body of research focusing on teachers' use of technology, definitions of "technology use" vary widely. Indepth studies such as those conducted by Becker and his colleagues and Mathews focus on a number of refined uses of technology, but many discussions centering on technology use in schools employ a generic definition of "teachers' technology use". The array of use definitions was identified as early as 1995 in the Office of Technology Assessment (OTA) report *Teachers and Technology: Making the Connection* which notes that previous efforts to examine teachers' use of technology employ different categorizations and definitions of what constituted technology use in the classroom. The report points out that a 1992 survey conducted by the International Association for the Evaluation of Educational Achievement (IEA), defined a "computer-using teacher" as someone who "sometimes" used computers with students. In 1994, Becker constructed a more sophisticated classification to identify computer-using teachers. Comparing the two measures, the OTA found that while the IEA study classified 75 percent of teachers as "computer-using teachers", Becker's measure classified only 25 percent of teachers this way. In recent years, the expansion of the

[1] For a complete description of the study design, response rates, sample demographics, and survey instruments see www.INTASC.org.

Internet and email access, the universal availability of software that are easier to use, and the growth of an entire industry dedicated to the production of educational software has further confounded the definition of "technology use".

In order to tap into the multidimensional construct that is technology use and using many of the survey items developed by Becker et al., the USEIT surveys were designed to measure a large number of variables that relate to technology use. Building upon the theory-driven design of the surveys, teacher responses were analyzed and combined into composite variables to create refined measures of technology use. Using principal component analysis, a number of scales representing specific categories of technology use were created by combining a subset of survey items that were closely related to each other. For example, some survey items focused on the use of a specific type of technology, such as an LCD projector or the use of technology for communication with parents, colleagues, and administrators, while other items focused on the many ways in which teachers ask students to use technology for writing papers, conducting research, using spreadsheets, or for creating web pages. Other survey items focused on teachers' use of technology such as for creating quizzes and tests, preparing lessons, or accommodating lessons. In this paper, four specific uses of technology are examined. These are as follows:

1. Teachers' use of technology for delivering instruction;
2. Teacher-directed student use of technology during class time;
3. Teacher-directed student use of technology to create products; and
4. Teachers' use of technology for class preparation.

*Table 1* presents the four technology use scales, the individual items used to create the scales, and the reliability of the scales for the elementary teachers. Use of technology for delivering instruction is measured using a single item and each of the other outcomes is made up of a linear combination of at least 3 items.[2] Each scale was created to have a mean of zero and a standard deviation of 1. In the multilevel regression models, these four outcome measures are modeled as a function of teacher, school, and district characteristics.

[2] Extensive exploratory data analysis was conducted in order to identify other variables that could be used in conjunction with the measure of technology use for delivery to create a composite, but this item consistently appeared to be measuring a different construct. This item was standardized to have a mean of zero and a standard deviation of 1.

*Table 1:* Outcome Scales, Constituent Items, and Reliability for Elementary Teachers

| Outcome Measure | Constituent Items |
|---|---|
| Teachers' use of technology for delivering instruction | How often do you use a computer to deliver instruction to your class? |
| Teacher-directed student use of technology during class time<br><br>Cronbach's alpha = 0.84 | During classtime how often did students work individually using computers this year?<br>During classtime how often did students work in groups using computers this year?<br>During classtime how often did students do research using the internet or CD-ROM this year?<br>During classtime how often did students use computers to solve problems this year?<br>During classtime how often did students present information to the class/ using a computer this year?<br>During classtime, how often did students use a computer or portable writing device for writing this year? |
| Teacher-directed student use of technology to create products<br><br>Cronbach's alpha = 0.72 | How often did you ask students to produce multimedia projects using technology?<br>How often did you ask students to produce web pages, websites or other web-based publications using technology?<br>How often did you ask students to produce pictures or artwork using technology?<br>How often did you ask students to produce graphs or charts using technology?<br>How often did you ask students to produce videos or movies using technology? |
| Teachers' use of technology for class preparation<br><br>Cronbach's alpha = 0.79 | How often did you make handouts for students using a computer?<br>How often did you create a test, quiz or assignment using a computer?<br>How often did you perform research and lesson planning using the internet? |

Presenting a deconstructed view of technology use does not imply that these measures are completely independent. In fact, *Table 2* shows that these uses are moderately positively correlated with each other, indicating that on average, teachers who use technology for one purpose are also likely to use technology for other purposes. The strongest relationship exists between teacher-directed student use of technology during class time and teacher-directed student use of technology to create products.

*Table 2:* Correlation Table of Technology Use Measures for Elementary Teachers

| | Teacher use of technology for delivering instruction | Teacher-directed student technology use during class time | Teacher-directed student technology use to create products | Teachers use of technology for class preparation |
|---|---|---|---|---|
| Teacher use of technology for delivering instruction | 1 | | | |
| Teacher-directed student technology use during class time | .486 | 1 | | |
| Teacher-directed student technology use to create products | .362 | .590 | 1 | |
| Teacher use of technology for class preparation | .265 | .300 | .284 | 1 |

All correlations are significant at the 0.01 level (2-tailed).

To provide a sense of the degree to which teachers employ technology for each of these four uses, *Figure 1* contains the average score across each of the items that comprise the four use scales.

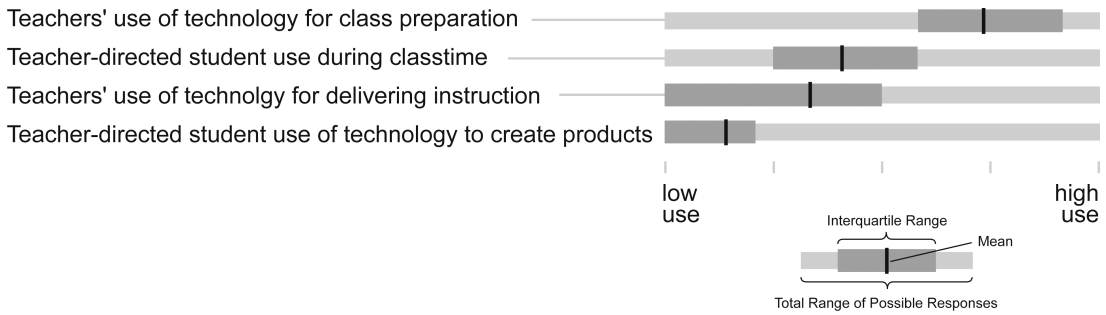


*Figure 1:* Frequency of elementary teacher technology uses.

The average scores are displayed on a scale which ranges from low to high use. The figure shows that teachers use technology most frequently for preparation purposes and least frequently for directing their students to create products using technology. These data support Cuban's (2001) argument that teachers tend not to use technology in the classroom very frequently.

## Methodology

The analyses presented in this research were conducted using a two-level hierarchical linear regression model. In this model, teacher use of technology is modeled at level-1 as a function of classroom aggregate student characteristics, teacher characteristics and beliefs, and at level-2 by school and district characteristics. The general hierarchical model assumes a random sample of i teachers within J schools, such that $Y_{ij}$ is the outcome variable (technology use in this case) for teacher i in school j. The level-1 or teacher model is expressed as follows:

$$Y_{ij} = \beta_{0j} + \beta_{1j}X_{1ij} + \beta_{2j}X_{2ij} + .... + \beta_{kj}X_{kij} + r_{ij}$$

In this model, the teacher outcome, $Y_{ij}$ is modeled as a function of a linear combination of aggregate classroom and teacher level predictors, $X_{kij}$. This model states that the predicted outcome is composed of a unique intercept $\beta_{0j}$, and slope for each school $\beta_{kj}$, as well as a random student effect, $r_{ij}$. The intercept represents the base technology use in each school and the random teacher effect is assumed to be normally distributed with a mean of zero and variance, $\sigma^2$. The chief difference between this model and an ordinary least squares model is that level-1 predictors may vary across schools (Bryk & Raudenbush, 1992). In the models used in this research, only mean technology use is allowed to vary between schools.

The variation in the level-1 predictors across schools is modeled at the second level; the level-1 predictors are modeled as outcomes at level-2. The level-2 model is expressed as follows:

$$\beta_{kj} = \gamma_{0k} + \gamma_{1k} W_{1j} + \gamma_{2k} W_{2j} + \ldots + \gamma_{P-1k} W_{P-1j} + u_{kj}$$

Each $\beta_{kj}$ is modeled as a function of a combination of school- or district-level predictors, $W_{pj}$, and each $\gamma_{pk}$ represents the effect of the predictors on the outcome. Each school has a unique random effect, $u_{kj}$, which is assumed to be normally distributed with a mean of zero and variance $\tau_{kk}$ for any k.

These models allow the total variability in technology use to be partitioned into its within-school and between-school variance components, and allow predictors to be added at each level that explain a portion of both the within-school and between-school variance available. Although it might be considered more appropriate to model technology use as varying within- schools, between-schools within-districts, and between-districts, it is not possible to reliably do so with this data. In order to be able to examine differences between schools within districts independently of the differences between districts, more districts than are available in the USEIT study would be required. For this reason, the between-school variability will be confounded with the between-district variability in the models presented in this research. At the district/school level, both district and school characteristics will be included in the models in order to explain differences among schools/districts.

Each of the predictor variables and composites measured at the teacher, school, or district level ($X_{kij}$ and $W_{pj}$) were standardized to have a mean of zero and standard deviation of 1. Principal components analysis was again used to validate the existence of measurement scales and to create standardized scale scores.

The hierarchical regression analyses were carried out in three stages. When conducting any hierarchical analysis, the first step requires the examination of the amount of variability in the outcome, technology use in this case, that exists within and between schools. In order to accomplish this, unconditional models, in which no predictors other than school membership are known, were formulated. To develop a better understanding of the organizational factors that are associated with increased technology use, the second stage of the analysis involved extensive theory-driven, exploratory data analysis to identify variables observed to be associated with each of the four technology uses. These variables include: grade level, number of years teaching, access to technology, type and availability of professional development, perceived need for technology-related professional development, pressure to use technology, the level of

technology-support available, teachers' pedagogical beliefs, as well as teachers' comfort level with technology, and beliefs about the efficacy of technology. For many variables, teacher measures were aggregated to the school level in order to create a measure of average school characteristics. Guided by past research and theory, exploratory multilevel models were formulated and predictors were identified that were significantly associated with technology at $p \leq 0.1$. Since the emphasis during this section of the analysis was on an exploratory approach, a significance level of 0.10 was adopted as the criterion for significance, in preference to the more stringent 0.05. The variables and composites included in the exploratory phase are listed in *Table 3* and a complete description, including scale reliability is included in Appendix A.

*Table 3:* Variables and Composites Included in Exploratory Analysis Phase

| **Measures taken at the teacher level** |
|---|
| Perceived importance of technology for the school/district |
| Characteristics that shape technology use in your classroom |
| Leadership emphasis on technology items |
| Teachers' need for professional development for basic skills |
| Teachers' need for professional development relating technology integration |
| Student characteristics obstruct technology use |
| Leadership and teacher input issues obstruct technology use |
| Access obstructs technology use |
| Quality of computers obstructs use |
| Poor professional development obstructs technology use |
| Problems incorporating technology obstruct use |
| Problems getting technology to work obstructs technology use |
| District success implementing the technology program |
| Importance of computers for teaching |
| Teacher confidence using technology |
| Pressure to use technology |
| Community support for change |
| Support for growth |
| Relationship with principal |
| Support for innovation |
| Computers harm student learning |
| Beliefs about teacher-directed instruction |
| Belief that computers help students |
| Constructivist beliefs |
| **Measures taken at the district level** |
| Number of restrictive policies scale |
| Line item funding for technology |
| Leaders discuss technology |
| Evaluations consider technology |
| Principal's technology decision |
| Variety of technology-related professional development |
| The extent to which professional development focuses on technology integration |

In the third stage of the analysis, variables identified during the exploratory stage were combined into more parsimonious models to predict each of the four technology use measures. In this way, each of the four uses are predicted by a different set of independent variables. In each model, an indictor of school socioeconomic status is included to examine whether differences between the wealth of the school contributes to differences among schools in terms of technology use. The index was created from three separate measures: school-mean number of books in students' homes, school-mean amount of technology available in students' homes, and percent of students not receiving free or reduced lunch. Principal components analysis was used

to confirm that these three variables were measuring the same construct; one component with an eigenvalue greater than 1 was extracted which accounted for 87 percent of the variance. The factor loadings for the three variables were each greater than .90.

## Results

*Table 4* presents the unconditional variance components for each of the four technology uses. The results indicate that although the majority of variability in each use exists among-teachers within-schools, a significant proportion of the variability lies between schools. The largest school-to-school differences occur for the measure concerned with how often teachers direct students to use technology during classtime; 16 percent of the total variability for this type of technology use lies between schools. It appears that the smallest between school differences occur for the use of technology for preparation measure. It is interesting to recall that *Figure 1* indicated that use for preparation was the most frequently occurring type of technology use among elementary teachers.

*Table 4*: Unconditional Variance Components for Four Technology Uses

| | Teacher use of technology for delivering instruction | Teacher-directed student technology use during class time | Teacher-directed student technology use to create products | Teachers use of technology for class preparation |
|---|---|---|---|---|
| Percent of variance within schools | 86% | 84% | 89% | 94% |
| Percent of variance between schools | 14%‡ | 16%‡ | 11%‡ | 6%‡ |

‡ The amount of variability between schools is significant at p<.001.

Once the total variability in the outcome has been partitioned, the hierarchical approach allows characteristics measured at the teacher, school, and district levels to be added to the models to explain some of the available variance.

*Table 5* presents the standardized regression coefficients for the variables that combine to produce the best prediction models for each of the four types of technology use. Hierarchical linear regression modeling is a generalization of ordinary least squares analysis in which each level in the hierarchy is represented by a separate regression equation. For this reason, the multilevel regression coefficients refer to specific levels in the hierarchical structure of the data and are interpreted in the same way as traditional regression coefficients. The results of the analyses are presented in two ways. First, each model is discussed independently in order to understand the processes associated with each of the four uses. Second, the strength of the associations are compared across models.

Comparisons Within Models

*Teacher use of technology for delivering instruction*

The strongest predictors of school-to-school differences among teachers' use of technology for delivering instruction are school-mean perceived pressure to use technology

(0.371) and, not surprisingly, school-mean availability of technology (0.375). At the school-level, mean perception regarding inadequate professional development (-0.193) has a negative relationship with technology use for delivering instruction. Conversely, increased variety in the types of technology-related professional development reported to be available to teachers within a school appears to have a small positive effect on teachers' use of technology for delivering instruction (0.067). The teacher-level model indicates that teachers who possess higher levels of confidence using technology (0.129) and more positive beliefs about technology (0.114) are more likely to use technology for delivering instruction. Not surprising, teachers who report having difficulty integrating technology into the curriculum are less likely to use technology for delivery.

*Teacher-directed student use of technology during class time*

In addition to their importance for predicting teachers' use of technology for delivery, school-mean perceived pressure to use technology (0.321) and school-mean availability of technology (0.265) are also highly, positively related to the rate at which teachers direct their students to use technology during classtime. The extent to which professional development focuses on the integration of technology (0.303) is also a strong between-school predictor for this type of use. The importance of being prepared to integrate technology is also mirrored at the teacher-level; teachers who report experiencing problems integrating technology into the curriculum (-0.106) are significantly less likely to direct their students to use technology during classtime. At the teacher level, beliefs about student-centered instruction (.069) and about the positive impacts of computers on students (.188) are positive predictors of teacher-directed student use of technology during class time.

*Teachers direct students to create products using technology*

Preparation to integrate technology through professional development (0.206) as well as pressure to use technology (0.307) are strong, positive predictors of school-to-school differences in the frequency with which teachers direct students to create products using technology. Teacher beliefs about the positive impacts of technology (0.157) and constructivist beliefs (0.109) are positively related to increased use at the teacher level. Conversely, perceived problems integrating technology into the curriculum is associated with less frequent use.

*Teachers use technology for preparation*

Although the extent to which professional development focuses on integration (0.134) and the variety of technology-related professional development available to teachers (.068) are significant, the availability of technology (0.233) is the strongest, positive predictor of technology use for preparation at the school level. At the individual level, beliefs about student-centered instruction (0.066), and positive beliefs about the effects of technology (0.067) are both associated with increased use of technology for preparation. Higher teacher confidence is associated with the largest increase in the use of technology for preparation (0.270).

Comparisons Across Models

The regression coefficients in *Table 5* indicate that for all four technology use measures, the predictor effects between schools are larger than the effects within schools. It is also clear from *Table 4* that school and district characteristics differ in their ability to predict the four uses

of technology defined here. At the school level, the extent to which professional development focuses on technology integration is associated with teachers' increased use of technology for class preparation (0.134) and increased use by students both during class time (0.303) and to create products (0.206). Interestingly, according to the model, this predictor is not associated with teachers' use of technology for delivering instruction (0.000).

The models show that increased availability of technology is likely to result in increased use of technology for delivering instruction (0.375), increased teacher-directed use of technology by students during class time (0.265), and increased use by teachers for class preparation (0.233). Given that products created using technology are typically done outside of the classroom, availability of technology is not as strongly related to technology use for this purpose (0.131) as it is for the other three purposes.

School-mean teachers' perceived pressure to use technology is positively associated with each of the four uses. The observed relationship shows that teachers are more likely to use technology for delivering instruction (0.371), to have their students use technology during class time (0.321) and to create products using technology (0.307), and to a lesser degree, use technology for class preparation (0.123) when, on average, teachers in their school feel pressure to use technology.

Across the four models, the variety of available technology-related professional development is positively related to each of the four technology uses. The amount of restrictive policies for using technology that are in place within a school or district is negatively associated with the frequency with which teachers' direct students to use technology during classtime (-0.052) and direct students to create products using technology (-0.033). Very restrictive policies may be discouraging teachers from directing their students to use technology.

At the individual or teacher level, teachers who report problems incorporating technology into the curriculum appear less likely to use technology to deliver instruction (-0.099), less likely to have their students use technology during class time (-0.106) or to create products using technology (-0.071), and are less likely to use technology themselves for class preparation (-0.022). It is interesting to note that neither the quality of the available technology nor issues relating to student characteristics in the classroom appear to be strongly associated with any of the four uses; although the relationship is negative, the regression coefficients are weak and non-significant.

Similar to previous research (Ravitz, Becker, & Wong, 2000), pedagogical beliefs and beliefs about the positive impacts of technology are positively related to each of the four technology uses. The strongest positive predictor of whether a teacher will use technology to deliver instruction (0.114), have their students use technology during class time (0.188), and have their students create products using technology (0.157) is a teacher's belief about the positive impacts of technology for students. As would be expected, teacher beliefs about technology's impact on students is not as strong a predictor of whether they themselves use technology for class preparation (0.067). Higher teacher confidence using technology is associated with increased use for delivering instruction (0.129) and in particular, increased use for class preparation (0.270). Consistent with Becker's findings, teachers who hold

constructivist beliefs are more likely to have their students use technology during classtime (0.069) and to create products (0.109), and are more likely to use technology themselves for class preparation (0.066).

It is interesting to note that socioeconomic status is not a significant predictor of the differences between schools for each of the four uses. Perceptions about inadequate professional development are associated with decreased use of technology for delivering instruction (-0.193) and for class preparation (-0.122).

Variance Explained

When context variables are added at each of the two levels, a portion of the available variance is explained. However, the percentages in *Table 6* indicate that the models are not powerful for explaining differences in use among teachers within schools; the models each only explain less than 10% of the available variance within schools. At the school-level, the models explain a larger proportion of the available variance, but because the amount of available variance between schools is small to begin with, the total amount of variance explained by the models remains small.

Despite the relatively small amount of total variability in use explained by the models, the findings at the school level demonstrate the importance of examining technology use as a phenomenon that may be influenced by characteristics at different levels in a school system's hierarchy. Importantly, the ability of a school or district to manipulate or alter all of the factors related to technology use at the school level suggests that school and district policies, practices, and leadership can influence the ways in which, and extent to which teachers use technology for a variety of purposes. However, the small amount of variance explained at the teacher (or within school) level indicates although we are moving toward a greater understanding of the differences in use among schools, we have much to learn about the processes that impact use within schools.