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Predictors of Teacher-Directed Student Use of Technology in Elementary Classrooms: A Multilevel SEM Approach Using Data from the USEIT Study

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Abstract

This study is a secondary data analysis of the USEIT data to inform school administrators and policymakers about the factors affecting instructional technology use in elementary classrooms. Researchers developed a predictive multilevel SEM model for teacher-directed student use of technology (TDS). The model depicts relationships between factors across district, school, and classroom levels of analysis. The strongest predictors of TDS were (a) teachers' experience with technology, belief that technology is beneficial to meet instructional goals, and perceived pressure to use technology; (b) principals' use of technology; and (c) technology standards, teacher and student accountability to standards, and principals' technology discretion. (Keywords: instructional technology, educational technology, computers, diffusion of instructional technology, and technology leadership)

Since the early 1990s, schools, districts, and the federal government have invested heavily in instructional technology (IT). Teacher and student access to technology in schools has improved dramatically. Today, all public schools are connected to the Internet, with 97% connected via high-speed connection. The student-to-computer ratio dropped from 4.4 in 2003 to 3.8 in 2005 (Wells & Lewis, 2006), and hundreds of schools and districts are experimenting with or have put in place one-to-one laptop programs that provide each student with their own laptop. Yet, evidence suggests that investments in IT may not have translated into widespread use in schools (Cuban, 2001; Russell, Bebell, O'Dwyer, & Miranda, 2003a; Russell, Bebell, O'Dwyer, & O'Connor, 2003b; Wells & Lewis, 2006). Diffusion theories provide insight into factors related to schoolteachers' disappointing adoption rates of instructional technologies (IT) (Miranda, 2007). Rogers' (1995) theory of diffusion and Surry and Farquhar's (1997) application of diffusion theory to IT suggest that the limited use of instructional technologies by teachers and their students may stem from the implementation of programs that address only a portion of the many aspects of diffusion.

The literature on diffusion indicates that to promote IT use, implementation plans should incorporate both micro-level and macro-level aspects of diffusion (Miranda, 2007). Micro-level theories that focus on adopter characteristics and processes follow an instrumentalist philosophy, which argues that the needs of individuals drive social change (Surry & Farquhar, 1997). This suggests that teachers' and students' needs drive the development of innovations and influence the extent to which teachers adopt instructional technologies. In contrast, Surry and Farquhar (1997) argue, macro-level theories focus on organizational characteristics and follow a deterministic philosophy, which contends that developers supply technological innovations and drive social change. Macro-level theories suggest that educational experts, industry, state education organizations, and district leaders define needs, develop solutions, and enforce technology use through policies, accountability, and regulations.

According to Surry and Farquhar (1997), top-down, macro-level approaches to IT adoption are rooted in deterministic philosophy, which sees technology as an autonomous driving force for social change that is outside human control. An extreme example of a technology program that employs only a macro-level approach while ignoring micro-level aspects is a school district that decides to purchase and implement IT—e.g., a classroom grading system, virtual science experiments, a diagnostic reading program—without first assessing classroom needs or involving teachers in the selection process. Macro-level approaches are likely to fail because teachers may not see the innovation's benefits and resist its adoption.

In contrast, Surry and Farquhar (1997) contend that micro-level approaches are rooted on instrumentalist philosophy, which believes humans are the driving force for social change and technology is a tool of change used by humans. Whereas deterministic philosophers view technology adoption as a revolutionary process that happens in leaps, instrumentalists view it as an evolutionary process that is slow, gradual, and initiated by the needs of adopters. An example of a program that employs only a micro-level approach is a school district that relies on teachers to identify needs, apply for external grants, and develop local partnerships with technology leaders to implement new technologies. This tends to result in the implementation of a diverse range of technologies across classrooms implemented without coordinated strategies for support. This type of approach rarely translates into widespread technology-infused instructional practices.

As the examples above illustrate, employing either a micro-level approach or a macro-level approach may limit IT adoption (Surry & Farquhar, 1997). Thus, given the importance of micro and macro aspects of diffusion to the adoption of an innovation, efforts to identify factors that influence instructional use of technology may benefit from a framework that integrates principles of both micro and macro theories of diffusion.

Research on educational technology identifies several factors that may influence the use of instructional technologies. Some of these factors reside at the organizational (e.g., school and/or district) or macro level, whereas others are specific to teachers and students and are classified as micro-level factors (Miranda, 2007). Educational technology literature points to district-level factors, such as resources, funding, leadership, vision, and technology planning, as important drivers of educational technology use. Research indicates that as resources and funding increase, so does the frequency of technology use (Anderson & Ronnkvist, 1999; Becker, Ravitz, & Wong, 1999; Fisher, Dwyer, & Yocam, 1996; Lemke, Quinn, Zucker, & Cahill, 1998). Evidence also suggests that leaders who have a well-defined technology vision and who develop clear technology plans tend to encourage the use of technology, resulting in increased frequency to instructional technology in their districts (Anderson & Dexter, 2005; Dawson & Rakes, 2003; Fisher et al., 1996; Lemke et al. 1998).

The literature features principal leadership, availability of professional development for principals, and perceived pressure to use technology among school-level factors related to instructional technology use. Evidence suggests that at the school-level leadership appears to be an important contributor to multiple uses of technology by teachers and students (Anderson & Dexter, 2005; Dawson & Rakes, 2003; Russell et al., 2003a). In light of school-level leadership's importance in driving teachers' and students' use of technology in schools, principals' technology training, particularly when focused on integration (Anderson & Dexter, 2005; Dawson & Rakes, 2003), also appears to be an essential condition to increase the use of educational technology. Russell et al. (2003b) also identified perceived pressure to use technology as a factor associated with technology use for multiple purposes. Russell et al. (2003b) reported perceived pressure to use technology at the school level as one of the predictors of teacher's use of technology for delivering instruction and for teacher-directed student use of technology during class time.

Within classrooms, micro-level factors cited in the literature include teacher-related characteristics as well as access to technology. Several authors report a teacher's educational philosophy as a possible contributor to educational technology use. This line of work reports that teachers who hold more constructivist teaching beliefs are more apt to use technology for educational purposes (Becker, 2000; Becker et al., 1999; Ertmer, Gopalakrishnan, & Ross, 2001; Fisher et al., 1996) than are teachers who hold less constructivist views. Likewise, the literature identifies teachers' beliefs about technology as a predictor of educational technology use. Seemingly, teachers who believe technology is valuable and beneficial for teaching and learning are more likely to use technology more frequently than are teachers who do not hold such beliefs (Ertmer, 2005; Ertmer, Ottenbreit-Leftwich, 2010; Russell et al., 2003b). The literature also refers to teachers' access to and experience and comfort level with technology as possible predictors of technology use. Essentially, teachers who have more access to technology and who have more experience with technology appear to be more comfortable with technology and, therefore, use technology more frequently than teachers who have less access and less experience (Becker et al., 1999; Miranda, 2007; Russell, O'Dwyer, Bebell, & Tao, 2007). Finally, at the classroom level, evidence indicates that there may be a link between teachers' background characteristics, such as number of years teaching and educational background factors, and frequency of technology use. Evidently, teachers who have strong academic backgrounds (i.e., college selectivity, level of degree earned, and advanced courses completed) appear to be more frequent technology users of technology than are teachers with weaker academic backgrounds (Becker, 2000; Becker et al. 1999; Becker & Riel, 2000; Guha, 2000; Mathews, & Guarino, 2001; Russell et al., 2003b).

Despite the breadth of research on IT, there is little empirical evidence of the magnitude of the influence factors listed above have on the use of IT. Research has focused on these factors in isolation, ignoring the interactions among the factors. Additionally, with the exception of O'Dwyer, Russell, & Bebell (2005), prior studies do not take into account that factors reside at different hierarchical levels within school systems. Findings from past research may misrepresent the importance of specific factors in shaping instructional use of technology and are minimally useful in helping districts shape technology initiatives.

The study presented here employs multilevel modeling techniques to examine the direct and indirect effects that a variety of macro- and micro-level factors have on instructional use of technology in the classroom and addresses the following questions:

- Which district-level factors have the largest effect on teachers' instructional use of technology?
- Which school level factors have the largest effect on teachers' instructional use of technology?
- Which classroom-level factors have the largest effect on teachers' instructional use of technology?
- How do factors interact within and across levels of a school level to affect teachers' instructional use of technology?

The authors define instructional technology as digital or computer technologies (e.g., computers, CDs, DVDs, LCD projectors, interactive media, Internet) used for teaching and learning in the classroom. The operational definition of IT use in this study followed Bebell, Russell, and O'Dwyer's (2004) framework for teacher technology. Researchers used the Teacher-Directed Students' Use of Technology (TDS) scale developed for the Use, Support, and Effect of Instructional Technology (USEIT) study as the outcome measure (refer to Method section).

Method

The study discussed in this article consisted of secondary data analyses of USEIT data (Russell et al, 2003a). The USEIT study originated from a field initiated study requested by 16 Greater Boston school districts and ultimately included 21 Massachusetts school districts. The USEIT sample consisted of a convenience sample of districts whose leaders wanted to assess the use of technology as well as conditions that supported or hindered the use of technology in their respective schools. The USEIT research team mailed surveys to district administrators, principals, and teachers in the districts interested in the Field Initiated study. The survey response rates were 96% of district administrators, 80.5% for principals, and 69% for teachers. The USEIT study examined technology programs in 3 small urban, 5 rural, and 13 suburban districts located in Massachusetts. Table 1 presents a comparison of Massachusetts' districts by locale type districts in the USEIT sample and shows that 14% of the districts in the USEIT sample were classified as urban, 62% were suburban, and 24% were rural.

Table 2 (p. 306) presents a comparison of sample demographics, including type of school, percent of white students in the district, and percent of students in the district receiving free or reduced lunch to state demographics.

Tables 1 and 2 show that the number of suburban districts is over-represented in the USEIT sample, whereas the number of urban districts is under-represented; and the number of white students is over-represented, whereas the number of students on free and reduced lunch is under-represented when compared to Massachusetts' districts. Note that USEIT researchers did not aim to generalize findings from this study but intended to investigate which district- and school-level supports translated to regular use of IT in the interested 21 districts. The USEIT district sample was a purposive sample designed to respond to the needs of a group of school districts in Massachusetts. Generalization of findings from the study discussed here is limited to schools with characteristics similar to those in the USEIT sample. Despite these limitations, the USEIT study is one of the most comprehensive educational technology studies conducted to date that includes multiple data sources collected at different hierarchical levels (i.e., district, school, classroom, and student). The USEIT study included surveys of district-level personnel, principals, and teachers, as well as site visits to each of the districts. This study employs

Table 1. Percentages of School Districts by Locale Type in Massachusetts

District Type	Massachusetts	USEIT Sample
Urban	29.5%	14%
Suburban	51%	62%
Rural	19.5%	24%

Table 2. Sample Demographics and Massachusetts Demographics Overal (Russel et al., 2003a)

District	Elementary	Middle	High	Race (% White)	SES (% Free Lunch)
A	5	0	0	87	3
B	0	1	1	88	1
C	7	1	1	87	10
D	3	1	1	96	7
E	2	1	1	89	4
F	4	1	1	86	7
G	1	0	0	89	3
H	1	1	0	94	0
I	3	1	0	90	4
J	0	0	1	86	4
K	7	0	1	74	37
L	6	1	1	96	6
M	2	1	1	97	8
N	0	0	1	94	9
O	16	4	2	82	5
P	4	1	1	95	28
Q	6	1	1	87	9
R	6	1	1	88	5
S	2	1	1	99	2
T	4	1	1	96	4
U	9	2	1	65	26
V	3	1	1	92	19
W	3	1	1	81	3
X	5	1	1	93	3
		Totals			
USEIT	104	23	22	89	9
Massachusetts	1270	282	318	76	25

data from each of these sources. The section below describes the sample, data sources, and analytic procedures.

Sample

District-level data for this study are based on survey responses from 104 district-level personnel, which included 18 superintendents, 1 assistant superintendent, 32 curriculum development directors, 15 head technicians, 17 professional development directors, and 21 directors of technology. Researchers collected school-level data from 81 elementary principals and classroom-level data from 1,040 teachers across the 81 elementary schools for which there was corresponding principal data. Of the 1,040 teachers surveyed, 14% taught kindergarten, 16% taught first grade, 18% taught second grade, 20% taught third grade, 19% taught fourth grade, and 13% taught fifth grade. Most teachers indicated they were veteran teachers with approximately 58% reporting that they had been teaching for more than 10 years. Approximately 84% of the teachers reported having Internet access in their classrooms, and 39% reported having access to three or more desktop computers in their classrooms. Approximately 14% of the teachers reported that they did not have access to desktop computers in their classrooms, and of this percentage, 35% had access to computers either in a lab/media center or in the library.

Data Sources

The authors used the following USEIT data sources for this study: (a) the district survey, (b) the principal survey, (c) the teacher survey, and (d) site visit ratings. The district, principal, and teacher surveys included a large number of items that focused on a variety of issues related to IT. Some of these issues included the ways and frequency with which instructional technologies were used, availability and participation in professional development related to IT, beliefs about teaching, learning and IT, obstacles to technology use, pressure to use IT, resources and support for IT, leadership for IT, community support for IT, and demographics. A large number of measures were created using items from each of the survey instruments from the USEiT study (see Russell et al., 2003a). Analyses presented here also used rating scores for several factors obtained from site visits to each of the districts (see Russell et al., 2003a).

Table 3 (p. 308) presents a summary of USEIT scales that were used in analyses and their respective data sources. Table 3 shows that this study included measures for eight district-level factors, three school-level factors, and eight classroom-level factors. Researchers used a scale, Teacher-Directed Student Use of Technology in the Classroom (TDS), which measures the extent to which students use technology in the classroom to complete work assigned by teachers (see Table 3 for reliability and factor scores) as the outcome measure for these analyses. Technology use in this instance refers to a variety of student uses that include individual work, group work, research work, writing, and so forth. This scale included the following items: (a) How often do students work individually using computers? (b) How often do students work in groups using computers? (c) How often do students use a computer or portable writing device for writing? (d) How often do students research/use the Internet or CD-ROM? (e) How often do students use a computer to solve problems?

Analytic Procedures

Researchers used structural equation modeling (SEM) and multilevel SEM to develop a single multilevel predictive model of TDS and three single-level

Table 3. Summary of Scales and Data Sources

Type of Variable	USEIT Scale	Reliability [a]	Data Source
Outcome variable	Teacher-directed student use of technology in the classroom (TDS)	.84	Teacher survey
District-level predictors	Funding	.60	Site visit data
	Resources	.41	Site visit data
	Evaluations consider technology	.61	District survey
School-level predictors	Principal's beliefs	.47 [b]	Principal survey
	Principal's use of technology	.75	Principal survey
	Principal's access to professional development	.60	Principal survey
Classroom-level predictors	Beliefs about the breadth of technology's benefits	0.95	Teacher survey
	Teacher pedagogical beliefs	0.63	Teacher survey
	Teacher's confidence with technology	0.85	Teacher survey
	Pressure to use technology	0.78	Teacher survey
	Obstacles to integrating technology into lesson plans	0.62	Teacher survey
	Perceived need for professional development for the integration of technology	0.73	Teacher survey
	Importance of computers for teaching scale	0.79	Teacher survey
	Teachers' experience with technology	0.71	Teacher survey

a Coefficients in normal font are Cronbach alphas and coefficients in italics are Cohen's kappas.
b Scale excluded from analyses due to poor reliability.

models of TDS: a classroom model, a school model, and a district model. Structural equation modeling is a family of "a priori" statistical techniques used to test hypotheses about the relationships between variables (Hoyle, 1995; Kline, 1998). In SEM, path diagrams, which are graphical representations of the hypothetical model, represent hypotheses to test relationships among variables (Hoyle, 1995). In path diagrams, analysts use rectangles to depict observed variables, ellipses to depict latent variables and measurement error, and arrows to indicate association between variables. Similar to regression, error terms represent the amount of variance in outcome variables that is not explained by the model and are graphically represented in the path diagram by circles linked to each endogenous variable (i.e., variables predicted by the model). Analysts use straight arrows to indicate the association between a predictor and an outcome variable and curved arrows to indicate correlations (Hoyle, 1995). Paths represent direct effects between predictor and outcome variables, whereas path coefficients are statistical estimates of relationships between variables, which the reader may interpret as regression coefficients (Kline, 1998).

As Hox (2002) points out, educational researchers model complex relationships between latent and/or observed variables using multilevel SEM models. In addition to facilitating the examination of direct, indirect, and reciprocal effects in a single analysis, as in HLM multilevel SEM has the added benefit of examining relationships between outcome variables at lower levels of analysis (i.e., at the individual level) and explanatory variables at higher hierarchical levels (i.e., at the group level). However, unlike HLM, SEM allows variables to be modeled as outcomes and predictors in separate but interrelated equations (Hox, 2002; Kline, 1998).

Researchers used a three-step process to generate a multilevel structural equation model (SEM) that estimated the magnitude of direct and indirect effects of district, school, and classroom-level factors on teacher-directed student use of technology in the classroom. These steps included correlation analyses, generation of single-level SEM models, and development of a multilevel model.

Correlation analyses. The first step in these analyses was running correlation analyses to investigate the strength of the relationships between TDS and other USEIT scales and to identify relationships among other predictor variables. To maximize the initial pool of possible predictors, researchers used a correlation of at least ±0.2 with TDS as the criterion to retain variables as predictor variables (Fraenkel & Wallen, 2003). To evaluate the relationship between TDS and school- and district-level USEIT variables, researchers aggregated the value of TDS to the appropriate hierarchical level. At the school level, researchers assigned each school the mean TDS score for teachers within that school. At the district level, researchers assigned each district the mean TDS score for teachers within that district. Researchers used the same aggregation procedure for classroom-level predictor variables of TDS that they used at higher-levels of analysis. Researchers aggregated teachers' experience with technology at the school level by calculating the mean scale score for teachers within the school. Schools' mean experience with technology scores were then correlated with the school mean TDS scores and with other school-level variables, such as the principal's use of technology.

Generation of SEM path models. Analyses described here used an iterative process to develop single level SEM models for TDS. Researchers developed separate single-level models for the classroom, school, and district-levels. The development of each single-level path model began by specifying a hypothetical path model (e.g., hypothesized model for TDS based on classroom-level factors) based on prior research findings and on correlation analyses; it was then estimated using AMOS. Since analyses presented here aimed to develop a multilevel path mode and to estimate effects at different levels within a school system, SEM analyses used covariance matrices. AMOS provides several fit indices that provide estimates for the extent to which the hypothetical model deviates from the theoretical model. Researchers used overall fit statistics, absolute fit indices, and incremental fit indices to evaluate model fit. Overall fit indices used were the chi-square statistic (χ^2) and the chi-square degrees of freedom ratio (χ^2/DF). Absolute indices used were the goodness of fit index (GFI) and the adjusted goodness of fit index (AGFI). Incremental fit indices used were the normed fit index (NFI) and the comparative fit index (CFI). Table 4 presents the evaluation criteria used.

Table 4. Criteria to Accept the Hypothesized Model

Index	Evaluation Criterion
χ^2	Small χ^2 with probability >0.05
χ^2/DF	Ratios of 3 or less
GFI	≥0.90
AGFI	≥0.90
NFI	≥0.95
CFI	≥0.95

When researchers accepted a model based on fit criteria presented in Table 4, they terminated estimation and selected that model as the final model for TDS at that particular level of analysis. Analyses proceeded by developing a model at the next hierarchical level. When fit indices suggested that improvements could be achieved, researchers used modification indices provided by AMOS to guide model respecification. According to Byrne (2001), modification indices (MI) "reflect the extent to which the hypothesized model is appropriately described" (p. 90) and to what extent the estimate model may be improved if specific parameters are specified. AMOS provides an MI for each fixed parameter, which represents the expected χ^2 drop if the parameter were estimated. The researchers repeated this process of modifying a model and examining fit indices until they obtained an adequately fitting single-level model at each level.

Multilevel model development. The researchers used relationships found in the single-level SEM models (i.e., classroom, school, and district) to inform the development of a multilevel model. Analyses reported here represent a multilevel model in a single diagram that contains paths between predictor variables at each level of analyses and the outcome variable. In the multilevel model, each path contains three path coefficients, which one may interpret as regression coefficients. To create datasets for each level of analysis, researchers aggregated variables from lower levels, assigned the mean score to the higher level, and assigned variables from higher levels to lower levels. As an example, for school-level analysis, researchers aggregated classroom-level variables (e.g., teacher beliefs about technology) to the school level by calculating the mean scale score for teachers within a given school and then assigning that mean to the school level. Conversely, at the classroom level, researchers assigned values for school-level variables (e.g., principal's use of technology) to each teacher, which remained constant across all teachers within a school. Table 5 presents a summary of variables used in analyses.

Analyses proceeded with model building. Multilevel model building employed a modified version of Hox's (2002) group approach. Hox (2002) recommends beginning multilevel model development at the lowest level of analysis and then proceeding with the introduction of variables at higher levels. Following this procedure, one arrives at the optimal model if adding a variable adds little or no improvement be-

Table 5. Summary of Scales in Multilevel Analyses by Dataset

Scales Used in Analyses	Values Used for the Scales by Dataset		
	Classroom	School	District
TDS	Individual [a]	Aggregated [b]	Aggregated [c]
Positive technology beliefs	Individual [a]	Aggregated [b]	Aggregated [c]
Technology experience	Individual [a]	Aggregated [b]	Aggregated [c]
Pressure	Individual [a]	Aggregated [b]	Aggregated [c]
Integration obstacles	Individual [a]	Aggregated [b]	Aggregated [c]
Technology standards	Disaggregated [d]	Disaggregated [e]	District's value [f]
Principal's discretion	Disaggregated [d]	Disaggregated [e]	District's value [f]

a Individual teacher's value on the scale was used

b Mean value on the scale for teachers within a school was used

c Mean value on the scale was used

d District's value on the scale used as a constant across teachers within a district

e District's value on the scale used as a constant across principals within a district

f District's value on the scale was used

tween two consecutive models. One evaluates model improvement by examining the chi-square drop between two consecutive models and the probability associated with chi-square, and by comparing the models' fit indices. The authors intended to begin multilevel model development at the classroom stage, but it was evident during the single-level model development stage that multicollinearity issues would arise if we promoted all classroom-level variables to the school level. Consequently, our multilevel model development began at the school level. The authors used the final school-level model obtained during single-level analyses (see Figure A1 in the Appendix on p. 322) as the base for the multilevel model. The initial model contained separate path coefficients for each level of analysis.

After estimation, using criteria listed in Table 4, researchers evaluated fit indices to assess the model's adequacy. When the authors judged a model as adequate, they introduced the best predictor of TDS at the next hierarchical level. If the model did not fit the data adequately, modification indices and theory guided the addition and removal of paths or variables. The researchers evaluated modification indices first for the classroom level of analysis, followed by the school level, and finally by the district level. As suggested by Rowe and Hill (1998) and by Hox (2002), multilevel modeling stopped when adding a new variable did not improve model fit (i.e., if the chi-square of the model with the new predictor variable was larger than the model without the variable).

Results

The authors designed the study presented here to examine direct and indirect effects of a variety of factors residing at different organizational levels

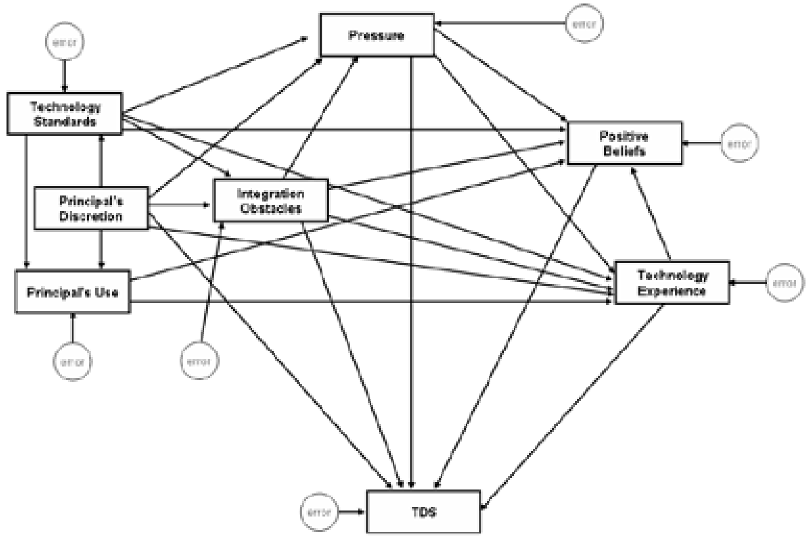

Figure 1. Final multilevel model for TDS.

within a school system on instructional use of technology in the classroom. To this end, the authors developed a multilevel SEM model following procedures described above.

Figure 1 presents the final multilevel model for TDS. It shows the relationships between eight variables:

- TDS
- Teacher's experience with technology (technology experience)
- Beliefs about the breadth of technology's benefits (positive technology beliefs)
- Obstacles to integrating technology into lessons (integration obstacles)
- Pressure relating to the use of technology (pressure)
- Principal's technology use (principal's use)
- The availability of and accountability to technology standards (technology standards)
- Principals' technology discretion scale (principal's discretion)

In practical terms, this model depicts factors that are associated with IT use in the classroom and that may have positive or negative effects (i.e., increase or decrease) on TDS. The outcome variable, TDS, resides at the classroom level and represents the frequency with which teachers direct their students to use technology in the classroom during instruction. Two predictors reside at the district level, one resides at the school level, and four reside at the classroom level. District-level variables include principal's technology discretion (principal's discretion) and availability/enforcement of technology standards (technology standards). The school-level

Table 6. Comparison of Fit Indices for the Final Multilevel Model with District-Level Predictors (Technology Standards and Principal's Discretion)

Model	χ^2	DF	p	χ^2/DF	GFI	AGFI	NFI	CFI
Multilevel model with technology standards and principal's discretion	3.50	9.00	.94	0.39	1.00	.99	1.00	1.00
Saturated	0.00	0.00			1.00		1.00	1.00
Independence	812.28	84.00	.00	9.67	.85	.81	.00	.00

Note: See Table 5 for evaluation criteria.

variable is principal's use of technology (principal's use). Classroom-level variables included teachers' beliefs about the variety of benefits of IT (positive technology beliefs), teacher's experience with technology (technology experience), perceived pressure related to technology use (pressure), and obstacles to integrating technology into lesson plans (integration obstacles). The model also depicts direct effects between the following variables and TDS: pressure, positive technology beliefs, integration obstacles, principal's discretion, and technology experience. Note that a direct effect is a relationship between a predictor and an outcome that does not involve the intervention of a moderator or mediating variable. The model also shows direct effects between several sets of variables (e.g., integration obstacles and pressure, positive beliefs and technology experience, and technology experience and positive beliefs).

Model Evaluation

The final model included two district-level variables: principal's discretion and technology standards. Note that, although the inclusion of principal's discretion did not improve model fit, it did increase the amount of variance explained and was consistent with the theoretical framework, so it was included in the final model. Table 6 presents fit indices for the final multilevel model.

Assessment of fit indicated that the final multilevel model fit the theoretical model well. The χ^2 was relatively small and nonsignificant (χ^2=3.50, p=0.94). χ^2/DF was 0.40 (below the recommended threshold of three), and all other fit indices indicated that the hypothesized model closely approximated the theoretical model. The obtained GFI and AGFI were greater than 0.9; the NFI and CFI were very close to one, indicating a very good model fit. When researchers added the predictor with the next highest correlation with TDS (external funding) to the model, its inclusion did not explain additional variance, nor did it improve model fit ($\chi^2_{\text{Final model}}$ =3.50; $\chi^2_{\text{External funding model}}$= 5.21; see Figure A2 and Table A2 in the Appendix, p. 323). Therefore, the authors stopped model building and concluded that the model presented in Figure 1 was the best fitting model for TDS.

Final Multilevel Model

Figure 2 shows the final multilevel model for TDS with standardized path coefficients, which may be interpreted as regression weights. The scales include:

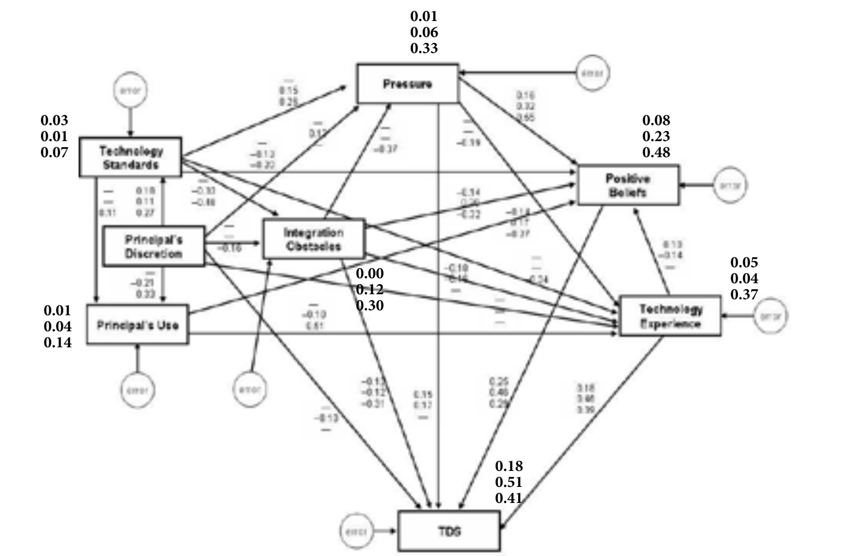

Figure 2. Final Multilevel Model for TDS with standardized path coefficients.

- TDS
- Teacher's experience with technology (technology experience)
- Beliefs about the breadth of technology's benefits (positive technology beliefs)
- Obstacles to integrating technology into lessons (integration obstacles)
- Pressure relating to the use of technology (pressure)
- Principal's technology use (principal's use)
- The availability of technology and accountability to technology standards (technology standards)
- Principals' technology discretion scale (principal's discretion)

As shown in Figure 2, the multilevel model shows relationships between and among scales at three levels of analysis (classroom, school, and district). Each path represents relationships between variables and has three coefficients, which may be interpreted as regression coefficients, representing standardized direct effect (b) between the predictor and outcome at each level of analysis. Top coefficients represent classroom-level effects, middle coefficients represent school-level effects, and bottom coefficients represent district-level effects. The model does not show path coefficients less than 0.10 as their effects are negligible (Kline, 1998). Finally, the figure shows squared multiple correlations for each of the scales in italics, which may be interpreted as the amount of variance in outcome variables explained by predictors. Table 7 presents standardized total effects.

Standardized total effects of predictor variables on TDS at the classroom level ranged from –0.02 to 0.25. Predictor variables that had the strongest

Table 7. Standardized Total Effects across Levels of Analysis [b]

Scale	Level[a]	Principal's Discretion	Technology Standards	Integration Obstacles	Pressure	Principal's Use	Technology Experience	Positive Beliefs
Technology Standards	C	0.18 (0.02)						
	S	0.11 (0.05)						
	D	0.27 (0.06)						
Integration Obstacles[c]	S	-0.11 (0.04)	-0.33 (0.07)					
	D	-0.30 (0.02)	-0.50 (0.03)					
Pressure[c]	S	0.16 (0.05)	0.17 (0.10)					
	D	0.23 (0.03)	0.44 (0.05)	-0.37 (0.18)				
Principal's Use[c]	S	-0.21 (0.10)						
	D	0.36 (0.05)	0.11 (0.08)					
Positive Beliefs	C			-0.16 (0.03)	0.17 (0.03)	-0.13 (0.03)	0.10 (0.03)	
	S			-0.30 (0.11)	0.33 (0.0.8)	0.20 (0.04)	-0.14 (0.86)	
	D		0.18 (0.05)	-0.52 (0.17)	0.54 (0.09)	-0.26 (0.06)		
TDS	C			-0.20 (0.03)	0.20 (0.03)		0.20 (0.026)	0.25 (0.026)
	S			-0.34 (0.08)	0.31 (0.06)		0.40 (0.06)	0.50 (0.06)
	D	0.13 (0.03)	0.27 (0.06)	-0.50 (0.20)	0.14 (0.12)	0.12 (0.06)	0.40 (0.12)	0.30 (0.12)

a C denotes classroom-level, S denotes school-level, and D denotes district level.

b Numbers inside parentheses are standard errors

c No Classroom effects detected

standardized total effect on TDS included positive technology beliefs ($\beta = 0.25$), pressure ($\beta = 0.20$), technology experience ($\beta = 0.20$), and integration obstacles ($\beta = -0.20$). Note that integration obstacles' effect was negative, whereas other variables had positive effects. Results suggest that, at the classroom level, predictor variables may have small to moderate effects on TDS. Integration obstacles appear to have moderate negative effects on TDS and on two important predictors of TDS, technology experience and positive technology beliefs. Results suggest that teacher factors such as beliefs about IT's benefits and experience with technology may increase the extent to which teachers direct their students to use technology, and that teachers whose principals emphasize IT use may increase the extent to which they direct students to use technology. Conversely, teachers who experience obstacles with IT integration may be less likely to direct their students to use technology than teachers who do not experience such obstacles.

At the school level, standardized total effects of predictor variables on TDS ranged from −0.04 to 0.50. Positive technology beliefs had the largest standardized total effect on TDS ($\beta = 0.50$), followed by technology experience ($\beta = 0.40$). This suggests that these variables may have moderate effects on TDS at the classroom level, yet their cumulative effect on TDS may increase at the school level. Likewise, pressure appears to have a larger effect ($\beta = 0.31$) on TDS at the school level that at the classroom level ($\beta = 0.20$). These results suggest that schools where on average teachers have stronger beliefs about technology's benefits tend to have teachers who direct their students to use technology more often than do schools where teachers on average have weaker beliefs.

Effects of predictor variables on TDS at the district level ranged from 0.12 to −0.50. Integration obstacles ($\beta = -0.50$) had the largest effect on TDS at the district level, followed by technology experience ($\beta = 0.40$) and positive technology beliefs ($\beta = 0.30$). Note that the effect of integration obstacles was negative, whereas the effects of technology experience and positive technology beliefs were positive. Regarding standardized total effects of one predictor variable on another, the large effects of technology standards on integration obstacles ($\beta = -0.50$) and on pressure ($\beta = 0.44$) are noteworthy. Also noteworthy are the large effects that integration obstacles and pressure had on positive technology beliefs ($\beta = -0.52$ and $\beta = 0.54$, respectively) and the large effect of a principal's use on teachers' technology experience ($\beta = 0.51$). The multilevel model suggests that the effect of a predictor variable on TDS and, at times, on other predictor variables, tends to be larger at higher levels within the model. These results indicate that districts where teachers have more experience with technology and perceive fewer obstacles to integrations tend to have teachers who, on average, direct their students to use technology more often than do districts with less experienced teachers or teachers who report more obstacles with integration.

Effects intensification across levels of analysis is evident when comparing effects between the classroom and school levels. At the classroom level, integration obstacles have a −0.20 effect on TDS, whereas, at the school level, the variable has a −0.34 effect; integration obstacles' effect on positive technology beliefs increases from −0.16 at the classroom level to −0.30 at the school level. Furthermore, pressure has a 0.33 effect on positive technology beliefs at the school level compared to a 0.17 effect at the classroom level. Finally, at the classroom level, the effect of technology standards on the integration obstacles is insignificant. Yet, at the school level, technology standards have a moderate effect on integration obstacles (−0.33).[1] This suggests that predictor variables' effects may be minimal at the classroom level, but those effects strengthen at the school level. Comparison of school- and district-level effects also suggests a magnification of effects from one hierarchical level to another. For instance, the negative effects of integration obstacles on TDS as well as those of integration obstacles on positive technology beliefs increase from −0.30 at the school level to −0.50 (same effect associated with both scales) at the district level. A practical interpretation of these results is that some factors may have a small impact on the extent to which an individual teacher uses technology in the classroom, but the overall effect of those factors may increase when considering entire organizations.

Discussion of Findings

Despite the widespread investment in IT during the 1990s, access to technology may not have translated into increased computer use (Cuban, 2001; Russell et al., 2003a; Russell et al. 2003b; Wells, & Lewis, 2006).To maximize educational technology's benefits for student learning, organizational leaders must understand which factors contribute to increased use of educational technology. This study aimed to identify factors that affect teacher-directed student use of technology in elementary classrooms by developing a multilevel path diagram that represents relationships between and among constructs at the district, school, and classroom levels to answer the following questions: (a) Which district-level factors contribute the most to teacher-directed student use of technology? (b) Which school-level factors contribute the most to teacher-directed student use of technology? (c) Which classroom-level factors contribute the most to teacher-directed student use of technology? (d) How do factors interact within and across organizational levels within school systems to contribute to teacher-directed student use of technology?

Analyses presented here suggest that the two strongest predictors of technology use at the district level appear to be (a) the extent to which district personnel are aware of technology standards and are held accountable to them and (b) principal's discretion over technology spending. These district factors also appear to be associated with other important predictors of IT, use such as principal's reported use of technology, teachers' beliefs about the instructional benefits of technology, and perceived pressure by teachers to use technology. In turn, at the school level, principal's reported use of technology appears to have the strongest effect on teachers' reported use of technology and may affect other important predictors of classroom IT use, such as teachers' beliefs about the instructional benefits of technology and perceived pressure by teachers to use technology. At the classroom level, results suggest that the strongest predictor of reported teacher directed student use might be teachers' belief about the instructional benefits of technology, followed by teachers' experience with technology and teachers' perceived pressure to use technology.

1 Note that integration obstacles represent the degree to which obstacles impede the integration of technology. The negative effect of technology standards on integration obstacles indicates that an increase in the presence and enforcement of technology standards leads to a decrease in the presence of integration obstacles.

Researchers often cite resources and funding as barriers to IT use (Anderson & Ronnkvist, 1999; Fisher et al., 1996; Lemke et. al., 1998). However, evidence from these analyses suggests that obstacles that teachers experienced to integrating technology into instructional practice may be just as detrimental. As reported here, perceived obstacles to integrating technology may be the biggest deterrent to directing students to use technology. Perceived obstacles to integrating technology, as defined by the USEIT study, include easy access to technology, availability of integration specialists, and timely access to technical support. Even when teachers have ample access to instructional technology because of adequate funding and access to IT resources, teachers may not use those resources if they do not have support.

Another important finding reported here regards the intensification of effects as the analytic focus shifts from a lower to a higher organizational level (e.g., from the classroom level to the school or district level). Factors such as beliefs about instructional benefits of technology, perceived obstacles to integrating technology, perceived pressure by teachers to use technology, and accountability to technology standards may have small effects at the individual classroom level but may have stronger effects at the school and district levels. This pattern is likely due to the cumulative effect a factor may have on teachers who work within a school or district. For instance, not all teachers within a school respond identically to obstacles integrating technology. Teachers who are technology innovators may reach out to external sources for assistance with IT integration (e.g., Internet resources, teachers in other districts), whereas less innovative teachers may resort solely to locally provided support; these teachers may be less likely to use technology in instruction, thereby decreasing the district's average use of IT.

The incremental pattern of effects concurs with macro-level adoption theories. Macro-level factors have a top-down effect that may influence individuals within the organization in different ways but move the entire organization to change culture. Due to the intensification of effects at higher organizational levels, organizations may pay close attention to factors identified in this study when considering changing the IT culture in educational organizations, including beliefs about instructional benefits of technology, perceived obstacles to integrating technology, perceived pressure reported by teachers to use technology, and accountability to technology standards .

The finding that micro- and macro-level factors interact across organizational levels to influence technology use in the classroom is consistent with Surry and Farquhar's (1997) recommendations that successful innovation adoption requires targeting micro- and macro-level factors. Thus, school systems could consider both micro- and macro-level factors when developing strategies to increase teachers' use of technology in the classroom. To address micro-level factors, a school system might place greater emphasis on teachers' prior technology experience when hiring teachers, promote professional development opportunities that focus on the benefits rather than the mechanics of using IT, and highlight IT strategies used by teachers who use technology innovatively and successfully. To address macro-level factors, a school system may consider IT use and technology standards in the development of teachers' professional development plans, emphasize a principal's prior use of technology during hiring deliberations, and allow principals to have discretion over their schools' technology expenditures. Collectively, these macro-level actions may lead to the selection of school leaders who are committed to technology, have the skills to be technology advocates within the school, and promote a school culture that embraces technology.

Limitations

This study represents a step forward in the analysis of factors that contribute to IT use, but it is not without limitations. SEM techniques used here allowed for complex data analysis, but an insufficient number of districts available in the USEIT data may have resulted in inflated effects at the district level. Other issues that limit generalizability are the purposive nature of the USEIT sample, the omission of other explanatory factors of IT use that were not included in USEIT surveys, and the elimination of factors from analyses due to measurement constraints. Additionally, analyses presented here focused only on one type of IT use: TDS. However, it is important to examine factors associated with teachers' use of technology for other instructional purposes (e.g., to deliver instruction). Finally, the attribution of factors to specific organizational levels in analyses presented here may not have reflected the respective assignment of factors in school organizations, as the assignment of factors in multilevel analysis is often arbitrary (Hox, 1998). In the future, researchers may gain a better understanding of factors that impact IT use by collecting data at the organizational level where they reside. Nonetheless, this study represents a more comprehensive analysis of the interaction between factors residing at various organizational levels of analysis than have previous studies. Perhaps more important, this study suggests that increasing the use of IT is not limited to a list of factors that individually contribute to affecting technology use in the classroom. Rather, results point to the importance of an entire school district culture committed to IT use, where district leaders set and enforce IT goals, encourage principals to make technology-related decisions, and communicate the importance of using technology across the organization.

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Appendix

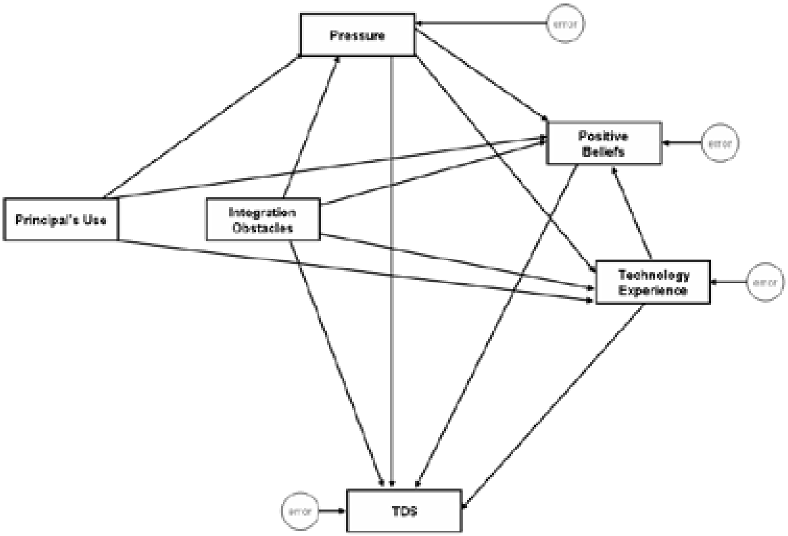

Figure A1. Initial multilevel model with school- and teacher-level predictors.

Table A1. Comparisons of Model Fit for Multilevel Model with Teacher- and School-Level Predictors

Model	χ^2	DF	*p*	χ^2/DF	GFI	AGFI	NFI	CFI
Initial Multilevel Model	4.13	6.00	0.66	0.69	1.00	.99	.99	1.00
Saturated model	0.00	63.00			1.00		1.00	1.00
Independence model	639.46	45.00	0.00	14.21	.85	.79	.00	.00

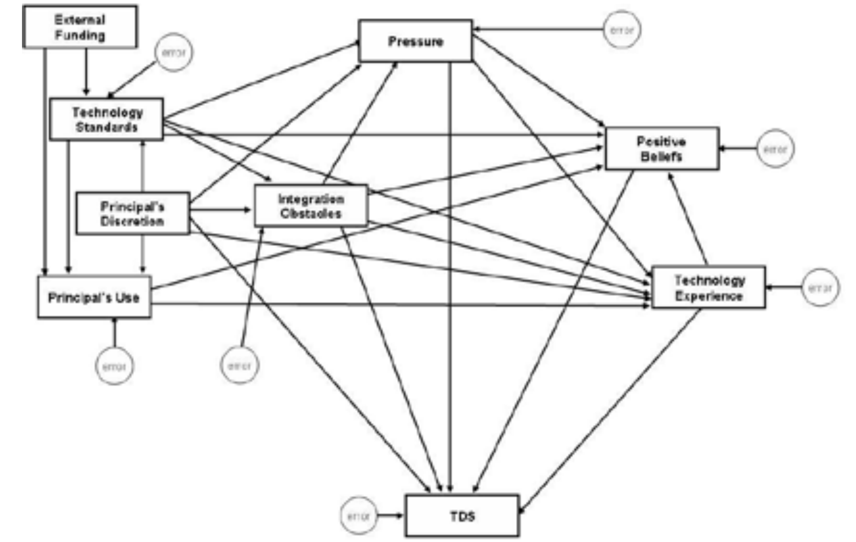

Figure A2. Multilevel model with district-level predictors, technology standards, principal's discretion, and external funding.

Table A2. Comparisons of Fit Indices for Multilevel Model with Technology Standards, Principal's Discretion, and External Funding

Models	χ^2	DF	*p*	χ^2/DF	GFI	AGFI	NFI	CFI
Multilevel technology standards, principal's discretion, and external funding	5.21	12.00	0.95	0.43	0.99	0.99	1.00	1.00
Multilevel model with technology standards and principal's discretion	3.50	9.00	.94	0.39	1.00	.99	1.00	1.00
Saturated	0.00	0.00			1.00		1.00	1.00