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ABSTRACT

Two self-report measures of technology integration are introduced along with a formal model illustrating their utility as outcome measures for level of technology infusion in classroom environments. Findings from two Texas studies involving: (1) more than 500 teachers from a large metropolitan school district; and (2) technology expenditures from a random sample of 100 Texas school districts illustrate that: technology integration as measured by Stage of Adoption can be predicted with high accuracy based on secondary school teachers' self-reported will, skill, and access to technology tools; higher classroom technology integration as measured by Concerns-Based Adoption Model Level of Use is positively associated with higher average elementary school classroom scores in Iowa Test of Basic Skills Vocabulary, Reading, and Writing; and average school district Scholastic Aptitude Test scores can be reasonably well predicted based on knowledge of district level technology expenditures. The paper proposes that the Will, Skill, Tool Model of Technology Integration warrants further testing in additional large-scale studies. (Author/SM)

Measures of Teacher Stages of Technology Integration and Their Correlates with Student Achievement

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Abstract

Two self-report measures of technology integration are introduced along with a formal model illustrating their utility as outcome measures for level of technology infusion in classroom environments. Findings from two Texas studies involving: 1) more than 500 teachers from a large metropolitan school district, and 2) technology expenditures from a random sample of 100 Texas school districts, illustrate that: a) technology integration as measured by Stage of Adoption can be predicted with high accuracy (RSQ = .84, $p < .001$) based on secondary school teachers' self-reported will, skill, and access to technology tools; b) higher classroom technology integration as measured by CBAM Level of Use is positively associated with higher average elementary school classroom scores in ITBS Vocabulary ($r=.89$, $p < .01$), Reading ($r=.70$, $p < .03$), and Writing ($r=.81$, $p < .02$); and c) average school district SAT scores can be reasonably well predicted (RSQ = .11, $p < .05$) based on knowledge of district level technology expenditures. The authors propose that the Will, Skill, Tool Model of Technology Integration warrants further testing in additional large-scale studies.

Introduction

Accountability for information technology expenditures is an issue at the forefront of state and national educational policy deliberations. Probably no question is more frequently asked by those who fund computers in the K-12 environment than whether it can be demonstrated that the use of information technology in the teaching/learning process has a positive impact on student achievement. Knezek and Christensen have formulated a model in which teacher will, skill, and access to technology tools are all postulated to be necessary components for effective integration of technology into the teaching/learning environment of the classroom (Knezek, Christensen, Hancock, and Shoho, 2000). Technology Integration is then hypothesized to have a positive impact on student achievement. In this paper the authors verify significant relationships among various model components after introducing instruments they and others have developed for measuring technology integration. They conclude by proposing that the full model should be further tested in large scale data acquisition environments.

Significance/Rationale

Studies have shown that students' attitudes about school and learning are likely to affect student achievement (U.S. Congress, 1995), and that appropriate teacher training in classroom computer use can be associated with higher student achievement (ETS, 1998, as reported in Pierce, 1998). In the words of Pierce (1998), "Not surprisingly, the [Educational Testing Service] study found that students whose teachers had been trained to teach with computers scored higher [in mathematics achievement] than students whose teachers lacked such training." (p.2) One missing component in the causal link was demonstrating that appropriate teacher preparation in classroom use of computers could result in positive attitudes among their students.

Christensen (1997) concluded in her doctoral dissertation that technology integration education appears to strongly influence teachers' attitudes toward computers. She also showed that the direct effect of (teacher) technology integration education on students is weaker although also present. She stated that training appears to foster meaningful use by teachers in the classroom, which in turn fosters student Computer Enjoyment and later a perception of importance of computers. Christensen (1997) also pointed out that greater positive perception of Computer Importance among the students in a classroom fosters higher Computer Anxiety in their teachers, which implies that teachers need some mechanism at their disposal (on-going education, for example) that continues to reduce their anxiety more rapidly than the advancing skill level of their students tends to cause teacher anxiety levels to increase.

Little formal work in the area of self-reported assessment of technology integration is reported in the literature prior to the currently reported work by the authors. Therefore, in the following sections, two quick measures of technology integration that can be implemented in a classroom or teacher training environment are introduced, and evidence of their reliability and validity is provided. Next the stage of adoption and level of use scores produced by these instruments are shown to be well predicted by other teacher measures of will, skill and access to technology tools. Finally, a test of the model regarding student achievement is carried out using data gathered on technology expenditures and student SAT scores in 100 Texas school districts.

Stages of Adoption

Stages of Adoption (Christensen, 1997) is a self-assessment instrument of a teacher's level of adoption of technology, based on earlier work by Russell (1995). There are six possible stages in which educators rate themselves: Stage 1 - Awareness, Stage 2 - Learning the process, Stage 3 -

Understanding and application of the process, Stage 4 - Familiarity and confidence, Stage 5 - Adaptation to other contexts, and Stage 6 - Creative application to new contexts. A more extensive description of each of these stages is provided on the instrument itself (See Appendix A).

Levels of Use

Levels Of Use (Griffin & Christensen, 1999) is a self-assessment instrument adapted from the Concerns-Based Adoption Model (CBAM) Level of Use designations for adoption of an educational innovation. There are 8 levels (coded for analysis as 1 – 8): 1 - Level 0 Non-use, 2 - Level 1 Orientation, 3 - Level 2 Preparation, 4 - Level 3 Mechanical Use, 5 - Level 4 A Routine, 6 - Level 4 B Refinement, 7 - Level 5 Integration, and 8 - Level 6 Renewal (See Appendix B).

Relationship Between Stages of Adoption and CBAM Levels of Use

Studies conducted on the CBAM Level of Use Scale using fall 1999 and spring 2000 teacher data from a large metropolitan school district in northern Texas indicate that levels of use of technology are related to stages of adoption, but the precise nature of that relationship is currently unknown. The Pearson Product Moment correlation between the two indices, using fall 1999 data for 508 teachers, was r = .72. The same coefficient, using spring 2000 data for 566 teachers, was r = .65. This indicates that about 40% (r^2) of the variation in one measure can be explained in terms of the other. Future research is needed to determine if certain levels of use correspond with precise stages of adoption.

Stages of Adoption as a Meaningful Measure

All 12 schools in the suburban school district described above furnished Stages of Adoption and Level of Use date in the fall of 1999 and spring of 2000. Educators in these schools received extensive technology integration support and mentoring from 14 full time instructional designers and from Technology Innovation Challenge Grant team members throughout the 1999-2000 school year. Pre-post findings based on the data are reported below.

As shown in Table 1 and graphically illustrated in Figure 1, this sample of teachers almost equally placed themselves in Stage 4, Stage 5 or Stage 6 at the beginning of the fall semester, 1999. The average Stage of Adoption was 4.44, on a Stage 1 to Stage 6 scale.

Table 1.
Fall 1999 Teachers Stages of Adoption

Stage	n
Stage 1 - Awareness	2
Stage 2 – Learning the Process	37
Stage 3 – Understanding and application of the process	61
Stage 4 – Familiarity and confidence	108
Stage 5 – Adaptation to other contexts	109
Stage 6 – Creative application to new contexts	111
Valid cases	428
Average Stage	4.44

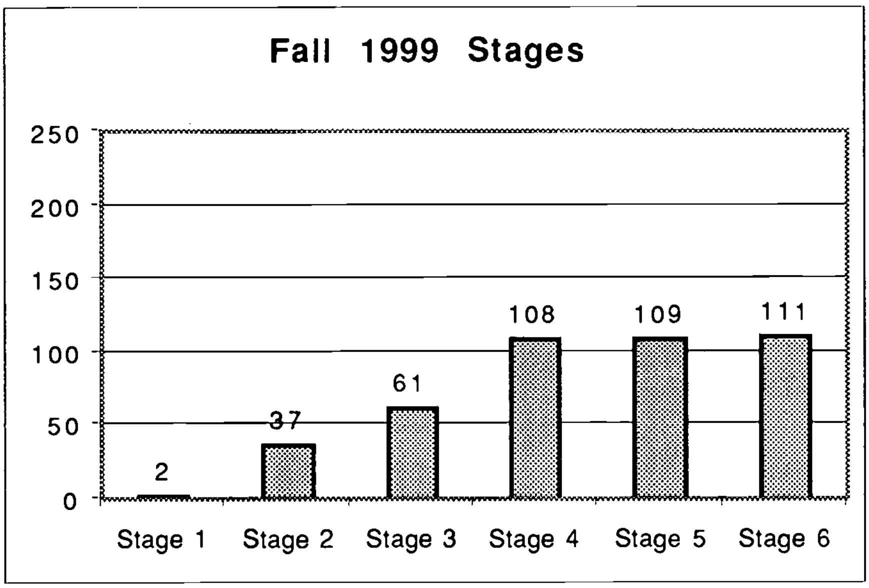

Figure 1. Distribution of Stages of Adoption for Teachers, Fall 1999

By late spring, 2000, the average stage of adoption had increased to 4.86 and more than 200 of these teachers reported they were at Stage 6. These trends are shown in Table 2 and Figure 2.

Table 2.
Spring 2000 Teachers' Stages of Adoption - Spring 2000

Stage	n
Stage 1 - Awareness	0
Stage 2 – Learning the Process	18
Stage 3 – Understanding and application of the process	50
Stage 4 – Familiarity and confidence	133
Stage 5 – Adaptation to other contexts	149
Stage 6 – Creative application to new contexts	208
Valid cases	558
Average Stage	4.86

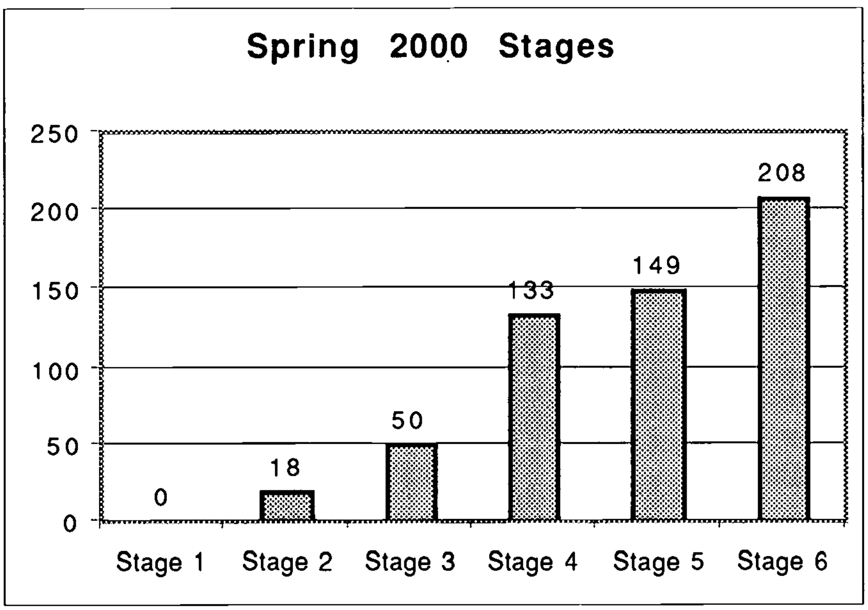

Figure 2. Distribution of Stages of Adoption for Teachers, Spring 2000

Level of Use of Technology as a Meaningful Measure

As shown in Table 3 and graphically illustrated in Figure 3, teachers' self-reported Level of Use increased from an average of 5.36 to 5.8 (on an 8-point scale) during the period September 1999 though May 2000. This increase was comparable to the increase in Stage of Adoption reported above.

Table 3.
CBAM Levels of Use Fall 1999 – Spring 2000

	CBAM LOU	n	Std Dev
Fall 1999	5.36	466	1.70
Spring 2000	5.8	566	1.46

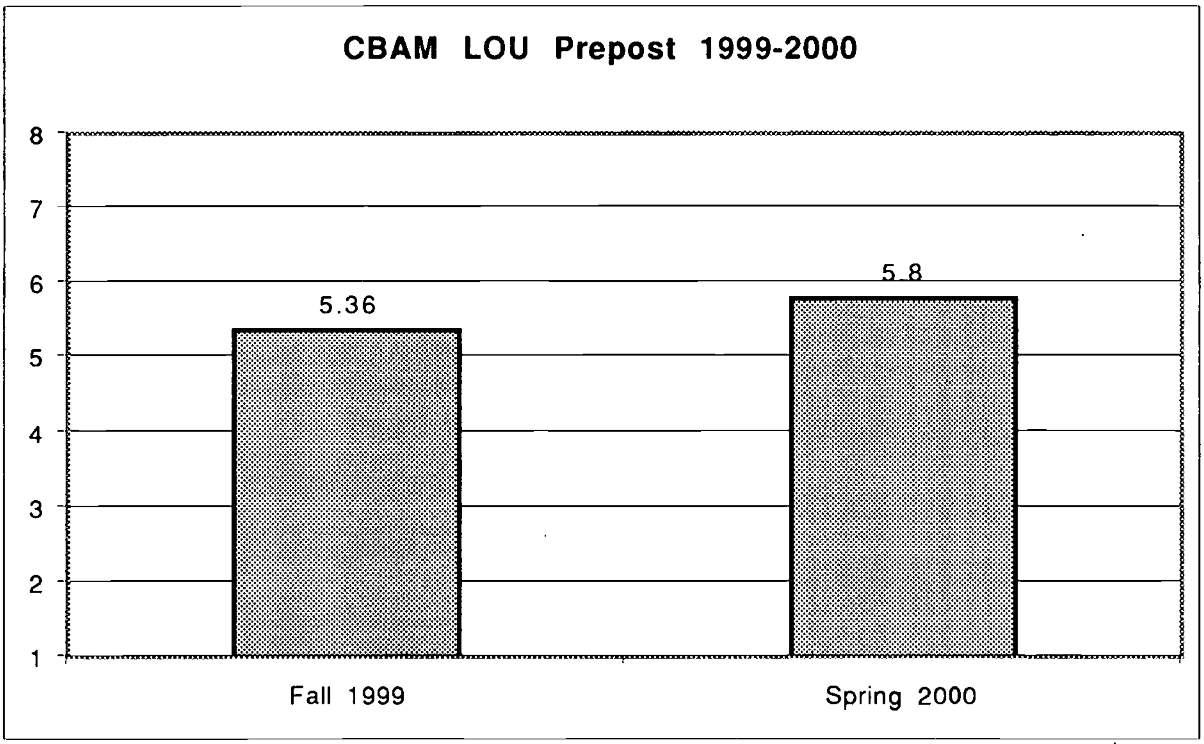

Figure 3. CBAM LOU pre-post changes, 1999 - 2000

Validation of Stages of Adoption and Level of Use through Distinctions Between High Technology and Low Technology Integration Classrooms

In the Fall, 1999, principals were asked to select a teacher who was a high integrator of technology (challenger) and one who was a low integrator of technology (challenged) from each grade level. As shown in Table 4 and Figure 4, the challengers vs. challenged own self-perception on CBAM Level of Use and Stages of Adoption differed on the average by approximately one level or stage.

Table 4.
Average Self-Assessments of High Technology Integrators vs. Low Technology Integrators

	CBAM-LOU	Stage
Challenged	4.85	3.91
Challengers	6.16	4.93

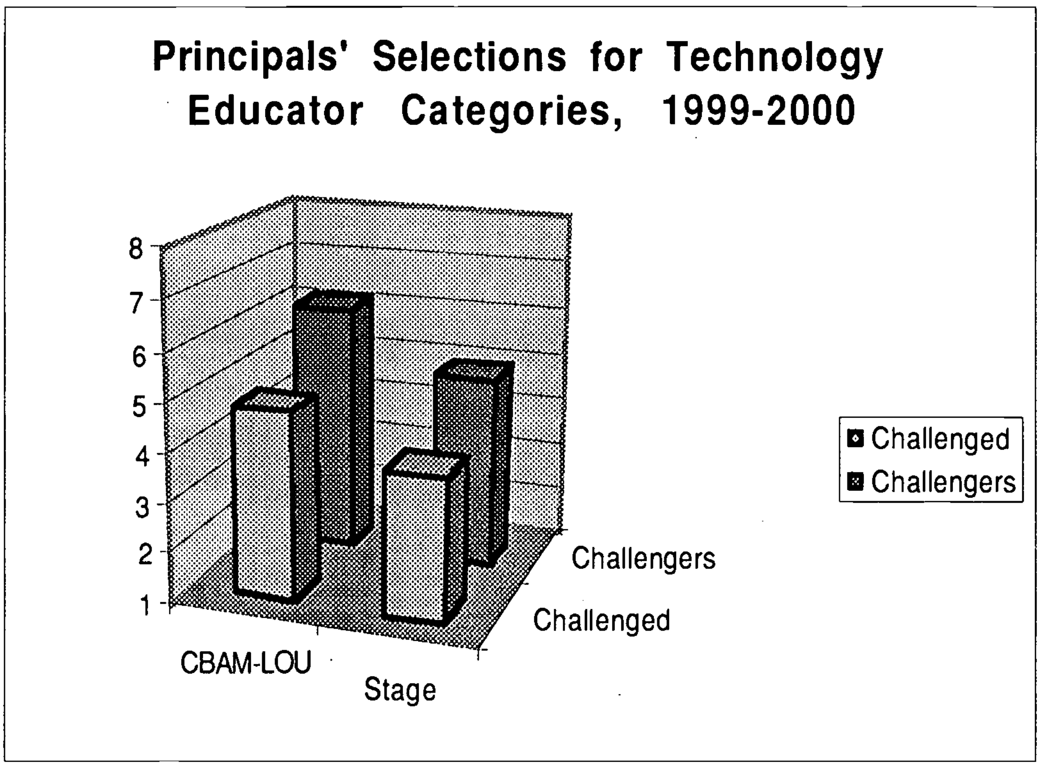

Figure 4. Stages of Adoption and Levels of Use for Two Classifications of Technology Infusing Teachers, 1999-2000

The differences in the average Stage of Adoption and CBAM Level of Use for the Challenged vs. the Challengers were highly significant (Challenged: CBAM-LOU mean = 4.85, SD = 1.49, n = 48; Challengers: CBAM-LOU mean = 6.16, SD = 1.70, n = 44; two-tailed $p < .001$) (Challenged: Stages mean = 3.91, SD =1.14, n = 54; Challengers: Stages mean = 4.93, SD = 1.22, n = 53; 2-tailed $p < .001$). It appears that the principals were quite accurate in their assessment of the classifications of these teachers.

Practical Significance of Challenger Classification

A common standardized measure of improvement that can be applied across many different areas is Effect Size. This index measures change in terms of standard deviations in the data. One common mathematical formula for calculating Effect Size is: (mean at time 2 - mean at time 1)/ standard deviation at time 1.

The Effect Size for Challenger vs. Challenged with respect to Stage of Adoption was .89, while the effect size of Level of Use was .88 for the same groups. This consistent difference validates the ability of the measurement scales (as independently confirmed by the principals) to distinguish between the groups.

Technology in the Classroom and Standardized Test Scores

The elementary school classroom was selected as the unit of analysis for exploratory research conducted on the relationship of classroom technology integration to standardized test scores. Associational indices were computed between the integration measures of: a) Stages of Adoption, b) CBAM Level of Use, and c) Challenged vs. Challenger designation; and the standardized achievement measures of the Texas Assessment of Academic Skills (TAAS) pass rate for reading, writing, and math, plus Iowa Test of Basic Skills (ITBS) scores (available for fifth grade only) in nine areas. Standardized test scores were gathered during the spring of 2000. Integration measures had been gathered for the classroom teachers during the fall of 1999.

No significant associations were found between TAAS pass rates and Stages of Adoption, Levels of Use, or Challenged/Challenger designations. In addition, no significant associations were found between Stages of Adoption or Challenged/Challenger designation and ITBS scores. However, significant associations were found between the teacher's self-reported CBAM Level of Use for fall 1999 and the class' average ITBS scores for the spring of 2000, among the six fifth grade classrooms that provided complete data. As shown in Table 7, ITBS Vocabulary, Total Classroom Reading Score, and Total Classroom Writing score were positively correlated with the teacher's self-reported Level of Use. This type of association is further emphasized in the cross-tabulations provided in Table 8 for ITBS Vocabulary.

Table 5.

Nonparametric Correlation Coefficients for Teacher Self-reported Level of Use of Technology and Student Classroom Average Score on ITBS National Percentile Ranking for Vocabulary, Reading Total, Writing Total, and Math Total Indices

Standardized Variable	**Correlation Coefficient with CBAM LoU**	**N**	**Significance**
ITBS Vocabulary	.89	6	.011
ITBS Reading Total	.70	6	.032
ITBS Writing Total	.81	6	.018
ITBS Math Total	.61	6	.063 (NS)

Note: One-tailed Sig reported

Table 6.

Cross-Tabulation for CBAM LoU by ITBS National Percentile Ranking (NPR) Vocabulary

CBAM (Count)	ITBS_NPR 54.00	56.00	63.00	65.00	66.00	Row Total
2.00	1					1 16.7
6.00		1	1			2 33.3
8.00				2	1	3 50.0
Column Total	1 16.7	1 16.7	1 16.7	2 33.3	1 16.7	6 100.0

Kendall's Tau-b Coefficient of Correlation = .89

Although a sample size of 6 classrooms is not large, the type of trend displayed in Table 8 and confirmed through nonparametric statistical techniques as very unlikely to have occurred by chance, must be taken seriously as worthy of further study. The undeniable relationship present in this small set of data is that elementary school teachers who at the beginning of the school year reported their level of use of technology as high, according to the Concerns-Based Adoption Model (CBAM) classification scheme (Hall & Rutherford, 1974; Hall, Loucks, Rutherford & Newlove, 1975), tended to have their students score high on ITBS reading, writing, and vocabulary tests taken in the spring of 2000. There is no reason to believe that the assignment of students to these classrooms at the beginning of the year was other than pseudo-random. The implication is that several teachers working with their students through a high level of use of technology positively influenced their students' ITBS scores. This type of analysis would appear to be worthy of replication on a much larger scale.

A Predictive Model of Technology Integration and Classroom Achievement

A new model for integrating technology into the classroom was developed by Knezek and Christensen (Knezek, Christensen, Hancock, & Shoho, 2000). This model includes three key elements for successful integration of technology: Will (attitude) of the teacher, Skill (technology competency), and Tools (access to hardware and software -- technology tools). The model also postulates that technology integration in the classroom contributes to higher student achievement. The model is graphically displayed in Figure 5.

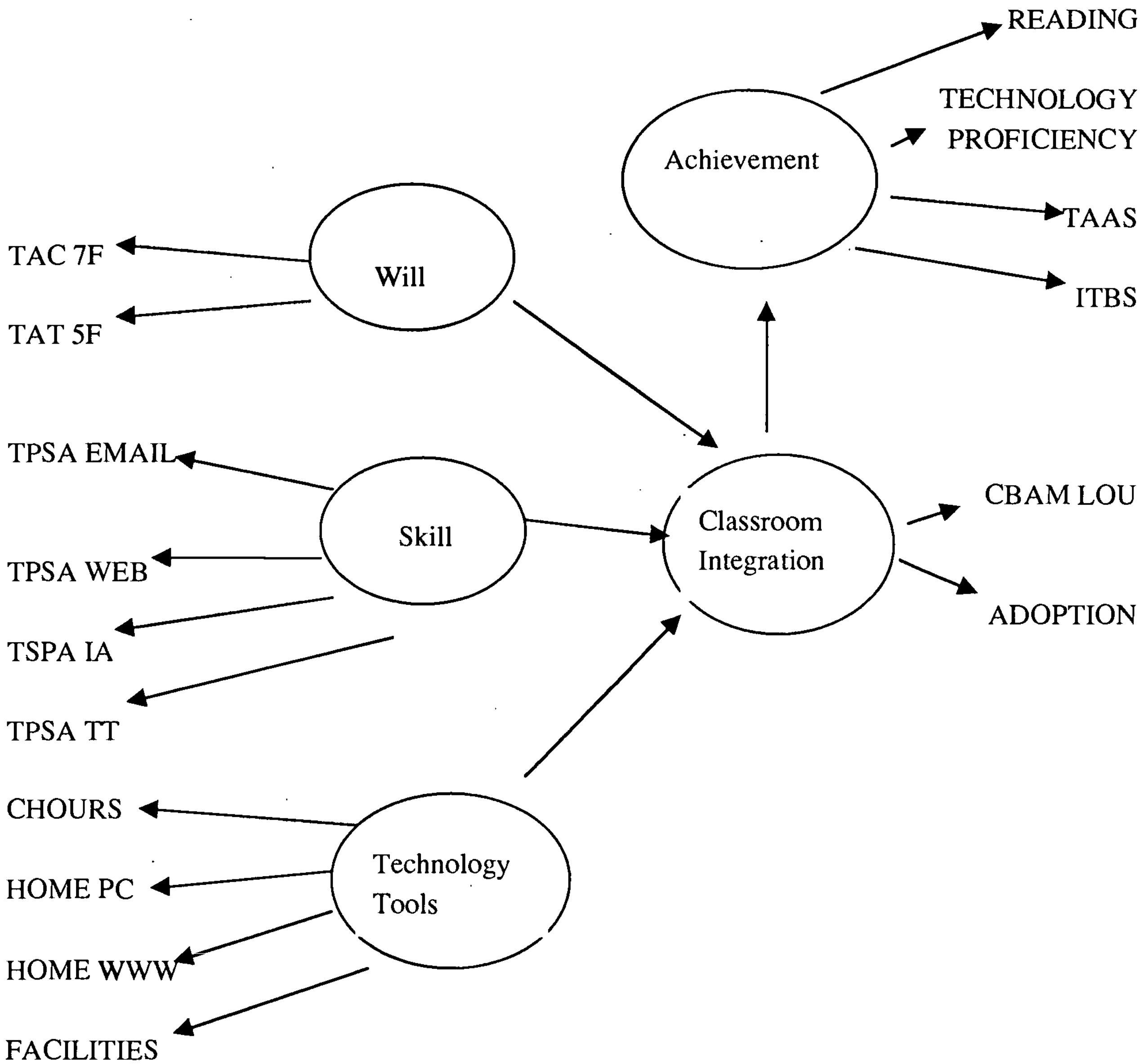

Figure 5: Will, Skill, Tool Model of the Impact of technology integration on achievement

Legend:

TAC = Teachers' Attitudes toward Computers
TAT = Teachers' Attitudes toward Information Technology
TPSA E-mail = Technology Proficiency Self - Assessment E-mail scale
TPSA Web = Technology Proficiency Self - Assessment WWW scale
TPSA IA = Technology Proficiency Self - Assessment Integrated Applications scale
TPSA TT = Technology Proficiency Self - Assessment Teaching with Technology scale
Chours = Current hours per week using the computer in the classroom
Home PC = Home computer access
Home WWW = Home WWW access

Facilities = Equipment and access to technology
Reading = Reading tests such as the Woodcock Reading Mastery Tests
TAAS = Texas Assessment of Academic Skills
ITBS = Iowa Test of Basic Skills
CBAM LoU = Concerns-based Adoption Model Levels of Use

This model was subjected to a preliminary test during the fall of 1999 using data gathered from 39 secondary school teachers (grades 10-12) in the metropolitan school district described above. Each educator completed instruments assessing Stages of Adoption, Level of Use of technology, technology skill proficiency, as well as attitudinal measures (Knezek, Christensen, Hancock, & Shoho, 2000). These instruments are described in the following paragraphs.

The Teachers' Attitudes Toward Computers 5.1 Questionnaire (TAC) (Christensen & Knezek, 1998) measures seven indices regarding teachers' attitudes. These scales are: F1 - Enthusiasm/Enjoyment, F2 - Anxiety, F3 - Avoidance/Acceptance, F4 - Email for Classroom Learning, F5 - Negative Impact on Society, F6 - Productivity, and F7 - Semantic perception of computers. The reliabilities for these scales typically range from .87 to .95 with K-12 teacher data.

Teachers' Attitudes Toward Information Technology Questionnaire (TAT) (Knezek & Christensen, 1998) is a semantic differential instrument that measures attitudes toward new information technologies including email (variable coded as EMAILT), the World Wide Web (WWWT), multimedia (MMT), technology for teacher productivity (PRODT) and technology for classroom learning (PRODCL). Reliabilities for these scales typically range from .91 to .98 for K-12 teachers.

The Technology Proficiency Self-Assessment (TPSA) (Ropp, 1999) measures technology skills in the following areas: E-mail (TPSA EMAIL), Integrated Applications (TPSA IA), use of the World Wide Web (TPSA WWW), and use of Technology in Teaching (TPSA TT).

Two self-reported outcome measures were also included in the battery of instruments. One was the Level of Use Questionnaire (CBAM LOU) based on the Concerns-Based Adoption Model/Level of Use scale for diffusion of innovation (Hall, Soucks, Rutherford, & Newlove, 1975), and the other was the Stage of Adoption of technology in education scale (STAGES) developed by Christensen (1997). Test-retest reliability for a group of K-12 teachers completing the Stage of Adoption form has been calculated to be .96 (Christensen & Knezek, 1999).

Three demographic variables indicating level of access to technology tools were included in the set of data available to researchers, as well. These were teachers' current hours per week using information technology in the classroom (CHOURS), whether or not teachers had access to a computer at home (HOME_PC), and whether or not teachers had access to the World Wide Web at home (HOMEWWW).

Impact of Will, Skill, and Tools on Technology Integration

Impact of Will. Approximately 40% of the variance in stage of adoption was found to be attributable to "will" measures for these teachers. The R-squared for stage of adoption predicted from the TAT attitude scales (EmailT, WWWT, MMT, ProdT, ProdCl) was .39 (Knezek, Christensen, Hancock, & Shoho, 2000).

Impact of Will and Skill Combined. Adding skill measures to the equation increases the predictability of stages of adoption of technology from roughly 40% to 70%. The R-squared for Stages predicted from TAT attitude measures and TPSA skill measures was .69 (Knezek, Christensen, Hancock, & Shoho, 2000).

Combined Impact of Will, Skill and Access to Technology Tools. Adding measures of access to technology tools for teachers increased the predictability of stages of adoption from 70% to 84% for this set of data. The R-squared for TAT attitudes, TPSA skills, and the three tool variables of current hours per week using technology in the classroom (CHOURS), access to a computer at home (HOME_PC) and access to the WWW at home (HOMEWWW), was .84 (Knezek, Christensen, Hancock, & Shoho, 2000).

Impact of Technology Investment on Student Achievement

A second data set was compiled to further test the model introduced above (Knezek, Christensen, Hancock, & Shoho, 2000). This analysis explored the relationship between available variables representing both ends of the technology infusion-to-student-achievement continuum shown in Figure 5. The Texas Assessment of Academic Skills (TAAS) test pass rate, and district wide average SAT score, are used as dependent variables. District-wide hardware expenditures, and district-wide expenditures on software and technology supplies, are the two independent variables used to indicate extent of support for information technology facilities. The data were gathered by randomly selecting 100 of approximately 1046 public school districts in the state and recording their scores from the Texas Academic Excellence Indicator System (AEIS). In order to normalize the distributions of the variables, scores for 1996 and 1997 data were averaged for each district.

SAT Scores

Hardware and software expenditures together accounted for approximately 11% of the variance in SAT scores across the sample of school districts (R squared = .11498). This relationship is significant at the .05 level (f = 3.25, 2 x 50 df, p = .0472). (Knezek, Christensen, Hancock, & Shoho, 2000).

TAAS Pass Rate

Hardware and software expenditures together account for approximately 11% of the variance in TAAS pass rates across school districts (R squared = .11). This relationship was also significant at the .05 level (f = 3.70, 2 x 58 df, p = .0307). (Knezek, Christensen, Hancock, & Shoho, 2000).

Discussion of Findings Regarding Achievement

Only thirty-nine teachers from one school are represented in the data for the portion of the model dealing with stage of adoption predicted as a function of will, skill, and access to technology tools. A much larger sample is needed to test all components of this portion of the model in a formal sense.

Similarly, only 100 school districts were included in the current analysis of the relationship of technology investment to two measures of student achievement. Notable non-normality in this data was accommodated by aggregating measures over two years for each school district, but a better approach might be to compile data from all 1000+ public school districts in the state of Texas, for each of the years 1996-97, and 1997-98. This would enable addressing direction-of-causality questions such as whether software expenditures lead to higher SAT scores, or whether higher SAT scores tend to foster higher spending, by using cross-lagged regression techniques such as Panel Analysis (Markus, 1979).

A comprehensive test of the portion of the model dealing with the impact of classroom technology integration on student achievement probably requires lowering the unit of analysis to the classroom level. Especially at the elementary school level, most public schools keep students with the same teacher all day, and leave students in the same classroom all year. This offers the opportunity to gather an aggregate measure of an entire class, using the class average on some standardized test score such as the Iowa Test of Basic Skills (ITBS), then assess the relationship of that indicator of achievement to known indicators of classroom (teacher) technology integration, such as stages of adoption or CBAM level of use.

Summary and Conclusions

Findings based on student attitude and achievement data from a large metropolitan school district in northern Texas during1999-2000, and technology expenditure plus achievement data from a random sample of 100 of the 1000 school districts in Texas, are consistent with reputable literature in the field. The predominant thinking is that several years of classroom computer use may be required to produce measurable results on standardized achievement tests.

Evidence gathered through several different methods indicates that high technology-integrating teachers are necessary for information technology utilization by students to have a positive impact on the students' perceptions of computers and related learning dispositions in school. The most observable immediate impact of appropriate technology utilization may be to more strongly engage the student in the teaching/learning process, thereby slowing the general decline in positive learner dispositions that traditionally takes place throughout the school year.

Research cited in this paper indicates that not every educator is best served by training aimed at some arbitrary level, and that different levels of integration may require different techniques. Teacher professional development could become more targeted/focused if instruments like those presented by the authors were used to pretest an entire campus before training began.

Additional evidence is cited that an increase in skill level can bring teachers to the point of technology proficiency (stage 5), but that a change in will is required before educators begin to creatively adapt their use of technology to a school environment. A new model is proposed in which will, skill, and access to technology tools are all claimed to be important for full integration of technology in the classroom learning environment, and full integration, in turn should lead to measurable positive impact on student achievement. Preliminary tests of the model indicate that it is sufficiently accurate to warrant further testing in a large-sample learning environment.

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Appendix A

Name: ______________________________ Date: _____________

Stages of Adoption of Technology

Instructions: Please read the descriptions of each of the six stages related to adoption of technology. Circle the stage that best describes where you are in the adoption of technology.

Stage 1: Awareness

I am aware that technology exists but have not used it - perhaps I'm even avoiding it.

Stage 2: Learning the process

I am currently trying to learn the basics. I am often frustrated using computers. I lack confidence when using computers.

Stage 3: Understanding and application of the process

I am beginning to understand the process of using technology and can think of specific tasks in which it might be useful.

Stage 4: Familiarity and confidence

I am gaining a sense of confidence in using the computer for specific tasks.
I am starting to feel comfortable using the computer.

Stage 5: Adaptation to other contexts

I think about the computer as a tool to help me and am no longer concerned about it as technology. I can use it in many applications and as an instructional aid.

Stage 6: Creative application to new contexts

I can apply what I know about technology in the classroom. I am able to use it as an instructional tool and integrate it into the curriculum.

From: Christensen, R. (1997). Effect of technology integration education on the attitudes of teachers and their students. Doctoral dissertation, Univ. of North Texas. Based on Russell, A. L. (1995) Stages in learning new technology. Computers in Education, 25(4), 173-178.

Appendix B

Concerns-Based Adoption Model (CBAM)
Levels of Use of an Innovation

Level 0 Non-use

I have little or no knowledge of information technology in education, no involvement with it, and I am doing nothing toward becoming involved.

Level 1 Orientation

I am seeking or acquiring information about information technology in education.

Level 2 Preparation

I am preparing for the first use of information technology in education.

Level 3 Mechanical Use

I focus most effort on the short-term, day-to-day use of information technology with little time for reflection. My effort is primarily directed toward mastering tasks required to use the information technology.

Level 4 A Routine

I feel comfortable using information technology in education. However, I am putting forth little effort and thought to improve information technology in education or its consequences.

Level 4 B Refinement

I vary the use of information technology in education to increase the expected benefits within the classroom. I am working on using information technology to maximize the effects with my students.

Level 5 Integration

I am combining my own efforts with related activities of other teachers and colleagues to achieve impact in the classroom.

Level 6 Renewal

I reevaluate the quality of use of information technology in education, seek major modifications of, or alternatives to, present innovation to achieve increased impact, examine new developments in the field, and explore new goals for myself and my school or district.

I best fit into Level ______.

Hall, G. E., & Rutherford, W. L. (1974). *Concerns Questionnaire. Procedures for Adopting Educational Innovations/CBAM Project.* R&D Center for Teacher Education, University of Texas at Austin.

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