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Evaluating the Implementation Fidelity of Technology Immersion and its Relationship with Student Achievement

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Special Edition:
Educational Outcomes and Research from 1:1 Computing Settings

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This special issue of the Journal of Technology, Learning, and Assessment focuses on the educational impacts and outcomes of 1:1 computing initiatives and technology-rich K–12 environments. Despite growing interest in and around 1:1 computing, little published research has focused on teaching and learning in these intensive computing environments. This special issue provides a forum for researchers to present empirical evidence on the effectiveness of 1:1 computing models for improving teacher and student outcomes, and to discuss the methodological challenges and solutions for assessing the effectiveness of these emerging technology-rich educational settings.

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Evaluating the Implementation Fidelity of Technology Immersion and its Relationship with Student Achievement

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Abstract:

In a pilot study of the Technology Immersion model, high-need middle schools were "immersed" in technology by providing a laptop for each student and teacher, wireless Internet access, curricular and assessment resources, professional development, and technical and pedagogical support. This article examines the fidelity of model implementation and associations between implementation indicators and student achievement. Results across three years for 21 immersion schools show that the average levels of school support for Technology Immersion and teachers' Classroom Immersion increased slightly, while the level of Student Access and Use declined. Implementation quality varied across schools and classrooms, with a quarter or fewer of schools and core-content classrooms reaching *substantial* implementation. Using hierarchical linear modeling, we found that teacher-level implementation components (Immersion Support, Classroom Immersion) were inconsistent and mostly not statistically significant predictors of student achievement, whereas students' use of laptops outside of school for homework and learning games was the strongest implementation predictor of achievement.

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Evaluating the Implementation Fidelity of Technology Immersion and its Relationship with Student Achievement

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Introduction

The Technology Immersion Pilot (TIP), created by the Texas Legislature in 2003, assumed that the use of technology in Texas public schools could be achieved more effectively by "immersing" schools in technology rather than by introducing technology resources in a cyclical fashion over time. The Texas Education Agency (TEA) has invested more than $20 million in federal Title II, Part D monies to fund Technology Immersion projects at high-need middle schools through a competitive grant process (i.e., a laptop computer for every student and teacher, wireless access throughout the campus, curricular and assessment resources, professional development, and ongoing technical and pedagogical support). Concurrently, a comprehensive, four-year research study partially funded by a federal Evaluating State Educational Technology Programs grant has investigated the effects of Technology Immersion on teachers and teaching, students and learning, and student achievement. The study's quasi-experimental research design included comparisons between 21 treatment schools and 21 control schools that enrolled Grades 6 to 8 students. The study also has examined the extent to which the Technology Immersion model was implemented as designed. The present article focuses on the 21 treatment schools' progress in implementing Technology Immersion and the associations between the strength of implementation and students' reading and mathematics test scores.

Technology Immersion Model

State statute (Senate Bill 396, 78^{th} Texas Legislature) described Technology Immersion generally, but to advance consistent interpretation of the Technology Immersion model at schools, the TEA issued a Request for Qualifications for commercial vendors to apply to become providers of Technology Immersion packages. Vendors' plans had to include six components: (a) a wireless mobile computing device for each educator and student on an immersed campus; (b) productivity, communication, and presentation software; (c) online instructional resources supporting the state curriculum in language arts, mathematics, science, and social studies; (d) online assessments to diagnose students' mastery of the core curriculum; (e) professional development designed to help teachers integrate technology into teaching, learning, and the curriculum; and (f) initial and ongoing technical support. Through an expert review process, the TEA selected three lead vendors to provide Technology Immersion packages (Dell Computer Inc., Apple Computer Inc., and Region 1 Education Service Center [ESC]). Package costs, which ranged from about $1,100 to $1,600 per student, varied according to the numbers of students and teachers, the type of laptop computer, and the vendor provider.

Of the 21 Technology Immersion schools studied in the evaluation, 5 middle schools selected the Apple package, 15 selected the Dell package, and 1 school selected the Region 1 ESC package (with Dell computers). Table 1 provides an overview of the basic components within each package and the individual vendors that provided various products. All vendors offered a wireless laptop as the mobile computing device (Apple or Dell), and all laptops had a suite of productivity tools (either *AppleWorks* or *Microsoft Office*). Dell computers also had a web-based portal to applications and resources (*eChalk*). Immersion packages included a variety of digital curricular resources and formative assessments. Additionally, each vendor provided professional development as well as ongoing technical support. Apple had its own professional development model. Dell relied on a commercial provider (*Pearson Learning Group*) and the *Dell Exchange* (an online resource). Region 1 ESC used a combination of service center support plus services offered through *Connected Coaching* and *Connected University*. See Appendix A for a more comprehensive description of the package components.

Table 1: Technology Immersion Packages

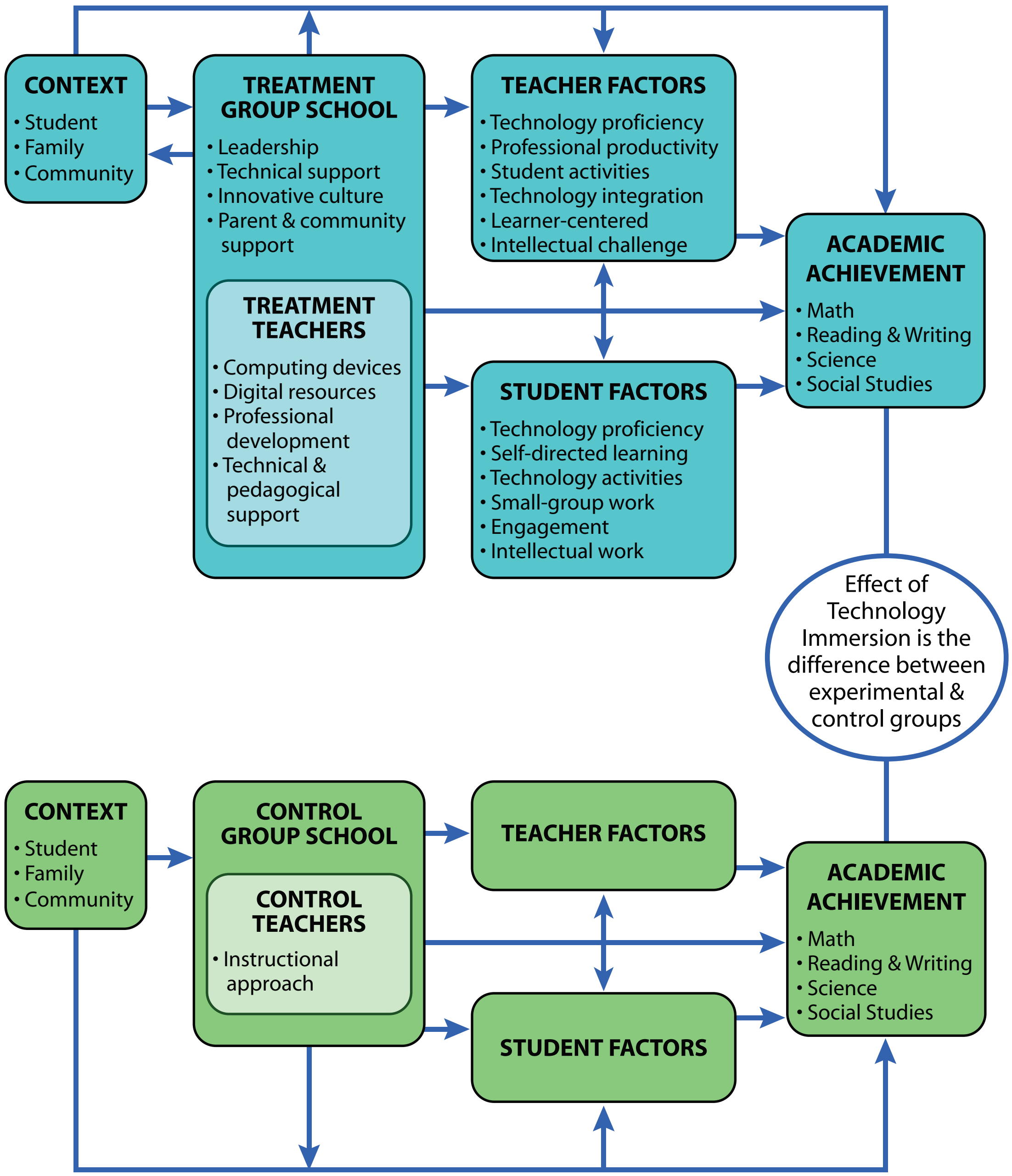
Component	Apple Computer *N* = 5 Schools 1,625 Students	Dell Computer *N* = 15 Schools 5,993 Students	Region 1 ESC *N* = 1 School 100 Students
Wireless laptop computer	Apple iBook G4	Dell Inspiron or Latitude	Dell Inspiron
Productivity software	Apple Works	Microsoft Office, eChalk	Microsoft Office, eChalk
Online resources	Various	Various	Various
Online assessment	AssessmentMaster	i-Know	i-Know
Professional development	Apple model	Pearson Learning Group, Dell Exchange	ESC 1, Classroom Connect
Technical and pedagogical support	Apple, Campus/District	Dell, Campus/District	ESC 1, Campus/District

Note. ESC = Education Service Center. Student enrollment in middle schools (Grades 6, 7, and 8) from Texas Education Agency AEIS reports 2005.

During the third and fourth implementation years, schools began to selectively purchase online resources and assessments according to their perceived needs. For example, some schools dropped the online assessments because they had state-provided or local assessments that filled their testing needs. Two schools (with Dell and ESC 1 packages) purchased the *My Access Writing* program included in the Apple package. Schools and teachers also continued to supplement package resources with products purchased locally, provided through state textbook adoptions, or obtained from the Internet free of charge.

The *Theoretical Framework for Technology Immersion* guided the evaluation (Figure 1). The framework postulates a linear sequence of causal relationships. First, treatment schools are to be "immersed" in technology through the implementation of Technology Immersion components. An improved school environment for technology is expected to produce teachers who are more technically proficient, use technology for professional productivity, have students use technology in their classes, and use laptops and digital resources to increase the intellectual rigor of lessons. In turn, changed school and classroom conditions are expected to improve students' technology proficiency, learning experiences, collaborative interactions with peers, personal self-direction, and engagement in school and learning. Changes in students and their learning experiences presumably contribute to increased academic performance as measured by standardized test scores. In the framework, prior student achievement and student, family, and school characteristics exert their own influence on learning.

Figure 1 Theoretical Framework for Technology Immersion



Prior Research on Implementation

Beginning in the 1970s, researchers and educators began to recognize the consequences of failed implementation (Fullan, 1993). Studies of large-scale educational reforms and organizational change revealed that the level and quality of implementation largely determined the achievement of desired outcomes (Berman & McLaughlin, 1978; Borman, Hewes, Overman, & Brown, 2003; Datnow, Borman, & Stringfield, 2000; Fullan & Stieglbauer, 1991). Studies of technology innovations, likewise, have shown that ineffective implementation undermines prospects for changes in student learning opportunities and academic outcomes (Cuban, 2001). Given mounting evidence, Desimone stressed the importance of measuring "the degree of implementation before assessing outcomes and attempting to attribute them to a specific program" (Desimone, 2002, p. 437).

Recent school change efforts have focused on transforming the whole school as a way to improve teaching, learning, and student outcomes. Increasing numbers of schools, particularly low performing ones, have undertaken comprehensive school reform. Spurred by the availability of federal funds and the No Child Left Behind Act of 2001, hundreds of comprehensive school reform (CSR) models have been developed and implemented in schools. As a result, the nature of model implementation and the school change process have been studied widely. Although Technology Immersion and CSR models are not exactly the same, they share the common focus of changing the whole school, including changes to the curriculum and delivery of instruction. Thus, past research contributes to a clearer understanding of implementation for this study.

In-depth studies of CSR model implementation demonstrate that achieving quality implementation is challenging. Studies involving hundreds of CSR schools revealed that none of the schools had fully implemented all components of the models they had adopted. Schools appeared to implement components selectively (Kurki, Aladjem, & Carter, 2005). And notably, schools had more difficulty following instructional practices prescribed by their model and practices aimed at increasing parental involvement in school affairs (Vernez, Karam, Mariano, & DeMartini, 2006). In these studies, higher levels of implementation were associated with higher levels of support (e.g., principal leadership, teachers' commitment, model developer support, professional development). Findings regarding the influence of contextual variables (school size or student characteristics) were mixed as were results regarding the improvement of implementation over time. Kurki et al. (2005) cited increased implementation for most indicators between the first and third year, whereas Vernez et al. (2006) found that the first year or so, for the most part, determined the degree of implementation, with levels remaining fairly constant across three years.

Evidence from a meta-analysis of CSR student achievement effects shows that the quality of implementation matters. Using the best available measure of implementation—the number of years a CSR model was implemented in a school—researchers found an increasing effect on achievement outcomes associated with a greater number of years of implementation. The CSR effect size was relatively strong in the first year (0.17), but there was a tendency for new initiatives to weaken in the second, third, and fourth years. On the other hand, schools that implemented models for five or more years showed achievement advantages nearly twice as large (Borman et al., 2003; Borman, 2005). These long-term effects, however, may be positively biased by the large proportions of schools (up to one third) that discontinued use of CSR models within the first few years, and consequently, were excluded from longitudinal analyses (Borman, 2005).

Researchers who have studied one-to-one laptop initiatives have also examined the quality of implementation and factors that affect program success. Although the goals and scale of one-to-one laptop projects vary widely, there is growing consensus that effective implementation requires a comprehensive or systemic approach that includes attention to aspects such as leadership and planning, supportive school culture, training and professional development, robust infrastructures and technical support, and access to digital content and instructional resources (Zucker, 2005). Specifically, committed leadership (at the state, district, school, and classroom levels) has been associated with stronger implementation. Effective leaders articulate a compelling vision of how laptops advance teaching and learning, develop policies and procedures that support change, foster collaborative environments, and marshal needed resources (Bradburn & Osborne, 2007; Pitler, 2005; Zucker, 2005; Zucker & McGhee, 2005).

Teachers' attitudes and beliefs about technology can also affect implementation (Penuel, 2006). Several studies report that the use of technology in a one-to-one classroom reflects teachers' beliefs about their students and the potential of technology for learning, as well as their conception of what constitutes effective teaching (Garthwait & Weller, 2005; McGrail, 2006; Russell, Bebell, Cowan, & Corbelli, 2002; Windschitl & Sahl, 2002). One study cited factors that diminished teachers' commitment to one-to-one computing, including top-down institutional decision making about the program, conflicts between technology use and test-preparation pressures, and conflicts about the fit of technology with the curriculum (McGrail, 2006).

Given teachers' important role in implementation, high-quality sustained professional development is a critically important factor. Studies cite the need for teacher professional development that builds teachers' basic technology skills as well as their understanding of curricular integration (Lowther, Ross, & Morrison, 2001; Ringstaff & Kelley, 2002; Owen, Farsaii, Knezek, & Christensen, 2005–06). Teachers also need follow-up support as they acquire and implement new skills in the instructional setting (Bradburn & Osborne, 2007; Neugent & Fox, 2007; Owen et al., 2005–06). Informal assistance from colleagues may also advance implementation, with teachers helping each other solve technical problems and sharing ideas about lessons (Silvernail & Harris, 2003; Windschitl & Sahl, 2002). Projects that reportedly have influenced teachers' beliefs about the value of laptops provided professional development that gave teachers a framework to develop problem-based lessons (Lowther et al., 2003), required teachers to engage in projects with students (Light, McDermott, & Honey, 2002), and provided resources that supported teachers' particular content area (Lane, 2003). Readily available technical support and dependable wireless networks also have been linked with implementation success (Lane, 2003; Silvernail & Harris, 2003; Silvernail & Lane, 2004; Zucker & McGhee, 2005). As a whole, findings point to the crucial need for researchers to measure the extent of implementation in evaluating the effectiveness of one-to-one laptop interventions.

Purpose of the Current Study

The research presented in this article represents one part of the overall evaluation of Technology Immersion. For the current study, we focused on the implementation aspect of the theoretical framework (i.e., the fidelity with which the components of Technology Immersion attained the model's envisioned ideal). In particular, we investigated the extent to which each of the 21 treatment schools implemented the Technology Immersion model as designed and assessed each school's progress across three implementation years. Additionally, given variations in implementation, we investigated the relationship between implementation strength (at the school, teacher, and student levels) and students' reading and mathematics achievement as measured by scores on the state's criterion-referenced assessment—the Texas Assessment of Knowledge and Skills (TAKS).

Method

Participants

Schools

In spring 2004, interested districts and associated middle schools responded to a Request for Application (RFA) offered by the TEA to become Technology Immersion schools. Applicants had to meet eligibility requirements for Title II, Part D funds (i.e., high need due to children from families with incomes below the poverty line, schools identified for improvement, or schools with substantial need for technology). The agency held an external review of proposals, with applications scored and rank ordered. Following the external review, researchers and agency staff reviewed proposals to ensure that applications met criteria established for Technology Immersion. Final selection of schools involved the consideration of several factors, including proposal ratings, size, location, student diversity, and academic achievement. Decisions were influenced by the need for geographic distribution and the availability of comparable schools for the control group pool. Schools received grants to support the implementation of Technology immersion for four school years (2004–05, 2005–06, 2006–07, and 2007–08). Twenty-one middle schools with Grades 6 to 8 students (treatment group) were drawn from rural, suburban, and urban locations across Texas. Middle schools were typically small, with more than three-quarters enrolling 600 students or fewer. The majority of schools were concentrated in small or very small school districts (2,999 or fewer students), but a third of schools were in large districts (10,000 or more students).

Teachers and Students

As Table 2 shows, nearly 600 teachers worked at Technology Immersion schools each year. Across four years, middle-school teachers were primarily female (about 66%), White (about 55%) or Hispanic (about 40%), and they were fairly experienced (about 11 years teaching, on average). About a fifth of teachers had advanced degrees.

Table 2: Demographic Characteristics of Teachers at Technology Immersion Schools by Year

	2004–05 Year 1	2005–06 Year 2	2006–07 Year 3	2007–08 Year 4
Number of teachers	593.0	604.0	591.0	612.0
% Female	65.6	63.4	66.5	66.3
% Minority	41.2	44.9	43.1	45.9
% African American	3.4	2.8	3.2	4.4
% Hispanic	35.3	40.4	39.9	39.3
% White	58.7	55.1	55.2	54.1
% with no degree	0.9	0.2	0.2	0.3
% with advanced degree	21.3	21.2	19.3	19.2
Average years experience	10.6	10.6	10.8	11.5

Note. Year 1 was the start-up year. Researchers developed implementation fidelity measures during that year. Statistics from Texas Education Agency AEIS reports.

Statistics in Table 3 show that most of the Technology Immersion students were economically disadvantaged (more than three-quarters qualifying for federal free or reduced-price lunches), and they were ethnically diverse (about 75% Hispanic, 19% White, and 5% African American). More than a fifth of students were limited English proficient (LEP). This study concentrates on three groups or cohorts of students. Cohort 1 students (8th graders in 2006-07) attended Technology Immersion schools across the first three project years (Grades 6, 7, and 8) and then enrolled at local high schools in the fourth year. Cohort 2 students (8th graders in 2007-08) attended immersion schools for three years (Grades 6, 7, and 8), and Cohort 3 students (7th graders in 2007-08) attended immersion schools for two years (Grades 6 and 7). A fourth group of sixth graders are included in implementation measures for Year 4 (2007-08).

Table 3: Demographic Characteristics of Technology Immersion Students by Cohort

	Cohort 1 8th Graders 2006–07	Cohort 2 8th Graders 2007–08	Cohort 3 7th Graders 2007–08
Number of students	2,586.0	2,578.0	2,547.0
% Economically disadvantaged	75.8	75.5	76.7
% African American	5.8	5.1	4.3
% Hispanic	72.7	75.1	75.9
% White	20.4	18.8	19.2
% Lmited English Proficient	22.7	20.8	26.3
% Female	48.6	49.7	48.4
% Male	51.4	50.3	51.6

Note. Statistics from school-provided files for the 2006–07 and 2007–08 school years.

Data Collection

Data collection for the study began in August 2004 and continued through spring 2008. This analysis focuses on the second (2005–06), third (2006–07), and fourth (2007–08) implementation years. Measures included teacher and student surveys completed at the end of each school year (April to May), and students' TAKS scores from annual administrations in April. The technology survey response rates for teachers and students are summarized in Table 4. Survey response rates for teachers ranged from 87% to 94% across years. Student survey response rates ranged from 82% to 89% across years for students who were members of Cohorts 1, 2, and 3, and from 82% to 87% for all students completing surveys.

Table 4: **Teacher and Student Technology Survey Respondents and Response Rates by Year**

	Teachers		Students: Cohort 1		Students: Cohort 2		Students: Cohort 3		Students: All	
Spring	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**
2006	560	92	2,291	87	2,379	89			7,022	87
2007	619	94	2,168	84	2,228	84	2,220	85	7,832	85
2008	534	87			2,110	82	2,130	84	7,680	85

Note. Teacher respondents in 2006, 2007, and 2008 included 318, 371, and 337 core-subject teachers, respectively (English language arts/reading, mathematics, social studies, and science teachers).

Table 5 displays five survey response-rate categories, and the number of schools that had teacher or student survey response rates that fell within the percentage ranges. Across years, nearly all of the 21 schools had survey response rates between 80% and 100%. In 2006 and 2007, a few schools had response rates between 60% and 79%. In 2008, the number of schools with survey response rates in the 50% to 59% and 60% to 69% ranges increased. As might be expected, lower implementing schools tended to have lower survey response rates.

Table 5: **Number of Schools within Response-Rate Categories by Teachers, Students, and Survey Year**

	Teachers			Students		
Survey response rate	**2006**	**2007**	**2008**	**2006**	**2007[a]**	**2008**
90–100%	12	18	12	10	12	13
80–89%	6	3	3	9	4	5
70–79%	2	0	2	2	3	0
60–69%	1	0	2	0	0	2
50–59%	0	0	2	0	0	1

Note. N = 21 Technology Immersion schools.
[a] In spring 2007, two schools did not return student surveys. Researchers used model-based imputation (AMOS 7.0) to predict a student's 2007 scale score from the spring 2006 score, gender, ethnicity, and economic status.

Teacher Questionnaire

Teachers completed an online technology survey that included items related to school technology, technology use, and professional development activities. Across three years, 560, 619, and 534 teachers, respectively, completing surveys. For school technology, teachers rated their strength of agreement with statements on a 5-point scale ranging from 1 *(strongly disagree)* to 5 *(strongly agree)* for four factors: Leadership (12 items), Technical Support (5 items), Innovative Culture (4 items), and Parent and Community Support (2 items). Cronbach's alpha measures of internal consistency for school-level factors ranged from 0.66 to 0.97 (see Appendix B). Teachers also completed items describing their professional development experiences (Contact Hours, Classroom Support, Content Focus, and Coherence), which were aggregated at the school level. Alpha scale reliabilities ranged from 0.67 to 0.92.

Surveys also included measures of individual teacher variables. Items pertained to teachers' perceptions of Professional Productivity (11 items), Communication (4 items), Student Classroom Activities (17 items), Technology Integration (10 items), and Learner-Centered Instruction (4 items). Cronbach's alpha reliability coefficients for scales ranged from 0.74 to 0.98. For Professional Productivity, Communication, and Student Classroom Activities, teachers used a 5-point scale to rate the frequency of activities or interactions: 0 *(never)*, 1 *(rarely–e.g., a few times a year)*, 2 *(sometimes–e.g., once or twice a month)*, 3 *(often–e.g., once or twice a week)*, and 4 *(almost daily)*. Measures of teachers' ideology—Technology Integration and Learner-Centered Instruction—involved a 7-point scale ranging from 0 *(not true of me now)* to 6 *(very true of me now)*.

Student Technology Survey

Grades 6 through 8 students at treatment schools completed paper-and-pencil surveys in spring 2006 (N =7,022), spring 2007 (N = 6,634), and spring 2008 (N = 6,327). These responses, which were used to generate school-level measures of implementation fidelity, included both cohort and non-cohort group students. The individual responses of students in Cohorts 1, 2, and 3 were used in analyses of the association between implementation and academic achievement. Student survey items measured (a) the extent of students' laptop access (items used to calculate the number of days out of the 180 day school year that a laptop was available), (b) the frequency of laptop use for Core-Content Learning (a 5-point scale used to rate the frequency of activities or interactions in English language arts/reading, math, science, and social studies classes: 0 *(never)*, 1 *(rarely–e.g., a few times a year)*, 2 *(sometimes–e.g., once or twice a month)*, 3 *(often–e.g., once or twice a week)*, and 4 *(almost daily)*, and (c) the extent of laptop use at home (0 = no home laptop access, 1 = home laptop access, and up to 5 additional points for laptop use for homework in language arts (reading/writing), social studies, science, math, and/or for playing games to learn). The Cronbach's alpha reliability coefficient for the Core-Content Learning scale was 0.73.

Academic Achievement

The academic outcome measures were TAKS reading and mathematics scores. The TAKS is a criterion-referenced assessment that annually measures students' mastery of the state's content standards. Reading is assessed at Grades 3 to 9 and mathematics at Grades 3 to 11. The TAKS was first administered in spring 2003. The TEA developed the objectives for the assessment program with input and feedback from educators and the general public. Test items were developed by test contractors Harcourt Assessment and Pearson. A technical advisory committee composed of nationally recognized educational testing experts was assembled to provide advice for setting performance standards. Internal consistency reliabilities for assessments are in the high 0.80s to low 0.90s range. Evidence also supports the content, construct, and criterion-related validity of TAKS assessments. Additional information about the technical quality of TAKS tests is available in Technical Digests on the TEA website at http://www.tea.state.tx.us/index3.aspx?id=4326&menu_id3=793.

The TAKS scale score has a passing standard set at 2100 for each grade level. Because scores are not equated across grades, we used TAKS scale scores to calculate standardized scores that could be used to measure student progress across grade levels. The standard score is a *T* score with a mean of 50 (state average) and a standard deviation of 10. The achievement analyses reported for this study used students' individual TAKS *T* scores for reading and mathematics as the dependent variables, and each student's TAKS reading or mathematics *T* score for the previous school year was used to account for prior academic achievement. Analyses were conducted separately for students in Cohorts 1, 2, and 3 who were continuously enrolled in treatment schools across implementation years.

Measuring Implementation Fidelity

Implementation was measured as the fidelity with which Technology Immersion *components* and related *elements* attained the envisioned "ideal." This approach involved gathering data on immersion components at each of the treatment schools and comparing school-to-school variations with the vision for "full" implementation. The seven immersion components (see Table 6 and Appendix B) included five supports for implementation (Leadership, Teacher Support, Parent and Community Support, Technical Support, and Professional Development) and two components related to teacher and student implementation outcomes (Classroom Immersion and Student Access and Use). We used a two-part measurement approach. First, we used indicators to describe each school's progress on a 4-stage scale toward immersion standards. Rating scales for components and related elements identified four levels of immersion: *minimal* (0 to 1.99), *partial* (2.00 to 2.99), *substantial* (3.00 to 3.49), and *full* (3.50 to 4.00). The scoring criteria for the four cut-points were articulated in scoring rubrics developed by researchers who had observed treatment schools' implementation progress during site visits that involved interviews, focus groups, building walkthroughs, and classroom observations. Researchers conducted site visits at baseline (fall 2004) and at the end of each implementation year (2005 through 2008). Scoring rubrics guided the assignment of second-year implementation ratings for each of the 21 treatment schools. Next, the scoring rubrics and second-year implementation ratings for schools were reviewed collectively by researchers, TEA staff and agency liaisons who were assigned to individual schools, and vendor representatives who had first-hand knowledge of their schools' progress. These expert judges generally agreed that schools had been accurately placed in low-to-high implementation categories. Their comments and suggestions for scoring were incorporated into revised versions of the scoring rubrics (see Appendix C).

As a second implementation measure, we used quantitative implementation indices to gauge the level of Technology Immersion using standardized scores (*z* scores). *Z* scores allowed the calculation of composite scores across indicators with varying scales and standard deviations. Table 6 provides descriptions of the Technology Immersion indicators. The data sources used for calculating implementation indicators are detailed in Appendix B. Explicitly defined procedures ensured consistent measurement of implementation indicators from year to year.

Table 6: Description of Implementation Indicators for Technology Immersion

Support for Technology Immersion	
Leadership	To what extent do teachers indicate that administrators establish a clear vision and expectations, encourage integration, provide supports, and involve staff in making decisions about instructional technology.
Teacher Support	To what extent do teachers share an understanding about technology use, do teachers continually learn and seek new ideas, are teachers unafraid to learn about and use technologies, and are teachers supportive of integration efforts.
Parent and Community Support	To what extent do teachers believe that parents and the surrounding community support the school's efforts with technology.
Technical Support	To what extent do teachers indicate that technical problems with computers, Internet access, repairs, and material availability pose barriers to Technology Immersion.
Professional Development	*Contact Hours* To what extent does the duration (hours) of technology-related professional development (PD) support the integration of technology into teaching, learning, and the curriculum.
	Classroom Support To what extent do core-subject teachers receive coaching or mentoring from an internal source, such as another teacher or technology coordinator, or an external (non-school) source.
	Content Focus To what extent do core-subject teachers indicate that PD emphasizes curriculum, instructional methods, and lesson development in core subjects.
	Coherence To what extent do core-subject teachers indicate that PD is consistent with personal and school goals, builds on prior learning, and supports state standards and assessments.
Classroom Immersion	
Technology Integration To what extent do core teachers alter instructional practices, allocate time, integrate research on teaching and learning, improve basic skills, and support higher order thinking through technology.	
Learner-Centered Instruction To what extent do teachers have students establish learning goals, use information and inquiry skills, complete alternative assessments, and have active and relevant learning experiences.	
Student Classroom Activities To what extent do teachers have students use particular technology resources for learning in core-subject classes, such as a word processor for writing, a spreadsheet for calculation or graphing, or the Internet for research.	
Communication To what extent do teachers use technology to communicate with students, parents, and colleagues or to post information on a class website.	
Professional Productivity To what extent do teachers use technology to enhance their professional productivity (e.g., keep records, analyze data, develop lessons, deliver information).	
Student Access and Use	
Laptop Access To what extent do students have access to wireless laptops throughout the school year.	
Core-Subject Learning How frequently do students use technology resources for learning in core-subject classes.	
Home Learning To what extent do students have access to and use laptops outside of the school for homework and learning.	

Note. See Appendix B for a technical description of the measurement of implementation indicators.

Scores for Immersion Standards

We used teacher and student survey data to compute implementation scores for indicators that measured progress toward immersion standards (i.e., minimal to full implementation). Adapting a process developed by the RAND Corporation,[1] the value for each indicator was computed relative to the maximum value (4.00—the value assigned to full implementation). Standardization based on the maximum value allowed comparisons across different types of indicators. For each component and element of Technology Immersion, standardization involved the following computations:

- *Agreement scales* (i.e., strongly agree or strongly disagree with a prescribed practice or behavior): 4 = strongly agree, 3 = agree, 2 = neither agree nor disagree, 1 = disagree, and 0 = strongly disagree.
- *Frequency scales* (i.e., four- or five-level frequencies of doing a prescribed practice): 4 = highest frequency met, 3 or 2.67 = second highest frequency, 2 or 1.33 = third-highest frequency, 1 = fourth-highest frequency, and 0 = never or do not do.
- *Continuous variables* (i.e., how much time or how often a prescribed practice is done): 4 = meet or exceed requirements, and 0-3.99 = proportional fraction of requirement.

We computed the following immersion standard scores on the 0 to 4 scale.

- A mean immersion standard score for each Technology Immersion support component at each school (e.g., Leadership was an average score for 12 items based on the responses of *all* teachers in a school who completed the survey; Professional Development was a mean score for core-subject teachers at a school based on their average scores for Contact Hours, Classroom Support, Content Focus, and Coherence);
- a mean Classroom Immersion score for each school's core-subject teachers (Classroom Immersion was an average score for Technology Integration, Learner-Centered Instruction, Student Classroom Activities, Communication, and Professional Productivity); and
- a mean Student Access and Use score for Grades 6, 7, and 8 students (Student Access and Use was an average score for Laptop Access Days, Core-Content Learning, and Home Learning).

Scores for Implementation Indices

In addition to the standards-based scoring system described above, we used teacher and student survey data to compute standardized implementation indicators (*z* scores) that could be aggregated to generate:

- a single implementation score for each Technology Immersion component for each school (e.g., Leadership Index was an average z score for 12 items based on the responses of *all* teachers in a school who completed the survey).
- a mean Immersion Support *z* score for the five support components (Immersion Support Index was an average of Leadership Index, Teacher Support Index, Parent and Community Support Index, Technical Support Index, and Professional Development Index);
- a mean Classroom Immersion *z* score for core-subject teachers in a school (Classroom Immersion was an average of Technology Integration, Learner-Centered Instruction, Student Classroom Activities, Communication, and Professional Productivity);
- a mean Student Access and Use *z* score (Student Access and Use was an average of Laptop Access, Core-Content Learning, and Home Learning); and
- an overall mean implementation *z* score for each school (Implementation Index was an average of Support Index, Classroom Immersion Index, and Student Access and Use Index).

Data Analyses

This study combined three analytic approaches to examine the implementation of Technology Immersion at the 21 treatment schools. First, we used descriptive statistics (mean standard scores, percentages of schools at implementation levels) to describe how the Technology Immersion model and its component parts were implemented. Second, we used implementation indices (mean *z* scores) to create school profiles and to examine associations between implementation components. Finally, we used two-level hierarchical linear models (with individual students nested within their reading and mathematics teachers) to investigate associations between treatment fidelity indicators (*z* scores) and student academic outcomes.

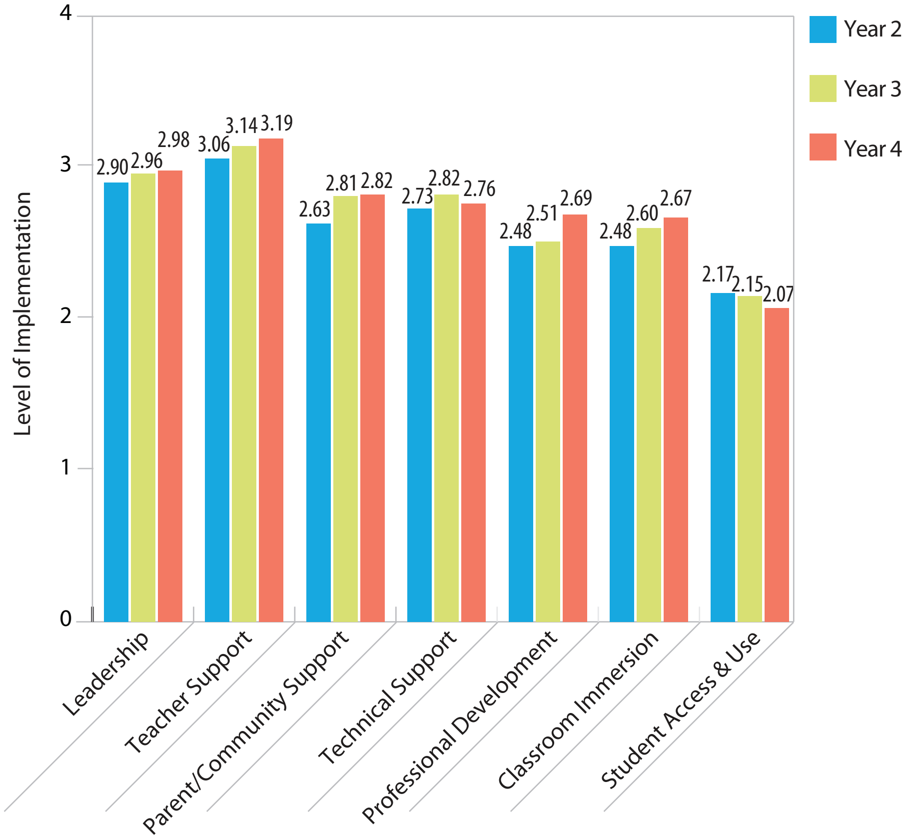
Results

In sections to follow, we first present results for implementation standards (measured at four levels) that describe the extent to which the Technology Immersion model's support components and instructional and learning components were implemented as designed. These scores showed whether middle schools attained the standards that represented what a substantially or fully immersed campus should achieve. Next, findings for implementation indices (z scores) provide an overall measure of the level of Technology Immersion (Implementation Index) and compare the relative level of implementation for individual components across schools. Finally, we present analyses of associations between implementation fidelity and student academic achievement.

Implementation of Technology Immersion—Implementation Standard Scores

As explained previously, progress toward Technology Immersion standards was measured at four levels (*minimal*, 0-1.99; *partial*, 2.00-2.99; *substantial*, 3.00-3.49; and *full immersion*, 3.50-4.00). Five components assessed the strength of supports for Technology Immersion (Leadership, Teacher Support, Parent/Community Support, Technical Support, Professional Development), whereas one component gauged the extent of teachers' Classroom Immersion and another component measured Student Access and Use (of technology). Figure 2 displays the mean implementation scores by component and project year. Mean standard scores for components generally showed small increases across years, with the exception of Technical Support (which remained fairly stable: 2.73, 2.82, and 2.76) and Student Access and Use (which declined each year: 2.17, 2.15, and 2.07). Fourth-year mean implementation support scores ranging from 2.69 (Professional Development) to 3.19 (Teacher Support) showed that supports for immersion from school administrators, teachers, the community, technical staff, and professional development providers did not reach *full* implementation standards (mean score of 3.50 to 4.00). Consistent with the second and third project years, teachers, on average, reported only *partial* levels of Classroom Immersion in the fourth year (M = 2.67), and students, as a whole, reported *partial* levels of technology access and use (M = 2.07).

Figure 2: Mean level of implementation (measured on a 0 to 4 scale) for seven Technology Immersion components (N = 21 middle schools) by year.[2]



Results for Year 4, reported in Table 7 and discussed below, showed that the level of implementation for individual components varied across schools.

Table 7: Level of Technology Immersion (Year 4) Measured by Implementation Standard Scores

	Average Implementation		Percentage of Schools at each Implementation Level			
Component	**Mean**	***SD***	**Minimal**	**Partial**	**Substantial**	**Full**
Immersion Support						
Leadership	2.98	0.26	0	48	52	0
Teacher Support	3.19	0.27	0	24	67	10
Parent/Community Support	2.82	0.36	0	71	24	5
Technical Support	2.76	0.36	0	67	29	5
Professional Development	2.69	0.49	9	52	33	5
Classroom Immersion	2.67	0.32	5	76	19	0
Student Access and Use	2.07	0.43	43	57	0	0

Note. SD = Standard Deviation. Level of implementation for components measured on a 0 to 4 scale.

Level of School Support

Leadership

Given the importance of administrators' support for Technology Immersion, teachers have been asked to rate the quality of administrative leadership at their schools. Administrators demonstrated leadership through behaviors such as involving staff in decisions, setting clear expectations for technology use, encouraging and participating in professional development events, and providing resources and support. Results in Figure 2 showed that administrative leadership was relatively stable across three years. Percentages reported in Table 7 for the fourth year show that teachers at about half of schools (52%) reported substantial levels of leadership, which indicated that these teachers either *agreed* or *strongly agreed* that administrators provided technology-related leadership. Teachers in an additional half of schools (48%) reported just partial levels of administrative support.

Teacher Support

Teacher "buy-in" for Technology Immersion is critically important because students' school experiences with technology are largely dictated by their teachers. Thus, it was noteworthy that teachers reported increased levels of support for technology innovation across years. In the fourth year, teachers at two campuses (10%) reported a full level of support. That is, teachers at these schools *strongly agreed* that they shared an understanding about technology use for student learning, were continually learning and seeking new ideas, were not afraid to learn about and use new technologies, and were supportive of integration efforts. Teachers at two-thirds of schools (67%) reported a substantial level of support for technology innovation, whereas teachers at a quarter of campuses (24%) reported only partial levels of support.

Parent and Community Support

Because parents must share responsibility for an expensive laptop computer with their child or children, their understanding of and support for Technology Immersion is imperative. Additionally, the enthusiastic support of community members, including elected members of the local school board and business people, may influence implementation through mechanisms such as the adoption of supportive policies or provision of financial resources. In the fourth year, teachers at about a third of schools reported substantial levels (24%) to full levels (5%) of parent and community support, with teachers generally agreeing that parents and the surrounding community supported their efforts with technology. Conversely, teachers at 71% of schools reported just partial levels of parent and community support. Thus, garnering adequate parent and community support remained a problem at many schools in the fourth year.

Technical Support

Technical support for immersion should be provided by vendor technicians as well as district and campus staff who assist with implementation and offer timely support when technical problems arise. Results showed that the average level of technical support was similar across years. However, results for the fourth year showed that teachers at about a third of schools reported substantial levels (29%) or full levels (5%) of technical support, whereas teachers at two-thirds of schools reported just partial levels of technical support (67%). Teachers at schools with partial implementation were generally *unsure* that school computers were kept in working order, requests for assistance were addressed in a timely way, Internet connections worked adequately, and classroom materials were readily available. Clearly, technical problems continued to challenge teachers at many schools in the fourth year.

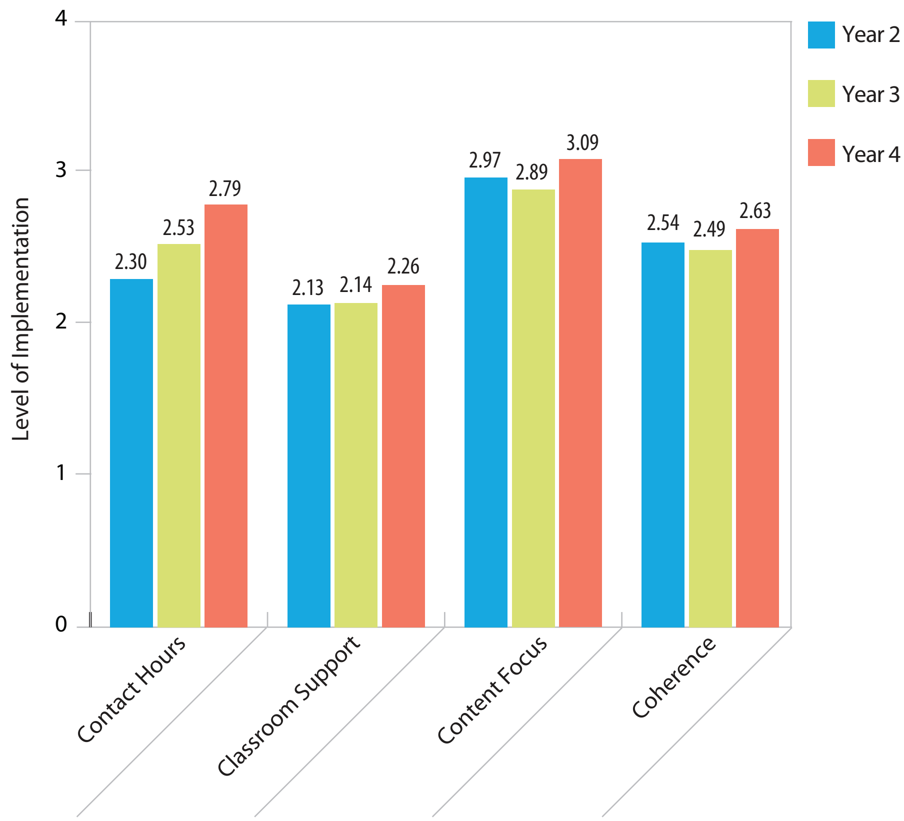
Professional Development

Technology Immersion packages included a professional development component designed to support all educators on an implementing campus. The immersion model required professional development that instructed teachers in effective classroom integration and was delivered through proven methods (i.e., learning through a variety of delivery systems, collaboration, sustained learning opportunities, and ongoing coaching and support). In addition to professional development provided by immersion package vendors, each school was offered a grant in the fourth year to participate in the Intel Teach Program (i.e., grant funds to train Intel Master Teachers [MTs] and stipends for at least 10 participant teachers to be trained by the MTs). Of the 21 treatment schools, 17 schools received grants to train at least one MT who provided school-based training for their peers.

Although professional development was for all teachers at a school, our implementation measure concentrated on core-subject teachers because of their close association with measured student academic outcomes. Year-to-year comparisons displayed in Figure 2 for the composite Professional Development indicator (mean score for four standards-based elements) showed that the level of professional development improved slightly in the fourth year (likely due to the Intel program). Even so, fourth-year results displayed in Table 7 showed that the majority of campuses had minimal (9%) to partial (52%) levels of professional development, while a third of campuses achieved substantial (33%) or full (5%) levels of professional development.

Figure 3 compares the implementation levels for each of the four elements that contributed to the composite Professional Development measures. Despite annual increases in Contact Hours, core teachers reported receiving less than the prescribed number of hours of technology-related professional development (50 or more hours per year). The mean implementation score for Year 4 (2.79) indicated that teachers, on average, participated in 37 hours or fewer of technology-related professional development. Additionally, teachers, reported just partial levels of classroom support indicating that teachers as a whole *rarely* (a few times a year) or *never* received classroom coaching or mentoring from an internal source (such as another teacher or technology coordinator) or external source (such as a vendor-provided professional trainer). Moreover, teachers' mean rating for Coherence indicated that professional development was consistent with their personal goals and experiences *to a minimal extent* (partial implementation). Core-subject teachers expressed stronger agreement about the content-focus of professional development. The mean fourth-year score (3.09) indicated that teachers' professional development had a *minor* to *major* emphasis on curriculum, instructional methods, and lesson development in core-content areas.

Figure 3: Level of Implementation (measured on a 0 to 4 scale) for elements of the Professional Development component by *mean implementation score* and year

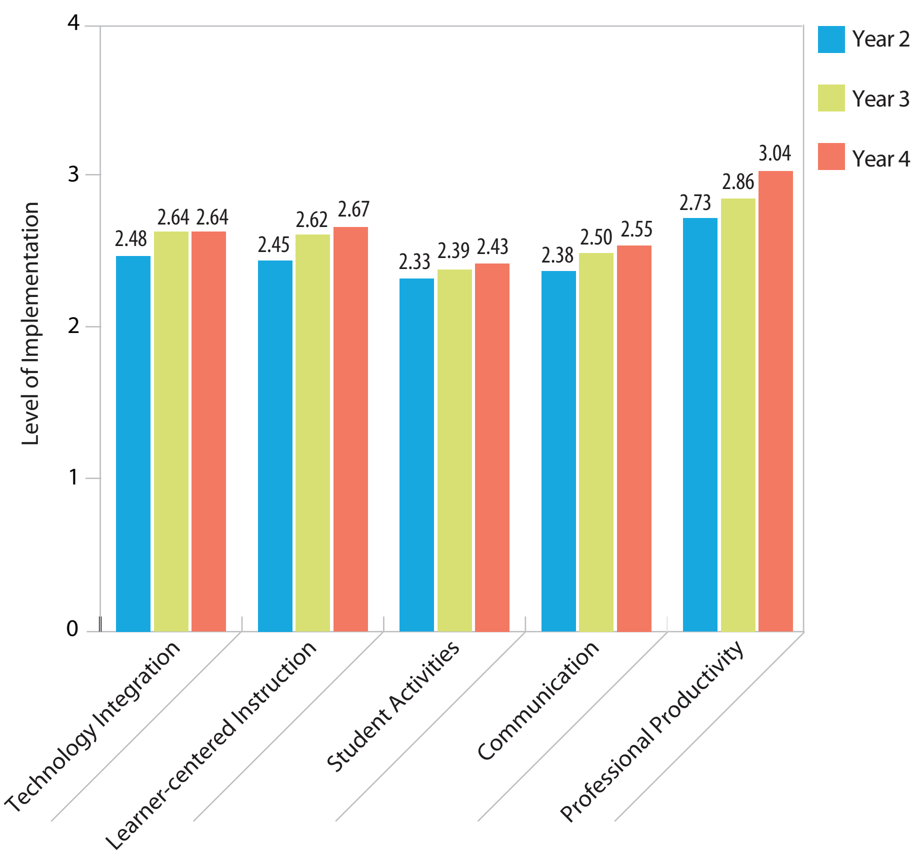


Level of Classroom Immersion

Given the needed equipment, digital resources, and support for Technology Immersion, teachers are expected to design technology-enhanced learning environments and integrate technology into teaching, learning, and the curriculum. Fourth-year results for teachers' composite level of Classroom Immersion (Table 7) showed that core-subject teachers at about a fifth of schools (19%) had reached substantial levels of Classroom Immersion. On the other hand, teachers at the majority of schools reported only partial levels of Classroom Immersion (76%), and teachers at one school (5%) had a minimal level of Classroom Immersion in the fourth year.

Figure 4 illustrates teachers' implementation progress relative to the five elements of Classroom Immersion: Technology Integration, Learner-Centered Instruction, Student Classroom Activities (with technology), Communication, and Professional Productivity. On average, teachers reported partial levels of implementation across years for four of five elements. Teachers' technology use for their own Professional Productivity reached a substantial level of implementation in the fourth year (M = 3.04). Comparisons across years indicated that teachers, on average, became somewhat more positive about technology integration, learner-centered instructional methods, and the use of technology as a communication and professional productivity tool. In contrast, the frequency with which core-subject teachers had *students* in their classrooms use technology for learning activities remained fairly stable across years. In general, teachers at many schools seemed to view technology as a more valuable tool for themselves than for their students.

Figure 4: Level of Implementation (measured on a 0 to 4 scale) for five elements of Classroom Immersion by *mean implementation score* and year

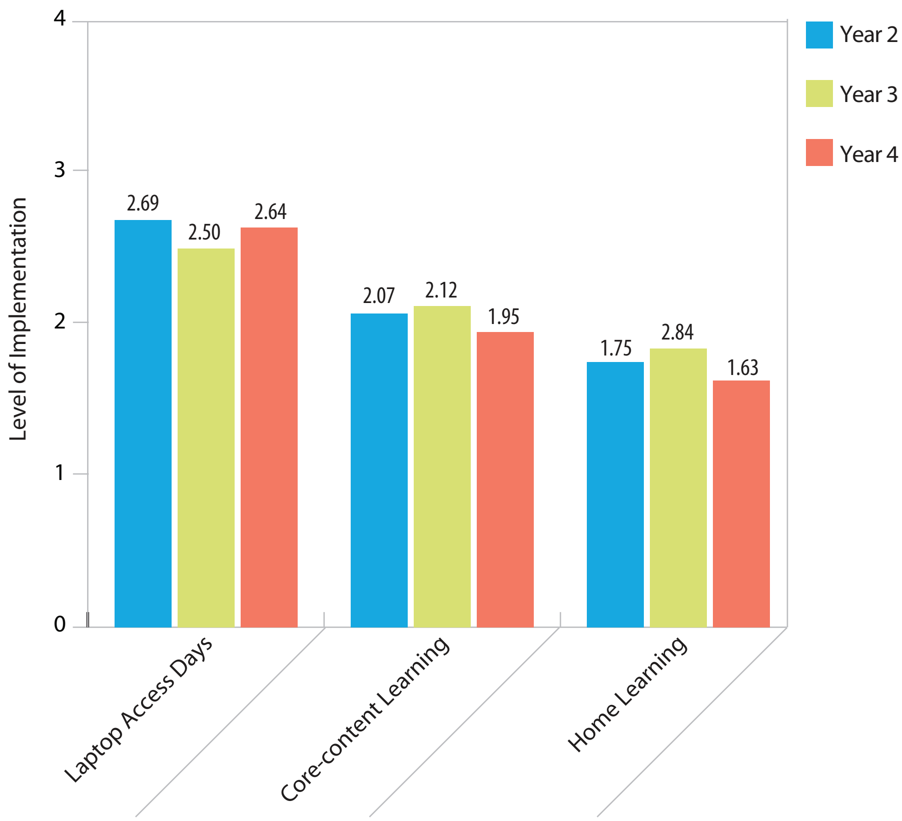


Level of Student Technology Access and Use

The transformation of students' classroom experiences is a vital part of Technology Immersion; however, the model also aims for students to have access to technology outside of school that allows them to become more independent and self-determined learners. Overall, data reported by students indicated that Student Access and Use remained relatively stable across the second and third project years but declined slightly in the fourth year. Between the second and fourth years, the percentages of schools with partial levels of Student Access and Use decreased (from 76% to 57%, respectively) whereas the percentages of schools with minimal access and use increased (from 24% to 43%, respectively). None of the schools reached substantial to full levels of Student Access and Use.

Figure 5 shows the average implementation levels for three elements: Laptop Access Days, Core-Content Learning, and Home Learning. First, in a fully immersed school, all students should have access to their wireless laptops and resources nearly the entire school year (about 170 to 180 days). Schools as a whole, however, had difficulty keeping laptops in the hands of students. Year-to-year comparisons indicated that students' Laptop Access Days declined in the third year (from 2.69 to 2.50) but improved in the fourth year (2.64). Thus, students, on average, had laptops available for a larger number of days in the fourth year. Students' access to laptops was affected by factors such as time for repairs, technical issues, disciplinary infractions, and parent resistance. In contrast to laptop access, students' use of their laptops in English/language arts, mathematics, science, and social studies classes and for home learning decreased in the fourth year. Students as a whole reported a minimal level of Core-Content Learning (M = 1.95), suggesting that they *rarely* (a few times a year) or *never* used laptops in core-subject classrooms. Across years, students used laptops in their classrooms most often to conduct Internet research, create presentations, write with a word processor, and to complete a test or quiz. Students also reported a minimal level of laptop use for home learning (M = 1.63) indicating that students, on average, used their laptops outside of school for homework and learning either *not at all* or *to a trivial extent*.

Figure 5: Level of Implementation (measured on a 0 to 4 scale) for three elements of Student Access and Use by *mean implementation score* and year



In sum, overall results for the implementation of Technology Immersion as measured by standards-based scores showed that the levels of support for implementation increased to some extent across project years. Similarly, teachers' reported slightly increased levels of Classroom Immersion, although it largely reflected their growing use of technology for their own productivity. In contrast, the level of Student Access and Use declined in the fourth year. Findings also showed that the level of implementation varied by campus. By the end of the fourth year, none of the middle schools achieved *full immersion*, and evidence suggested that just a few campuses reached *substantial immersion*. A majority of schools had *minimal* to *partial immersion*.

Implementation of Technology Immersion—Implementation Indices

To further illustrate each school's level of immersion in the fourth year, Table 8 presents the composite campus Implementation Index (*z* score) alongside implementation indices (*z* scores) for each of the seven components. The Implementation Index is an average score for the Immersion Support Index, Classroom Immersion Index, and Student Access and Use Index. *Z* scores have a mean of zero and a standard deviation of 1.0. Thus, the campus score indicates how many standard deviations from the mean a score lies. Schools with scores above zero have higher values on the components of Technology Immersion, whereas schools with index values below zero show less evidence of immersion. Despite some variations in component scores, middle schools with positive values on the Implementation Index tended to have component scores that indicated a stronger presence of the immersion attributes such as administrative leadership and teacher support for immersion. In contrast, middle schools that had the most negative values on the Implementation Index generally had negative values for nearly all of the immersion components.

Table 8: Fourth-Year Implementation of Technology Immersion by School

	Immersion Support Index							
Middle School (MS)	Leadership Index	Teacher Support Index	Parent/ Comm. Index	Technical Support Index	PD Index	Classroom Immersion Index	Student Access/ Use Index	Implementation Index
MS 1	1.69	2.19	2.25	2.05	0.88	1.23	2.02	**2.58**
MS 2	1.00	0.36	0.15	0.48	0.54	1.52	1.77	**1.78**
MS 3	1.30	0.54	1.60	1.11	–0.28	0.75	0.49	**1.08**
MS 4	0.45	2.27	0.73	–0.16	2.08	1.71	–0.99	**0.99**
MS 5	0.42	0.50	0.38	–0.83	0.75	0.10	0.47	**0.40**
MS 6	0.01	0.36	–1.06	0.19	0.52	–0.13	0.97	**0.39**
MS 7	0.49	–0.56	–0.09	0.98	0.41	–0.05	0.25	**0.25**
MS 8	0.50	0.13	0.70	0.72	0.01	–0.45	0.20	**0.15**
MS 9	–0.19	0.35	–0.11	–0.74	0.94	–0.19	0.39	**0.12**
MS 10	-0.53	0.03	–0.57	–1.48	0.80	0.45	–0.33	**–0.17**
MS 11	-0.83	0.94	–1.58	–1.67	–1.30	1.57	–0.81	**–0.22**
MS 12	0.81	–0.23	–0.88	–0.17	–0.71	0.25	–0.42	**–0.23**
MS 13	–0.02	–0.81	0.85	0.95	–0.02	0.66	–1.50	**–0.25**
MS 14	0.39	–0.23	0.43	–0.02	0.09	–0.35	–0.41	**–0.25**
MS 15	–1.29	–0.23	0.39	1.08	0.96	–1.31	0.20	**–0.38**
MS 16	0.85	–0.10	–0.50	–0.13	–1.77	–0.77	0.14	**–0.49**
MS 17	–1.61	–1.58	–0.12	–0.12	–1.05	–1.21	0.79	**–0.72**
MS 18	–2.33	–0.28	0.81	0.79	–2.05	–2.07	0.73	**–0.98**
MS 19	–0.51	–1.38	–1.34	–1.08	–0.20	–0.44	–1.08	**–1.24**
MS 20	–0.98	–1.19	–0.96	–1.61	0.04	–0.45	–1.21	**–1.33**
MS 21	0.36	–1.10	–1.32	–0.34	–0.61	–0.82	–1.69	**–1.49**

Note. Implementation indices are z scores with a mean of zero and a standard deviation of 1.0. Scores above zero indicate a greater presence of Technology Immersion components and higher levels of implementation. The Implementation Index is an average score for the Immersion Support Index, Classroom Immersion Index, and Student Access and Use Index.

Findings suggest that the implementation indices are relatively effective in discriminating higher and lower implementing schools. Still, there are exceptions to the prevailing trends. Some schools, such as MS 3, had generally higher implementation values for most of the indicators except Professional Development (–0.28). This suggests that professional development for teachers was a lower priority at this school in the fourth year. MS 4 had generally high levels of school support and Classroom Immersion, but students had a low score for Student Access and Use (–0.99) because they were not allowed to use their laptops at home for learning. In other schools, such as MS 17 and MS 18, students reported higher levels of technology access and use even though strong implementation supports were not in place, and their teachers' levels of Classroom Immersion were low. Results for the Implementation Index combined with evidence from standards-based scores suggest that about a quarter of middle schools (6), with Implementation Index scores ranging from 0.39 to 2.58 standard deviations above the mean, had a stronger presence of the components of Technology Immersion compared to other schools, and thus a higher level of implementation that more nearly approximated expected standards.

Table 9 displays the correlations between the seven components of Technology Immersion (*z* scores), with statistically significant coefficients denoted in bold. Core-subject teachers' extent of Classroom Immersion was associated at a statistically significant level with their perceptions of the strength of the school's administrative leadership (r = .59), teachers' collective support for technology innovation (r = .67), and the quality of professional development (r = .47). Surprisingly, there was virtually no association between core-subject teachers' level of Classroom Immersion and Student Access and Use (r = .04). Instead, students' reported access to and use of laptops was positively associated at a statistically significant level with teachers' perceptions of the strength of Parent and Community Support (r = .50) and the quality of Technical Support (r = .52) for immersion. In general, students had more robust technology experiences when all teachers in the school supported innovation, technical supports addressed maintenance issues that created barriers to technology use, and parents and community members supported the school's technology efforts.

Table 9: Fourth-Year Correlations of Technology Immersion Components

	Immersion Support						
Middle School (MS)	**Leadership**	**Teacher Support**	**Parent Support**	**Technical Support**	**PD**	**Classroom Immersion**	**Student Access/Use**
Leadership	1.00						
Teacher Support	.48*	1.00					
Parent/Community Support	.30	.47*	1.00				
Technical Support	.34	.25	.76**	1.00			
Professional Development	.33	.47*	.28	.09	1.00		
Classroom Immersion	.59***	0.67**	.15	–.03	.47*	1.00	
Student Access and Use	.21	.38	.50*	.52*	.09	.04	1.00

Note. N = 21 Technology Immersion schools. PD = Professional Development.
*p < .05. **p < .01. ***p < .001.

Association between Implementation and Academic Outcomes

Implementation evidence for the fourth year, similar to previous years, revealed wide variation across schools and teachers. Given differences in implementation from school-to-school and from classroom-to-classroom, we investigated the relationships between implementation levels and student academic achievement. For analyses, we used standardized implementation indicators (z scores) that could be analyzed individually or aggregated as component scores. Analyses involved predictors that measured school supports for immersion (Immersion Support Index), the extent of teachers' classroom immersion (Classroom Immersion Index), and the extent of students' technology access and use (Student Access and Use Index). Our dependent variables were students' TAKS reading and mathematics *T* scores (standardized scores with a mean of 50 and standard deviation of 10). Students included in analyses were continuously enrolled in Technology Immersion schools across project years, and thus, about a third of students were lost due to attrition. Student retention rates were fairly consistent across cohorts and years: Cohort 1 (59%), Cohort 2 (58%, 61%), and Cohort 3 (69%, 66%). Analyses for student cohorts involved approximately 1,000 to 1,400 students. Across cohorts and years, similar numbers of core-subject teachers were included in analyses for reading (34 to 39 language arts teachers) and mathematics (37 to 40 mathematics teachers).

HLM Analysis

HLM refers to hierarchical linear models, statistical models used for analyzing data in a clustered or nested structure. In education, data structures are often hierarchical—that is, lower-level units are nested within higher-level units. For example, students are nested within classrooms (two levels). HLM models allow researchers to "think about the possible mechanisms on each of the levels separately and then join the separate models in a joint analysis" (Raudenbush & Bryk, 2002, p. xxi). For this study, we used a series of two-level HLM models, in which students were nested within teachers, to investigate whether the levels of implementation for two teacher-related implementation components (Immersion Support Index, Classroom Immersion Index) and one student-specific component (Student Access and Use Index) were significant predictors of students' TAKS reading and mathematics scores. We used HLM models to analyze the effects of implementation on academic achievement for two implementation and testing years: (a) third-year implementation, TAKS 2007, Cohorts 1, 2, and 3; and (b) fourth-year implementation, TAKS 2008, Cohorts 2 and 3. In sections below, conceptual summaries are provided along with HLM equations.

Level 1: Student-Level Model

At the student level, we denote the academic outcome (TAKS reading or mathematics achievement) for student *i* nested in teacher *j* as Y_{ij}. This outcome is represented as a function of individual student characteristics and model error (r_{ij}). In Model 1, students' spring 2007 TAKS *T* scores were regressed on spring 2006 TAKS *T* scores (or spring 2008 *T* scores were regressed on spring 2007 *T* scores), Student Access and Use (*z* score), economic status (0 if not disadvantaged, 1 if disadvantaged), African American status (0 if not African American, 1 if African American), Hispanic status (0 if not Hispanic, 1 if Hispanic), and gender (0 if male, 1 if female). That is,

$$Y_{ij} = ß_{0j} + ß_{1j}(\textit{Spring 2006/2007 T score [grand mean centered]}_{ij} + ß_{2j}(\textit{Student Access and Use [grand mean centered]})_{ij} + ß_{3j}(\textit{Economic status})_{ij} + ß_{4j}(\textit{African American status})_{ij} + ß_{5j}(\textit{Hispanic status})_{ij} + ß_{6j}(\textit{Female})_{ij} + r_{ij}.$$

The regression coefficients ($ß_{0j}$ through $ß_{6j}$) indicate how achievement is distributed for teacher j as a function of the measured student characteristics.

In Model 2, spring 2007/2008 TAKS *T* scores were regressed on spring 2006/2007 TAKS *T* scores, Laptop Access Days (*z* score), Core-Content Learning (*z* score), Home Learning (*z* score), economic status (0 if not disadvantaged, 1 if disadvantaged), African American status (0 if not African American, 1 if African American), Hispanic status (0 if not Hispanic, 1 if Hispanic), and gender (0 if male, 1 if female). That is,

$$Y_{ij} = ß_{0j} + ß_{1j}(\textit{Spring 2006/2007 T score [grand mean centered]})_{ij} + ß_{2j}(\textit{Laptop Access Days [grand mean centered]})_{ij} + ß_{3j}(\textit{Core-Content Learning [grand mean centered]})_{ij} + ß_{4j}(\textit{Home Learning [grand mean centered]})_{ij} + ß_{5j}(\textit{Economic status})_{ij} + ß_{6j}(\textit{African American status})_{ij} + ß_{7j}(\textit{Hispanic status})_{ij} + ß_{8j}(\textit{Female})_{ij} + r_{ij}.$$

Statistics in Table 10 show that the variance in TAKS reading *T* scores that was between teachers ranged from 10.6% to 25.8%, and the variance in TAKS mathematics *T* scores that was between teachers ranged from 12.0% to 33.8%. Thus, in the models described above, the teacher means ($ß_{0j}$) were specified as randomly varying. The coefficient for spring 2006/2007 *T* scores ($ß_{1j}$) was also specified as randomly varying (significant reduction in model deviance). The coefficients for the remaining independent variables in the models were specified as fixed.

Table 10: Between-Teacher Variance (Intraclass Correlation Coefficients) for TAKS Reading and Mathematics Scores

	Cohort 1	Cohort 2		Cohort 3	
	Grade 8	Grade 7	Grade 8	Grade 6	Grade 7
TAKS	**2007**	**2007**	**2008**	**2007**	**2008**
Reading	25.8%	24.1%	20.1%	17.2%	10.6%
Mathematics	33.8%	23.0%	24.4%	12.0%	17.0%

Note. The total variability of TAKS scores can be divided between variation among students and variation among teachers. The percentage of this total variation in TAKS scores between teachers (classrooms) is reported here.

Level 2: Teacher-Level Model

At the teacher level (Level 2), researchers investigated whether two teacher-related implementation components, Immersion Support Index (*z* score) and Classroom Immersion Index (*z* score), as well as school poverty were significant predictors of students' TAKS reading and mathematics scores (Y_{ij}), after adjusting for students' prior achievement and demographic characteristics, and student-level implementation indicators. School poverty was a continuous variable indicating the percentage of economically disadvantaged students in a school, with a mean of 68% to 71%. The combined prediction equation for Model 1 is:

$Y_{ij} = \Upsilon_{00} + \Upsilon_{01}(\textbf{School poverty}[\text{grand mean centered}])_j + \Upsilon_{02}(\textbf{Immersion Support}\ [\text{grand mean centered}])_j + \Upsilon_{03}(\textbf{Classroom Immersion}\ [\text{grand mean centered}])_j + \Upsilon_{10}(\text{Spring 2006/2007 T score})_{ij} + \Upsilon_{20}(\text{Student Access and Use})_{ij} + \Upsilon_{30}(\text{Economic status})_{ij} + \Upsilon_{40}(\text{African American status})_{ij} + \Upsilon_{50}(\text{Hispanic status})_{ij} + \Upsilon_{60}(\text{Female})_{ij} + \mu_{0j} + \mu_{1j}{}^*(\text{Spring 2006/2007 T score})_{ij} + r_{ij}.$

The Model 2 prediction equation is:

$Y_{ij} = \Upsilon_{00} + \Upsilon_{01}(\textbf{School poverty}[\text{grand mean centered}])_j + \Upsilon_{02}(\textbf{Immersion Support}\ [\text{grand mean centered}])_j + \Upsilon_{03}(\textbf{Classroom Immersion}\ [\text{grand mean centered}])_j + \Upsilon_{10}(\text{Spring 2006/2007 T score})_{ij} + \Upsilon_{20}(\text{Laptop Access Days})_{ij} + \Upsilon_{30}(\text{Core-Content Learning})_{ij} + \Upsilon_{40}(\text{Home Learning})_{ij} + \Upsilon_{50}(\text{Economic status})_{ij} + \Upsilon_{60}(\text{African American status})_{ij} + \Upsilon_{70}(\text{Hispanic status})_{ij} + \Upsilon_{80}(\text{Female})_{ij} + \mu_{0j} + \mu_{1j}{}^*(\text{Spring 2006/2007 T score})_{ij} + r_{ij}.$

In the Level 2 models, Υ_{01}, Υ_{02}, and Υ_{03} represent the impact of the teacher-level explanatory variables on the achievement outcome, controlling for all other predictors; and Υ_{10}, Υ_{20}, ... Υ_{80} represent the impact of the student-level explanatory variables on the outcome controlling for all other predictors; μ_{0j} is the unique effect of teacher *j* on mean achievement and μ_{1j} is the unique effect of teacher *j* on the achievement slope (expected change in achievement), after controlling for other predictors.

In summary, the student-level models (Level 1) investigated whether Student Access and Use (or the elements of Student Access and Use) predicted higher 2007 or 2008 TAKS scores, after adjusting for initial achievement, student demographic characteristics, school poverty, Immersion Support, and Classroom Immersion. The teacher-level models (Level 2) investigated whether the Immersion Support Index (average school *z* score) and Classroom Immersion Index (language arts or mathematics teacher's individual *z* score) predicted higher 2007 or 2008 TAKS scores, after adjusting for school poverty, students' prior achievement and demographic characteristics, and Student Access and Use.[3]

TAKS Reading

Estimates of the effects of implementation on Cohorts 1, 2, and 3 students' TAKS reading *T* scores are presented in Table 11. At the teacher level in Model 1, we investigated whether the strength of language arts teachers' school support for implementation (Immersion Support) and their reported levels of Classroom Immersion were predictors of students' reading achievement. Results revealed that only one of the teacher-level implementation measures was a statistically significant predictor of TAKS reading scores. After controlling for student variables (prior achievement, demographic characteristics, Student Access and Use) and other teacher variables (school poverty and Classroom Immersion), Immersion Support was a positive predictor of Cohort 1 eighth graders' reading achievement. Moreover, language arts teachers' level of Classroom Immersion was an inconsistent predictor of students' TAKS reading achievement. After adjusting for other variables in the analysis, Cohort 2 students, who had language arts teachers with average levels of Classroom Immersion, had slightly higher TAKS reading *T* scores (0.69 and 0.22 points, respectively) than students whose teachers had below average Classroom Immersion scores. Conversely, Cohorts 1 and 3 students who had language arts teachers with average levels of Classroom Immersion had lower TAKS scores (–0.23, –0.71, and –0.21 *T*-score points) than students whose language arts teachers had below average Classroom Immersion.

Table 11: Hierarchical Regression Models Predicting the Effects of Technology Immersion Implementation Indicators on TAKS Reading Achievement

	Cohort 1		Cohort 2				Cohort 3			
	Eighth Graders 2007, *N* = 1,217		Seventh Graders 2007, *N* = 1,297		Eighth Graders 2008, *N* = 1,101		Sixth Graders 2007, *N* = 1,606		Seventh Graders 2008, *N* = 1,168	
	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value
Model 1										
Intercept	49.803	128.06***	50.984	74.56***	50.264	128.56***	48.869	103.51***	49.204	99.61***
Teacher-level predictors										
School poverty	3.112	1.76	3.125	0.97	-0.016	-1.18	1.185	0.75	-0.021	-1.15
Immersion Support	1.340	5.62***	-0.129	-0.25	0.064	0.52	-0.030	-0.10	-0.315	-1.16
Classroom Immersion	-0.234	-0.64	0.688	1.21	0.215	1.45	-0.705	-2.02†	-0.211	0.73
Student-level predictors										
Spring 2006/2007 *T* score	0.537	23.03***	0.654	19.77***	0.689	21.38***	0.532	27.99***	0.666	34.78***
Student Access and Use	0.542	2.05*	0.895	2.56*	0.466	1.38	0.523	1.88†	0.791	1.93†
Eco. Disad-vantaged	-1.039	-2.53*	-0.625	-1.13	-0.601	-1.33	-0.266	-0.68	-0.875	-1.63
African American	-0.285	-0.31	-2.562	-2.91**	-1.862	-2.12*	-0.837	-1.21	-1.649	-2.18*
Hispanic	-0.949	-2.07*	-2.443	-2.84**	-0.164	-0.43	-0.939	-1.91†	-0.518	-0.83
Female	0.394	1.10	-0.027	-0.06	0.674	1.95†	0.785	2.98**	0.216	0.52

(Continued)

Table 11: Hierarchical Regression Models Predicting the Effects of Technology Immersion Implementation Indicators on TAKS Reading Achievement (continued)

	Cohort 1		Cohort 2				Cohort 3			
	Eighth Graders 2007, N = 1,217		Seventh Graders 2007, N = 1,297		Eighth Graders 2008, N = 1,101		Sixth Graders 2007, N = 1,606		Seventh Graders 2008, N = 1,168	
	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value
Model 2										
Intercept	49.803	130.90***	51.196	75.77***	50.326	126.61***	48.883	104.32***	49.274	100.01***
Teacher-level predictors										
School poverty	3.287	1.65	2.916	0.93	-0.019	-1.32	1.026	0.65	-0.032	-1.88
Immersion Support	1.325	5.45***	0.143	0.32	0.105	0.85	-0.030	-0.10	-0.263	-0.98
Classroom Immersion	-0.261	-0.72	0.762	1.33	0.239	1.55	-0.688	-2.03*	0.365	1.41
Student-level predictors										
Spring 2006/2007 *T* score	0.537	22.03***	0.640	18.44***	0.686	20.83***	0.531	27.80***	0.658	34.87***
Laptop Access Days	-0.033	-0.32	0.120	0.41	0.195	0.89	0.060	0.22	-0.186	-0.73
Core-Content Learning	0.246	0.81	-0.485	-2.00*	-0.098	-0.41	-0.050	-0.30	-0.344	-1.54
Home Learning	0.311	1.37	1.010	6.14***	0.304	1.27	0.394	3.01**	0.985	4.77***
Eco. Disadvantaged	-1.054	-2.60*	-0.558	-1.06	-0.627	-1.39	-0.289	-0.74	-0.765	-1.41
African American	-0.284	-0.31	-2.423	-2.84**	-1.872	-2.12*	-0.785	-1.16	-1.624	-2.27*
Hispanic	-0.931	-1.96*	-2.630	-3.05**	-0.202	-0.52	-0.904	-1.86†	-0.648	-1.07
Female	0.415	1.19	-0.142	-0.32	0.641	1.88	0.752	2.82**	0.152	0.37

Note. TAKS 2007 = third implementation year; TAKS 2008 = fourth implementation year.
Number of language arts teachers 2007: Cohort 1 = 39, Cohort 2 = 37, Cohort 3 = 41.
Number of language arts teachers 2008: Cohort 2 = 37, Cohort 3 = 34.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

In contrast to teacher-level predictors, the level of Student Access and Use (of technology) was a stronger and more consistent predictor of reading achievement. After controlling for students' prior reading achievement, demographic characteristics, and teacher-level variables (school poverty and implementation components), the Student Access and Use effect on TAKS reading achievement was consistently positive for Cohort

1 (0.54 *T*-score point), Cohort 2 (0.90 and 0.47 points), and Cohort 3 (0.52 and 0.79 points). Results generally were either statistically significant or marginally significant.

Additionally, we conceptualized Student Access and Use as having multiple elements (Laptop Access Days, Core-Content Learning, and Home Learning), and thus, were interested in separately predicting variation for each element. Table 11 provides statistics for the HLM models used to predict each of the three elements (Model 2). Findings revealed that Home Learning—which measured the extent of a student's laptop use outside of school for homework in each of the four core-subject areas and for learning games—was the strongest implementation predictor of reading achievement. The Home Learning effect on TAKS reading scores was positive for Cohort 1 (0.31 *T*-score point), Cohort 2 (1.01 and 0.30 points), and Cohort 3 (0.39 and 0.99 points). Results were statistically significant for sixth graders (Cohort 3) and seventh graders (both Cohorts 2 and 3). As an example, after controlling for all of the other variables in the analysis, an economically advantaged, non-minority, male seventh grader (Cohort 3) with a score one standard deviation above average for Home Learning (z = 1.00), had a 0.99 *T*-score point higher TAKS reading score. Moreover, with each additional standard deviation increase in Home Learning, students' reading achievement was predicted to increase.

In contrast to Home Learning, the number of days during the school year that students had laptops available for use (Laptop Access Days) was not a statistically significant predictor of students' reading achievement. The frequency that students reported using their laptops across their four core-subject classes (Core-Content Learning) was a positive predictor of reading achievement for Cohort 1 (although not by a statistically significant margin), but a negative predictor of reading achievement for Cohorts 2 and 3 students, after controlling for other variables in the analysis.

TAKS Mathematics

We also estimated the effects of implementation on students' TAKS mathematics *T* scores. Like reading, we examined implementation effects for students and teachers (see Table 12). Comparable to reading, in Model 1, the school- and teacher-level implementation indicators were typically not statistically significant predictors of students' TAKS mathematics scores. After controlling for other variables in the analysis, Immersion Support was a positive predictor for Cohort 1 students' mathematics achievement but a mixed predictor for Cohorts 2 and 3 students' mathematics scores. Similarly, after statistical adjustments for the other variables in the analysis, mathematics teachers' reported Classroom Immersion level was an inconsistent predictor of TAKS math achievement for Cohorts 1, 2, and 3 students.

Table 12: Hierarchical Regression Models Predicting the Effects of Technology Immersion Implementation Indicators on TAKS Mathematics Achievement

	Cohort 1		Cohort 2				Cohort 3			
	Eighth Graders 2007, *N* = 1,174		Seventh Graders 2007, *N* = 1,382		Eighth Graders 2008, *N* = 999		Sixth Graders 2007, *N* = 1,389		Seventh Graders 2008, *N* = 1,165	
	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value
Model 1										
Intercept	51.550	83.22***	48.703	85.70***	50.542	108.15***	47.917	80.95***	50.313	101.20***
Teacher-level predictors										
School poverty	8.713	2.84**	4.608	1.55	0.011	0.57	5.418	1.55	-0.010	-0.40
Immersion Support	1.464	2.99**	0.643	0.98	-0.168	-0.55	-0.206	-0.26	0.026	0.07
Classroom Immersion	-0.174	-0.23	0.621	1.76†	0.451	1.03	0.292	0.59	-0.614	-1.49
Student-level predictors										
Spring 2006/2007 *T* score	0.707	28.19***	0.731	28.15***	0.702	32.65***	0.689	32.23***	0.730	35.24***
Student Access and Use	0.809	3.34**	0.864	3.40**	0.303	1.01	0.889	2.97**	0.505	1.39
Eco. Disad-vantaged	-0.736	-1.96*	0.129	0.31	-0.607	-1.41	-0.518	-0.94	-0.632	-1.26
African American	-1.037	-1.63	-0.553	-1.11	-1.528	-2.19*	-1.219	-1.34	-2.475	-2.74***
Hispanic	-0.611	-0.82	-1.187	-2.31*	-0.436	-1.08	-0.667	-0.98	-0.998	-1.73†
Female	-0.477	-1.52	-0.178	-0.60	-0.338	-0.86	1.025	2.67**	0.509	1.78†

(Continued)

Table 12: Hierarchical Regression Models Predicting the Effects of Technology Immersion Implementation Indicators on TAKS Mathematics Achievement (continued)

	Cohort 1		Cohort 2				Cohort 3			
	Eighth Graders 2007, $N = 1{,}174$		Seventh Graders 2007, $N = 1{,}382$		Eighth Graders 2008, $N = 999$		Sixth Graders 2007, $N = 1{,}389$		Seventh Graders 2008, $N = 1{,}165$	
	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value	Gamma Coeff.	*t*-value
Model 2										
Intercept	51.612	85.74***	48.787	85.55***	50.588	109.51***	47.912	79.65***	50.343	98.36***
Teacher-level predictors										
School poverty	8.304	2.82**	4.617	1.61	0.007	0.35	5.191	1.49	-0.013	-0.51
Immersion Support	1.432	3.06**	0.703	1.09	-0.159	-0.52	-0.186	-0.24	0.214	0.57
Classroom Immersion	-0.244	-0.34	0.612	1.80†	0.416	0.98	0.340	0.70	-0.584	-1.42
Student-level predictors										
Spring 2006/2007 *T* score	0.699	27.99***	0.728	27.24***	0.698	33.54***	0.686	31.42***	0.725	35.57***
Laptop Access Days	-0.002	-0.01	0.244	1.81	0.019	0.12	0.278	1.02	0.181	0.72
Core-Content Learning	0.019	0.07	0.032	0.15	-0.146	-0.72	0.057	0.29	-0.322	-1.70†
Home Learning	0.675	3.52**	0.508	2.54*	0.324	1.74†	0.504	2.68**	0.482	2.07*
Eco. Disad-vantaged	-0.801	-2.12*	0.140	0.33	-0.627	-1.48	-0.506	0.91	-0.605	-1.19
African American	-1.061	-1.68	-0.539	-1.08	-1.542	-2.23*	-1.169	-1.27	-2.418	-2.70**
Hispanic	-0.562	-0.78	-1.249	-2.42*	-0.442	-1.10	-0.647	-0.94	-1.017	-1.78†
Female	-0.490	-1.54	-0.215	-0.69	-0.376	-0.98	0.974	2.49*	0.438	1.48

Note. TAKS 2007 = third implementation year; TAKS 2008 = fourth implementation year.
Number of mathematics teachers 2007: Cohort 1 = 39, Cohort 2 = 40, Cohort 3 = 33.
Number of mathematics teachers 2008: Cohort 2 = 37, Cohort 3 = 38.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Similar to reading achievement, Student Access and Use was a consistently positive predictor of students' TAKS mathematics scores. Controlling for students' prior math achievement, demographic characteristics, and teacher-level variables (implementation components as well as school poverty), the sizes of the Student Access and Use effects were statistically significant for 2007 TAKS scores associated with third-year implementation (0.81, 0.86, and 0.89 *T*-score points for Cohorts 1, 2, and 3 students, respectively). Student Access and Use was a positive although not statistically significant predictor of 2008 TAKS mathematics scores associated with fourth-year implementation.

Comparable to TAKS reading achievement, we wanted to have a better understanding of the association between students' reported technology access and use and mathematics test scores. Thus, we used an HLM model to predict mathematics achievement for each of the three Student Access and Use elements (Laptop Access Days, Core-Content Learning, and Home Learning). Results for Model 2 presented in Table 12 show that the extent to which students reported using their laptops for Home Learning was a positive and statistically significant predictor of TAKS mathematics scores. As an example, after controlling for the other variables, an economically advantaged, non-minority, male eighth grader in Cohort 1 with a Home Learning score about one standard deviation above average ($z = 0.99$) had a 0.68 *T*-score point higher TAKS mathematics score. With each additional standard deviation increase in Home Learning, students' mathematics achievement was predicted to increase incrementally.

Discussion

This study advances research on one-to-one computing environments by defining a comprehensive Technology Immersion model (i.e., a laptop computer for every student and teacher, wireless Internet access, curricular and assessment resources, professional development, and ongoing technical and pedagogical support), positing a theoretical framework for how the model is expected to work, and examining how implementation indicators link to student outcomes. The Technology Immersion model assumes that school-wide provisions of technology resources and supports will produce teachers who are more technologically adept, use laptops and digital resources to transform their teaching, and have students use technology more often in their classrooms. Improved school and classroom environments, in turn, should allow students to have more engaging schoolwork, and laptops should extend student learning beyond school walls and the school day. Changes in students' learning experiences, accordingly, are expected to improve academic achievement as measured by state assessments. In the sections to follow, we discuss how Technology

Immersion was implemented at 21 pilot schools, factors that influenced progress, and associations with student achievement. In some instances, our explanations reflect the views expressed by school administrators, teachers, and students during interviews and focus groups conducted as part of school site visits near the end of the fourth implementation year (Shapley, Sheehan, Maloney, & Caranikas-Walker, 2009). Additionally, we discuss the implications of our findings for other educators who are undertaking one-to-one laptop initiatives.

Implementation of Technology Immersion

Full implementation of the Technology Immersion model was challenging, with just 6 of 21 schools reaching substantial levels of implementation by the end of the fourth year. The Technology Immersion model was expected to overcome obstacles that in the past have posed barriers to effective technology use in schools by promoting robust access to technology resources in concert with substantive supports from school leaders, teachers, parents, technicians, and professional development providers. Mean immersion standard scores, measured on a 4-stage progression encompassing *minimal* (0 to 1.99), *partial* (2.00 to 2.99), *substantial* (3.00 to 3.49), and *full immersion* (3.50 to 4.00) levels, revealed small yearly increases across most of the implementation support components (Leadership, Teacher Support, Parent/Community Support, and Professional Development) as well as modest increases in teachers' overall level of Classroom Immersion. Unexpectedly, the level of Student Access and Use declined slightly across three years (from 2.17 to 2.07). An examination of the correlations among fourth-year implementation measures revealed notable differences and similarities in the kinds of supports that advanced teachers' or students' technology use. For core-subject teachers, higher levels of Classroom Immersion were associated with the strength of administrative leadership, teachers' collective support for innovative practices, and the quality of professional development. Students, on the other hand, had more robust access to and use of technology when all teachers in the school supported technology innovation, support from technicians addressed maintenance issues that created obstacles to laptop use, and parents and community members supported the school's one-to-one laptop initiative. A common element was the importance of support from *all* teachers in the school. When teachers at a school shared understandings about the use of technology for learning and were supportive of technology integration, implementation was stronger at both the classroom and student levels.

Core-subject teachers at 4 of 21 schools achieved substantial levels of Classroom Immersion in the fourth year, whereas teachers at 16 schools had partial implementation levels and teachers at one school had minimal Classroom Immersion. As a whole, the standards-based implementation scores for Classroom Immersion increased slightly across years (from 2.48 to 2.69). Teachers' use of technology for their own purposes (Professional Productivity) increased the most (2.73 to 3.04), while the frequency with which teachers allowed students in their classes to use technology for learning (Student Activities) remained relatively stable across years (from 2.33 to 2.43). Thus, teachers, on average, used technology increasingly to support their own teaching but there was little change in the frequency of students' technology use in classes. Nevertheless, some teachers at almost every school embraced technology and had higher Classroom Immersion ratings, but teachers reached higher Classroom Immersion levels as a group if they worked in schools with the most supportive environments.

Students' access to laptops and use of laptops for learning fell short of expectations. By the end of the fourth year, there were no schools that had reached substantial to full levels of Student Access and Use, with all students having consistent access to laptops, using laptops almost daily in core-subject classes, and using laptops outside of school for homework and learning. Moreover, the percentages of schools with at least *partial* levels of Student Access and Use decreased across evaluation years (76%, 68%, and 57%), while the percentages of schools with *minimal* student access and use increased (24%, 32%, and 43%). Several factors affected students' opportunities to use their laptops, including mainly time lost for repairs due to aging laptops, schools that opted to transfer laptops from individual students to carts or classroom sets, schools that restricted students' use of laptops outside of school, and teachers' preferences regarding classroom laptop use. Putting laptops on carts or distributing laptops as classroom sets appeared to provide more consistent student access to laptops (although not "ownership") at some schools in the fourth year—however, such configurations did not increase the frequency of students' classroom activities with laptops, and taking laptops out of the hands of individual students either reduced or eliminated their opportunities to use laptops outside of school for learning.

The lack of a start-up year for planning was a major barrier to effective implementation. The majority of middle schools received their Technology Immersion Pilot (TIP) grant awards just before the start of the first implementation year. Thus, many administrators and teachers in spring 2008 thought implementation would have progressed more smoothly if there had been a start-up year to plan for immersion. Various respondents said a planning year would have allowed them to involve teachers in the decision to become an "immersed" school, to develop a plan for managing laptops (especially at larger campuses with as many as 1,500 laptops), to build the school's infrastructure for wireless technology, to provide professional development for teachers to strengthen their technical skills and ability to plan technology-integrated lessons, and to give teachers a chance to "try out" lessons with laptops in the classroom before students had their own laptops.

Respondents at higher implementing schools reported that committed leaders, thorough planning, teacher buy-in, preliminary professional development for teachers, and a commitment to the transformation of student learning were keys to their successful implementation of Technology Immersion. Respondents at middle schools that had been more successful attributed effective implementation to several factors. Foremost, despite a quick start, district and school administrators had a well-conceived plan for implementation, were excited about the project, and listened to teacher input. Administrators had high expectations for technology use but allowed time for teachers to become comfortable. One teacher explained:

> We had the right combination of encouragement and push… Leadership, encouragement, and push. It wasn't punitive, it was positive…but they kept up the pressure…That constant, positive pressure moved me forward.

Professional development for teachers was a high priority. Training typically began before the first year started and was ongoing across implementation years. These schools also had collegial cultures. Teachers learned by "seeing what other teachers were doing and how they were implementing technology." "We were all in this together," explained one teacher. The improvement of students' learning experiences was a driving force for higher quality implementation at these schools. Despite myriad laptop management issues, respondents believed the challenges had been worthwhile because one-to-one student laptops and digital resources had increased the depth of learning across subject areas, exposed students to more real-life experiences, and allowed students to demonstrate greater responsibility. Conversely, many respondents at lower implementing schools reported that administrative turnover, noncommittal teachers, insufficient professional development, inadequate school infrastructures, and laptop management problems were impediments to effective implementation of the Technology Immersion model.

The implementation trends reported for Technology Immersion are generally consistent with other research on whole-school reform and one-to-one initiatives. Specifically, higher levels of implementation were associated with administrative leaders who set the direction for change, developed supportive policies, fostered collaborative school cultures, and acquired resources (e.g., Bradburn & Osborne, 2007; Kurki et al., 2005;

Vernez et al., 2006; Zucker & McGhee, 2005). Effective leaders recognized the critical importance of teachers' commitment to change (Vernez et al., 2006), and the need to influence their beliefs about technology's potential for effective teaching and learning (Penuel, 2006; Russell et al., 2002; Windschitl & Sahl, 2002). Consistent with other studies, schools had difficulty changing instructional practices (Vernez et al., 2006). Many teachers at immersion schools, especially veterans, opted to continue traditional practices and rejected practices that required innovation and instructional change (Cuban, 2001; Russell et al., 2004). Teachers who made greater progress participated in high-quality sustained professional development that built their technology skills and understanding of curricular integration, and they had follow-up support as they implemented new practices in their classes (Bradburn & Osborne, 2007; Lowther et al., 2003; Neugent & Fox, 2007; Owen et al., 2005-06).

Despite efforts aimed at promoting a comprehensive reform model, many Technology Immersion schools, like CSR schools, tended to implement model components selectively (Vernez et al., 2006). Technology Immersion schools were most likely to modify the requirement that students have laptops available for use 24/7 (24 hours a day, 7 days a week). Decisions sometimes reflected educators' financial or security concerns, but restrictions also arose from some educators' beliefs that middle-school students were too immature to assume responsibility for expensive laptops outside of school or that students would not use their laptops productively outside of classrooms.

Association between Implementation and Student Achievement

The ultimate goal of immersing middle schools in technology was to increase students' academic achievement as measured by state assessments. Knowing that prior research has linked implementation quality with positive effects on students' achievement (Borman et al., 2003; Borman, 2005), and recognizing the implementation variations across Technology Immersion schools and classrooms, it was important to understand whether stronger implementation of Technology Immersion was associated with higher test scores. We limited our analysis to students' reading and mathematics TAKS scores because students completed tests for those subjects each year, and thus, pre-tests were available to control for prior achievement. Our analysis aimed to assess the predictive strength of variables that measured the extent to which the Technology Immersion model was implemented as designed at the school, teacher, and student levels. We used two-level HLM models with individual students nested within their language arts and mathematics teachers to test the "value added" to student achievement by teachers' Immersion Support (a school-level measure reflecting all teachers) and language arts and mathematics teachers' Classroom Immersion (individual teacher measure), and to test the "value added" to academic achievement by Student Access and Use (individual student measure) and three elements of access and use (Laptop Access Days, Core-Content Learning, and Home Learning). Evidence from the third and fourth implementation years allowed researchers to examine relationships for schools that had sufficient time to reach more advanced stages of implementation and to examine the replication of findings across years.

The implementation strength of Student Access and Use (of technology) was a consistently positive predictor of students' TAKS reading and mathematics scores. In our HLM models (Model 1), Student Access and Use was an aggregate implementation measure of the extent to which a student had access to a laptop throughout the school year (number of days), the frequency of technology use for learning in core-content classes, and the extent of laptop use for homework and learning games. Student-level results showed that after controlling for a student's prior achievement and demographic characteristics and other implementation variables, the composite measure of Student Access and Use was a consistently positive predictor of students' TAKS reading scores for Cohorts 1, 2, and 3 students across two implementation years. Gamma coefficients generally were either statistically significant or marginally significant. Similar to reading, Student Access and Use was a consistently positive predictor of students' TAKS mathematics scores. Gamma coefficients for the third implementation year were statistically significant for Cohorts 1, 2, and 3 students, but the coefficients for the fourth implementation year were not statistically significant.

Students' use of their laptops for Home Learning—a measure of the extent to which a student used a laptop outside of school for homework in the four core-subject areas or for learning games—was the strongest implementation predictor of students' TAKS reading and mathematics scores. Additional HLM models (Model 2) examined the extent to which each of the elements of Student Access and Use predicted student achievement, after controlling for other variables in the analysis. Of the three elements of Student Access and Use, a student's use of a laptop for Home Learning (i.e., use of a laptop outside of school for homework in core-subject areas and for learning games) was the strongest implementation predictor of both TAKS reading and mathematics achievement. Home Learning was a positive predictor of TAKS reading scores for Cohorts 1, 2, and 3 students. Results were statistically significant for sixth and seventh graders but not eighth graders. The extent of laptop use for Home Learning was a positive and statistically significant predictor of TAKS mathematics scores for Cohorts 1, 2, and 3 students. In contrast, a student's reported number of Laptop Access Days and the frequency that a student reported using a laptop for Core-Content Learning were mixed predictors (positive and negative) and were typically not statistically significant predictors of test scores.

It should be noted, however, that about a third of students were lost through attrition. Consequently, reported results represent outcomes for students who were continuously enrolled in middle schools and findings may not generalize to the more mobile group of students who left schools. Nevertheless, students who remained in schools, like the full student population, were largely economically disadvantaged and members of minority groups. Thus, the finding for Home Learning is important because it underscores the role that individual student laptops play in promoting ubiquitous learning and equalizing the out-of-school learning opportunities for students in disadvantaged family and school situations (Burbules, 2007; Dede, 2007). Individual student laptops, in contrast to laptops on carts or computers available in libraries, labs, and classrooms, expanded where and how student learning occurred. Students at higher Technology Immersion schools typically had access to their laptops "24/7," and teachers at these schools encouraged students' use of laptops outside of school by engaging students in projects or assignments in class that motivated students to continue working outside of school. Also, access to electronic resources and textbooks on laptops motivated many students to continue working on assignments at home (Shapley, Maloney, Caranikas-Walker, & Sheehan, 2008).

The school's level of Immersion Support and teachers' reported levels of Classroom Immersion were inconsistent predictors of students' TAKS reading and mathematics scores. After controlling for student-level variables and other teacher-level variables in analyses, the school's level of Immersion Support (a composite measure of implementation supports) was an inconsistent predictor of student achievement. Similarly, the levels of Classroom Immersion reported by language arts teachers were inconsistent, and for the most part, not statistically significant predictors of students' TAKS reading scores. Likewise, the levels of Classroom Immersion reported by mathematics teachers were inconsistent and not statistically significant predictors of students' TAKS mathematics scores. There are several potential explanations for teacher-level findings. First, measures of Immersion Support may have an indirect rather than a direct association with student achievement through the provision of supports for changes in teachers' instructional practices and students' learning experiences. Whole-school supports also may have a stronger relationship with composite measures of student achievement (e.g., percentages of students passing all TAKS tests) rather than students' test scores for individual subject areas.

At the individual teacher level, the measured elements of Classroom Immersion were designed to capture teachers' growth in ideological beliefs (Technology Integration, Learner-Centered Instruction), the frequency of classroom activities with technology (Student Activities), the use of technology to extend classroom boundaries (Communication), and the use of technology for administrative and instructional purposes (Professional Productivity). Scores for individual variables and the composite Classroom Immersion Index were useful in measuring teachers' development in areas that have been associated with positive effects on students' learning experiences (Shapley et al., 2009). However, there may be other technology-related variables that link more directly to student academic achievement. For example, some researchers recommend the use of specific measures of technology use rather than more general measures of how often technology is used (Bebell, Russell, & O'Dwyer, 2004; O'Dwyer, Russell, Bebell, & Tucker-Seeley, 2005; O'Dwyer, Russell, Bebell, & Seeley, 2008). Thus, future exploratory analyses might test the associations between students' test scores and the specific technology uses reported by teachers or students (e.g., students express themselves in writing; enter, calculate, and graph information; visually represent or investigate concepts). Student-reported activities with technology in classrooms will likely provide the most salient predictors of academic effects because students' experiences varied within classrooms due to inconsistent access to laptops caused by lost days for repairs, disciplinary infractions, or other reasons.

Alternatively, it is also possible that the quality of Classroom Immersion in language arts and mathematics classes (*partial immersion*, on average) or the frequency of student laptop use in core-content classes (*rarely* or *never* used, on average) have not reached levels that are effective enough to impact student achievement. Additionally, immersion effects on achievement may reflect the interdisciplinary efforts of many teachers rather than single core-subject teachers. For instance, the use of laptops for social studies research and compositions may positively affect reading outcomes. Similarly, exposure to investigations and problem-solving activities in science may positively affect mathematics scores.

In conclusion, findings from four implementation years suggest that Technology Immersion can be implemented with fidelity. If districts and schools are committed to the model's specifications, especially students' personal access to laptops within and outside of school, the prospects for raising academic achievement are promising. Certainly, effective technology integration involved much more than just buying laptops for students. Technology Immersion requires a comprehensive approach that transforms the school culture, changes the nature of teaching and learning, and expands the educational boundaries of the school and classrooms. This study confirms that fundamental school change is difficult and requires a long-term commitment at all levels of the school system (board members, superintendent, principals, teachers, students, and parents). Given the challenges and costs of implementing Technology Immersion, statewide implementation of the model may not be feasible. However, those districts and schools that are committed to Technology Immersion should have federal and state support for their innovative school-reform efforts.

Appendix A

Technology Immersion Components

The Texas Education Agency selected three lead vendors as providers of Technology Immersion packages (Dell Computer, Inc., Apple Computer Inc., and Region 1 Education Service Center [ESC]). Sections to follow provide descriptions of package components.

Wireless laptops and productivity software

All vendors offered a wireless laptop as the mobile computing device. Campuses could select either Apple laptops (iBook and MAC OSX) or Dell laptops (Inspiron or Latitude with Windows OS). For Apple laptops, *AppleWorks* provides a suite of productivity tools, including Keynote presentation software, Internet Explorer, Apple Mail, iCal calendars, iChat instant messaging, and iLife Digital Media Suite (iMovie, iPhoto, iTunes, GarageBand, and iDVD). For Dell laptops, *Microsoft Office* includes Word, Excel, Outlook, PowerPoint, and Access. In addition, *eChalk* serves as a "portal" to other web-based applications and resources included in the immersion package and a student-safe e-mail solution. Region 1 ESC provided Dell products.

Online instructional and assessment resources

Immersion packages included a variety of digital resources. Apple included the following online resources: *netTrekker* (an academic Internet search engine), *Beyond Books* from Apex Learning (reading, science, and social studies online), ClassTools Math from Apex Learning (complete math instruction), *ExploreLearning Math and Science* (supplemental math/science curriculum), *TeenBiz3000* from Achieve 3000 (differentiated reading instruction), and *My Access Writing* from Vantage Learning (support for writing proficiency). Dell, Inc. selected *netTrekker* (an academic Internet search engine) and *Connected Tech* from Classroom Connect (technology-based lessons and projects). Region 1 ESC selected *Connected Tech* but also added a variety of teaching and learning resources including *Unitedstreaming* (digital videos), *Encyclopedia Britannica*, *EBSCO* (databases), *NewsBank*, and *K12 Teaching and Learning Center*. For the Apple package, *AssessmentMaster* (Renaissance Learning) provides a formative assessment in all four core subject areas. Both the Dell and Region 1 ESC packages provide *i-Know* (CTB McGraw Hill) for core-subject assessment. In addition, all campuses have access to the online Texas Mathematics Diagnostic System (TMDS) and Texas Science Diagnostic System (TSDS) that are provided free of charge by the state.

Professional development

Each immersion package includes a different professional development provider. Apple uses its own professional development model, whereas the Dell package relies on *Pearson Learning Group*, a commercial provider (formerly *Co-nect*), to support professional development. Region 1 ESC uses a combination of service center support plus other services offered through *Connected Coaching and Connected University*. Although the professional development models and providers differ, they all were expected to include some common required elements, such as support for immersion package components, the design of technology-enhanced learning environments and experiences, lesson development in the core-subject areas, sustained learning opportunities, and ongoing coaching and support. Individual districts and campuses collaborated with vendors to develop specific professional development plans for their teachers and other staff.

Technical and pedagogical support

Each Technology Immersion package provider also is required to provide campus-based technical support to advance the effective use of technology for teaching and learning. Apple designed a Master Service and Support Program. Dell established a Call Center dedicated to technical support for TIP grantees as well as an 800 telephone number for hardware and software support. Region 1 ESC had an online and telephone HelpDesk to answer questions and provide assistance.

Appendix B

Table B1: Data Sources for Technology Immersion Implementation Indicators

Indicator	Source	Item Description	Index Score	Standards-Based Score
Leadership *(all teachers)*				
Cronbach's alpha = .97 (spring 2007)	Teacher survey	*Q11: Please indicate the extent of your agreement with each of the following statements.* c) The principal consults with staff before making decisions about instructional technology that affect us. d) In this school there are clear expectations that technology will be used to enhance student learning. j) The principal in my school actively encourages teachers to pursue professional development geared towards curricular integration of technology. o) Our school has a well-developed technology plan that guides all technology integration efforts. p) The principal is an effective leader for instructional technology in this school. q) Overall, considering the uses of technology in my school today, I am confident that this use is leading to increased student achievement. r) The principal encourages teachers to be innovative and try new methods. t) The principal is willing to support—through funding or manpower—teachers' efforts at technology integration. v) Administrators in this school help teachers to use technology to access, analyze, and interpret student performance data w) Teachers receive adequate administrative support to integrate technology into classroom practice. x) Teachers and administrators rely on research-proven teaching and learning principles in making decisions about technology use. y) When our school has professional development focused on technology, the principal often participates.	5-point scale *z* score	0 = Strongly Disagree 1 = Disagree 2 = Unsure 3 = Agree 4 = Strongly Agree
Teacher Support (Innovative Culture) *(all teachers)*				
Cronbach's alpha = .82	Teacher survey	*Q11: Please indicate the extent of your agreement with each of the following statements.* b) Teachers in this school share an understanding about how technology will be used to enhance learning. i) Teachers in this school are continually learning and seeking new ideas. k) Teachers are not afraid to learn about new technologies and use them with their class(es). aa) Teachers in this school are generally supportive of technology integration efforts.	5-point scale *z* score	0 = Strongly Disagree 1 = Disagree 2 = Unsure 3 = Agree 4 = Strongly Agree
Parent & Community Support) *(all teachers)*				
Cronbach's alpha = .84	Teacher survey	*Q11: Please indicate the extent of your agreement with each of the following statements.* f) Parents support our school's emphasis on technology. h) The surrounding community actively supports our instructional efforts with technology.	5-point scale *z* score	0 = Strongly Disagree 1 = Disagree 2 = Unsure 3 = Agree 4 = Strongly Agree

Table B1: Data Sources for Technology Immersion Implementation Indicators (continued)

Indicator	Source	Item Description	Index Score	Standards-Based Score
Technical Support *(all teachers)*				
Cronbach's alpha = .67	Teacher survey	*Q11: Please indicate the extent of your agreement with each of the following statements.* a) Most of our school computers are kept in good working condition. b) Internet connections in my class are often too slow or not working. c) My requests for technical assistance are addressed in a timely manner. d) Materials (e.g., software, printer supplies) for classroom use of computers are readily available in my school. e) Problems such as computers freezing or an inability to access the Internet make it difficult for me to use technology.	5-point scale *z* score	0 = Strongly Disagree 1 = Disagree 2 = Unsure 3 = Agree 4 = Strongly Agree
Professional Development *(core-subject teachers)*				
Contact Hours	Teacher survey	*Q20: Indicate the number of hours spent in technology-related professional development (PD) over the past school year (i.e., since August 1, 2006).*	Continuous variable 0 to *x* * *z* score	Continuous variable 0 to *x* * >= 3 *SD* from mean excluded
Classroom Support Cronbach's alpha = .67	Teacher survey	*Q12: About how often do you interact with colleagues in each of the following ways.* j) receive coaching or mentoring from an external (non-school) source such as a professional curriculum developer k) receive coaching or mentoring from an internal source, such as another teacher or technology coordinator	5-point scale *z* score	0 = Never 1 = Rarely (a few times a year) 2 = Sometimes (once or twice a month) 3 = Often (once or twice a week) 4 = Almost Daily
Content Focus Cronbach's alpha = .92	Teacher survey	If core-subject teacher participated in technology-related PD, *Q24: How much emphasis did the "most time" technology-related professional development activity give to each of the following areas?* a) Curriculum (e.g., units, texts, standards) b) Instructional methods d) Lesson development in English language arts, mathematics, science, or social studies [mean of teachers' responses pertinent to their subject-area assignments (e.g., math teachers rate math)]	3-point scale *z* score	0 = No Emphasis 2 = Minor Emphasis 4 = Major Emphasis

Table B1: Data Sources for Technology Immersion Implementation Indicators (continued)

Indicator	Source	Item Description	Index Score	Standards-Based Score
Professional Development *(core-subject teachers)*				
Coherence Cronbach's alpha = .92	Teacher survey	If core-subject teacher participated in technology-related PD, *Q27: To what extent was the "most time" technology-related professional development activity:* a) Consistent with your own goals for professional development b) Consistent with your school's or department's plan to change practice c) Based explicitly on what you had learned in earlier professional development experiences d) Followed up with activities that built upon what you learned in this professional development activity e) Designed to support state or district standards/curriculum frameworks f) Designed to support state or district assessment.	5-point scale *z* score	0 = Not at All 1 2 3 4 = Great Extent
Classroom Immersion *(core-subject teachers)*				
Technology Integration Cronbach's alpha = .93	Teacher survey	*Q12: Please indicate your present level of classroom technology implementation.* c) I alter my instructional use of the classroom computer(s) based upon the newest software applications and research on teaching, learning, and standards-based curriculum. d) My students discover innovative ways to use classroom computers to make a difference in their lives. e) I allocate time for students to practice their computer skills on the classroom computer(s). g) I integrate the most current research on teaching and learning when using the classroom computer(s). h) In my classroom, students use technology-based computer and Internet resources beyond the school (NASA, other government agencies, private sector) to solve authentic problems. i) My students' authentic problem solving is supported by continuous access to a vast array of computer-based tools and technology. k) I plan computer-related activities in my classroom that will improve my students' basic skills (e.g., reading, writing, math computation). l) It is easy for me to design student-centered, integrated curriculum units that use the classroom computer(s) in a seamless fashion. n) I seek out activities that promote increased problem-solving and critical thinking using the classroom computer(s). o) Using cutting edge technology and computers, I have stretched the instructional computing in my classroom.	7-point scale *z* score	0 = Not true of me now 1 = Somewhat true of me now 2 = Somewhat true of me now 3 = Somewhat true of me now 4 = Very true of me now

Table B1: Data Sources for Technology Immersion Implementation Indicators (continued)

Indicator	Source	Item Description	Index Score	Standards-Based Score
Classroom Immersion *(core-subject teachers)*				
Learner-Centered Instruction Cronbach's alpha = .81	Teacher survey	*Q12: Please indicate your present level of classroom technology implementation.* b) Students authentic use of information and inquiry skills guides the type of instructional materials used in my classroom. j) My students are involved in establishing indivual goals within the classroom curriculum. m) In addition to traditional assessments, I consistently provide alternative assessment opportunities that encourage students to "showcase" their content understanding in nontraditional ways. q) My instructional approach emphasizes experiential learning, student involvement, and students solving "real-world" issues.	7-point scale *z* score	0 = Not true of me now 1 = Somewhat true of me now 2 = Somewhat true of me now 3 = Somewhat true of me now 4 = Very true of me now
Student Classroom Activities Cronbach's alpha = .90	Teacher survey	*Q16: About how often do students in your typical class use technology in the following ways during class time. Students in my class use technology to...* a) express themselves in writing (e.g., word processing). b) learn and practice skills (e.g., instructional software or educational games). c) enter, calculate, and graph information (e.g., Excel spreadsheet). d) create a database of information for a class project (e.g., Filemaker Pro, Access). e) create and make presentations (e.g., PowerPoint). f) communicate by email with peers, experts, or others on topics they are studying. h) conduct Internet research on an assigned topic. i) conduct multimedia research (reference CDs, online encyclopedias). j) enhance or express conceptual understanding through simulation/modeling software. k) visually represent or investigate concepts (e.g., through concept mapping, graphing, reading charts). l) produce print products (e.g., desktop publishing). m) produce multimedia reports/projects (e.g., with video, graphics, and sound editing). n) analyze information using tools such as graphing calculators or digital microscopes. p) complete a test or quiz (e.g., online assessments, Texas Math Diagnostic System).	5-point scale *z* score	0 = Never 1.333 = Rarely (a few times a year) 2.667 = Sometimes (once or twice a month) 4 = Often (once or twice a week) or Almost Daily

Table B1: Data Sources for Technology Immersion Implementation Indicators (continued)

Indicator	Source	Item Description	Index Score	Standards-Based Score
Classroom Immersion *(core-subject teachers)*				
Communication Cronbach's alpha = .74	Teacher survey	*Q13: About how often do you use technology in each of the following ways? As a teacher I. . .* e) communicate with students. f) communicate with parents. g) communicate with colleagues/other professionals. m) post homework, class requirements, or project information on a website.	5-point scale *z* score	0 = Never 1 = Rarely (a few times a year) 2 = Sometimes (once or twice a month) 3 = Often (once or twice a week) 4 = Almost Daily
Professional Productivity Cronbach's alpha = .85	Teacher survey	*Q13: About how often do you use technology in each of the following ways? As a teacher I. . .* a) keep administrative records (e.g., attendance). b) manage student assessment data (e.g., electronic gradebooks). c) use technology to analyze and interpret student data to guide my instruction. d) create electronic lesson plans. h) create instructional materials (e.g., tests, handouts). i) gather information from the Internet to create a lesson (e.g., text, video, clipart). j) access model lesson plans integrating technology. k) deliver information using presentation software (e.g., PowerPoint). l) deliver information using multimedia presentations (text, audio, video, graphics). p) use the Internet at home for instructional purposes. q) use a computer to do schoolwork at home.	5-point scale *z* score	0 = Never 1 = Rarely (a few times a year) 2 = Sometimes (once or twice a month) 3 = Often (once or twice a week) 4 = Almost Daily

Table B1: Data Sources for Technology Immersion Implementation Indicators (continued)

Indicator	Source	Item Description	Index Score	Standards-Based Score
Student Access and Use				
Laptop Access Days	Student survey	*Q3.a: Does your school provide a laptop that you can use?* [Yes = 180 days, No = 0 days] *Q3.b: Have you had a laptop taken away from you for more than a class period?* [No = 180 - 0 days; Yes = 180 – Q3.d. no laptop days] *Q3.d: How many days was the laptop taken away?* [1 to 180]	Continuous variable 0 to 180 *z* score	Continuous variable 0 to 180 4 = Meet or exceed expectations 0–3.99 = proportional fraction of requirement [campus mean adjusted for variance (–2 SDs)]
Core Content Learning Cronbach's alpha = .73	Student survey	*Q6: About how often do you use technology in each of the following classes?* a) Reading/English language arts b) Math c) Science d) Social studies	5-point scale *z* score	0 = Never or Rarely (a few times a year) 1.333 = Sometimes (once or twice a month) 2.667 = Often (once or twice a week) 4 = Almost Daily
Home Learning	Student survey	*Q4.a: How often can you take a laptop home?* [0 = Never (no access); 1 = Only when I have a project or assignment or Other (restricted access) or As often as I want (full access)] *Q4.b: When you take a laptop home, how do you use it?* Homework for language arts (reading/writing) [+1] Homework for social studies [+1] Homework for science [+1] Homework for math [+1] Play games to learn [+1]	Continuous variable 0 to 6 *z* score	Continuous variable 0 to 6 0 = No access to laptop outside school 1 = Restricted or full access to laptop outside school + Laptop used for homework and/or learning outside of school (up to 5 points) 4 = Meet or exceed expectations 0–3.99 = proportional fraction of requirement
Implementation Index			**Composite *z* score**	

Appendix C

Table C1: Scoring Rubrics for Measuring the Implementation Fidelity of Technology Immersion

Component/ Element	Minimal Immersion 0–1.99	Partial Immersion 2.00–2.99	Substantial Immersion 3.00–3.49	Full Immersion 3.50–4.00	Implementation Index
Leadership					**Campus *z* Scores**
	Teachers *disagree or strongly disagree* that administrators establish clear vision and expectations, encourage integration, provide supports, and involve staff in decisions.	Teachers are *unsure* that administrators establish clear vision and expectations, encourage integration, provide supports, and involve staff in decisions.	Teachers *agree* that administrators establish clear vision and expectations, encourage integration, provide supports, and involve staff in decisions.	Teachers *agree or strongly agree* that administrators establish clear vision and expectations, encourage integration, provide supports, and involve staff in decisions.	
Teacher Support (Innovative Culture)					
	Teachers *disagree or strongly disagree* that they share an understanding of technology, continually learn, are unafraid, and support integration.	Teachers are *unsure* that they share an understanding of technology, continually learn, are unafraid, and support integration.	Teachers *agree* that they share an understanding of technology, continually learn, are unafraid, and support integration.	Teachers *agree or strongly agree* that they share an understanding of technology, continually learn, are unafraid, and support integration.	
Parent and Community Support					
	Teachers *disagree or strongly disagree* that parents and the surrounding community support the school's efforts with technology.	Teachers are *unsure* that parents and the surrounding community support the school's efforts with technology.	Teachers *agree* that parents and the surrounding community support the school's efforts with technology.	Teachers *agree or strongly agree* that parents and the surrounding community support the school's efforts with technology.	
Technical Support					
	Teachers *disagree or strongly disagree* that computers are in good condition, Internet connections are adequate, responses to requests are timely, and materials are available.	Teachers are *unsure* that computers are in good condition, Internet connections are adequate, responses to requests are timely, and materials are available.	Teachers *agree* that computers are in good condition, Internet connections are adequate, responses to requests are timely, and materials are available.	Teachers *agree or strongly agree* that computers are in good condition, Internet connections are adequate, responses to requests are timely, and materials are available.	

Table C1: Scoring Rubrics for Measuring the Implementation Fidelity of Technology Immersion (continued)

Component/ Element	Minimal Immersion 0–1.99	Partial Immersion 2.00–2.99	Substantial Immersion 3.00–3.49	Full Immersion 3.50–4.00	Implementation Index
Professional Development					**Campus *z* Scores**
Contact Hours	Core-subject teachers, on average, participated in 25 or less hours of PD during the past school year.	Core-subject teachers, on average, participated in 26 to 37 hours of PD during the past school year.	Core-subject teachers, on average, participated in 38 to 49 hours of PD during the past school year.	Core-subject teachers, on average, participated in 50 or more hours of PD during the past school year.	
Classroom Support	Core teachers indicate that they *rarely or never* receive classroom coaching or mentoring from an internal or external source.	Core teachers indicate that they *rarely* (a few times a year) receive classroom coaching or mentoring from an internal or external source.	Core teachers indicate that they *sometimes* (once or twice a month) receive classroom coaching or mentoring from an internal or external source.	Core teachers indicate that they *often* (once or twice a week) or almost daily receive classroom coaching or mentoring from an internal or external source.	
Content Focus	Core teachers indicate there is *no or almost no PD emphasis* on curriculum, instructional methods, and lesson development in core areas.	Core teachers indicate there is a *minor PD emphasis* on curriculum, instructional methods, and lesson development in core areas.	Core teachers indicate there is a *minor to major PD emphasis* on curriculum, instructional methods, and lesson development in core areas.	Core teachers indicate there is a *major PD emphasis* on curriculum, instructional methods, and lesson development in core areas.	
Coherence	Core teachers indicate that PD is *not at all* consistent with personal and school goals, prior learning, and state standards and assessment.	Core teachers indicate that PD is consistent with personal and school goals, builds on prior learning, and supports state standards and assessment to a *minimal extent*.	Core teachers indicate that PD is consistent with personal and school goals, builds on prior learning, and supports state standards and assessment to a *moderate extent*.	Core teachers indicate that PD is consistent with personal and school goals, builds on prior learning, and supports state standards and assessment to a *great extent*.	

Table C1: Scoring Rubrics for Measuring the Implementation Fidelity of Technology Immersion (continued)

Component/Element	Minimal Immersion 0–1.99	Partial Immersion 2.00–2.99	Substantial Immersion 3.00–3.49	Full Immersion 3.50–4.00	Implementation Index
Student Access and Use					**Campus *z* Scores**
Laptop Access Days	Students' laptop access days vary to an *extremely large extent* at a campus, with laptops available from about 80 to 168 days per student.	Students' laptop access days vary to a *large extent* at a campus, with laptops available from about 95 to 175 days per student.	Students' laptop access days vary to a *moderate extent* at a campus, with laptops available from about 140 to 175 days per student.	Students' laptop access days vary to a *small extent* at a campus, with laptops available from about 160 to 180 days per student.	
Core-Content Learning	Students *rarely* (a few times a year) *or never* use technology resources in core-subject classes	Students *sometimes* (once or twice a month) or *often* (once or twice a week) use technology resources in core-subject classes.	Students *often* (once or twice a week) or *almost daily* use technology resources in core subjects.	Students use technology resources in core subjects *almost daily*.	
Home Learning	Students, on average, use their laptops outside of school for homework or learning either *not at all* or to a *trivial extent*.	Students, on average use their laptops outside of school for homework and learning to a *small extent*.	Students, on average, use their laptops outside of school for homework and learning to a *moderate extent*.	Students, on average, use their laptops outside of school for homework and learning to a *large extent*.	

Table C1: Scoring Rubrics for Measuring the Implementation Fidelity of Technology Immersion (continued)

Component/ Element	Minimal Immersion 0–1.99	Partial Immersion 2.00–2.99	Substantial Immersion 3.00–3.49	Full Immersion 3.50–4.00	Implementation Index
Classroom Immersion					**Campus *z* Scores**
Technology Integration	Core teachers indicate it is *not true now* that I alter instructional practices, allocate time, integrate research on teaching and learning, improve basic skills, and support higher order thinking through technology.	Core teachers indicate it is *somewhat true now* that I alter instructional practices, allocate time, integrate research on teaching and learning, improve basic skills, and support higher order thinking through technology.	Core teachers indicate it is *somewhat* or *very true now* that I alter instructional practices, allocate time, integrate research on teaching and learning, improve basic skills, and support higher order thinking through technology.	Core teachers indicate it is *very true now* that I alter instructional practices, allocate time, integrate research on teaching and learning, improve basic skills, and support higher order thinking through technology.	
Learner-Centered Instruction	Core teachers indicate it is *not true now* that my students establish learning goals, use information and inquiry skills, complete alternative assessments, and have active and relevant experiences.	Core teachers indicate it is *somewhat true now* that my students establish learning goals, use information and inquiry skills, complete alternative assessments, and have active and relevant experiences.	Core teachers indicate it is *somewhat* or *very true now* that my students establish learning goals, use information and inquiry skills, complete alternative assessments, and have active and relevant experiences.	Core teachers indicate it is *very true now* that my students establish learning goals, use information and inquiry skills, complete alternative assessments, and have active and relevant experiences.	
Student Activities	Core teachers *rarely* or *never* have students use technology resources to support core-content learning.	Core teachers *sometimes* have students use technology resources to support core-content learning.	Core teachers *sometimes* to *often* have students use technology resources to support core-content learning.	Core teachers *often* to *almost daily* have students use technology resources to support core-content learning.	
Communication	Core teachers *rarely* or *never* use technology to communicate with students, parents, and colleagues or to post information on a class website.	Core teachers *sometimes* use technology to communicate with students, parents, and colleagues or to post information on a class website.	Core teachers *often* use technology to communicate with students, parents, and colleagues or to post information on a class website.	Core teachers *often* to *almost daily* use technology to communicate with students, parents, and colleagues or to post information on a class website.	
Professional Productivity	Core teachers *rarely* or *never* use technology to enhance their professional productivity (e.g., keep records, analyze data, develop lessons, deliver information).	Core teachers *sometimes* use technology to enhance their professional productivity (e.g., keep records, analyze data, develop lessons, deliver information).	Core teachers *often* use technology to enhance their professional productivity (e.g., keep records, analyze data, develop lessons, deliver information).	Core teachers *often* to *almost daily* use technology to enhance their professional productivity (e.g., keep records, analyze data, develop lessons, deliver information).	
Implementation Index					**Campus *z* Score**

Endnotes

1. Vernez, G., Karam, R., Mariano, L.T., & DeMartini, C. (2006). *Evaluating Comprehensive School Reform Models at Scale: Focus on Implementation*. Santa Monica, CA: RAND.
2. Standards-based scores for Professional Development, Classroom Immersion, and Student Access and Use are averages across elements of these components. These scores serve descriptive purposes. Composite z scores were used in statistical analyses.
3. Exploratory hierarchical regression analyses of the relationships between each of the elements of Immersion Support and each of the elements of Classroom Immersion, and students' reading and mathematics achievement yielded inconsistent coefficients (positive and negative). Variables typically were not statistically significant predictors of test scores.

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