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Technology and Education Change: Focus on Student Learning

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Abstract

This study examined technology implementation practices associated with student learning gains. Interviews and observations were conducted with staff at schools where teachers using reading or mathematics software with their students attained above-average achievement gains and at schools where software-using teachers had below-average gains. The findings highlight the importance of school practices in the areas of principal support and teacher collaboration around software use and of teacher practices concerning classroom management and use of software-generated student performance data. The issues of instructional coherence and competition for instructional time are highlighted as challenges to software implementation. (Keywords: Technology, implementation, software)

Observers of technology use in schools and classrooms have long noted the relatively modest use of educational technology within most schools and classrooms (Cuban, 2001). As the lives of students and teachers outside of school have evolved to include more and more use of technology, the situation presents a paradox. Despite decades of national, state, and local promotion of educational uses of technology, classroom practice in most schools has changed little from that of the mid-20th century. Recent large-scale national surveys of teacher practices with technology found an increase in teacher use of technology as a productivity tool supporting their own work between 2005 and 2007 but no increase in the level of teacher-assignment of technology-based learning activities for students during the same time period (Bakia, Means, Gallagher, Chen, & Jones, 2009). Teachers and students use technology more frequently outside of school than they do during class time.

Although many teachers certainly are using today's technologies in innovative ways, they remain the exception rather than the rule. In terms of Moore's (1999) innovation adoption model, few learning technologies have managed to "cross the chasm" from adoption by technology enthusiasts and visionaries to acceptance by the vast majority of teachers, who are pragmatists and conservatives.

Technology adoption and implementation require not just funding resources but also ongoing effort. The premise underlying this paper is that teachers' and school systems' fundamental priorities concern student

Table 1. Recommended School-Level Instructional Technology Practices

Implementation Recommendation	Recommended by	Prior Research Support for Practice: Correlation with Technology Use	Prior Research Support for Practice: Correlation with Learning Outcomes	Prior Research Support for Practice: Controlled Studies on Technology Use
Schoolwide Coherence				
Technology use integrated with a consistent school-wide instructional vision	Barnett (2002) Means & Olson (1995) OTA (1995)	Means & Olson (1995)		
Technology aligned with local curriculum	Barnett (2002) Ertmer (1999) Sarama et al. (1998) Sweet et al. (2004)			
Principal demonstration of support for technology integration	Brand (1997) Coley et al. (1997) OTA (1995)	Mann et al. (1998) O'Dwyer et al. (2004, 2005) Zhao et al. (2002)		
Teacher Training				
Teachers trained on concepts of student-centered teaching and technology integration	Barnett (2002)	Becker (1994, 2000) Mann et al. (1998) O'Dwyer et al. (2004, 2005) Zhao et al. (2002)	eMINTS (2003) Wenglinsky (1998)	
Teachers trained on implementation of the specific software/innovation	EETI vendors	Becker (1994) Mann et al. (1998) U.S. Department of Education (2000)	Mann et al. (1998)	
Professional development is ongoing, not one-time (e.g., mentoring or coaching)	Brand (1997) Jones et al. (1995) OTA (1995)	Adelman et al. (2002) Becker (1994) U.S. Department of Education (2000)	Cole, Simkins, & Penuel (2002)	
Professional development involves teachers in designing technology-supported learning activities/resources		Martin et al. (2003) Yamagata-Lynch (2003)		
Technology Access				
Computers/Internet accessible in regular classrooms	Barnett (2002) Mann et al. (1998) OTA (1995)	Becker (2000)	Mann et al. (1998)	
Adequate access to technology for all students	Barnett (2002)	O'Dwyer et al. (2004, 2005)		
Support for Technology Use				
Technical support available at the school	Barnett (2002) Sweet et al. (2004)	Becker (1994) Hill & Reeves (2004) Zhao et al. (2002)	Cole, Simkins, & Penuel (2002)	
Teachers collaborate around technology use	Brand (1997)	Becker (2000) Frank, Zhao, & Borman (2004) Means & Olson (1995) Zhao et al. (2002)		

Table 2. Recommended Classroom-Level Instructional Technology Practices

		Prior Research Support for Practice		
Recommendation (1)	Recommended by (2)	Correlation with Technology Use (3)	Correlation with Learning Outcomes (4)	Controlled Studies on Learning Outcomes (5)
Integration of technology with learning goals and offline learning activities		Becker (1994) Means & Olson (1995)	Wenglinsky (1998)	
Technology used frequently	Van Dusen & Worthen (1995)		Mann et al. (1998) Wenglinsky (1998)	
Teacher present and facilitates learning when technology is used		Sandholtz et al. (1997)		Powell et al. (2003)
Teacher reviews software reports				Powell et al. (2003)
Efficient routines established for shifting in and out of technology use (classroom management)	Coley et al. (1997)	OTA (1995)		
Low student-to-computer ratio in classroom	Barnett (2002) Glennan & Melmed (1996) OTA (1995)	O'Dwyer et al. (2004, 2005)	Cavalier & Klein (1998)	

learning outcomes. Most educators will expend the effort needed to integrate technology into instruction when, and only when, they are convinced that there will be significant payoffs in terms of student learning outcomes. Hence, to make technology an agent of education change, the field needs to understand the kinds of learning outcomes that technology can enhance and the circumstances under which that enhancement will be realized in practice. Sound guidance on how to implement technology in ways that produce student learning gains is integral to efforts to use technology as a lever for education change.

As illustrated in Tables 1 and 2, an extensive literature on "best practices" in technology implementation does exist. The first column in Table 1 lists common recommendations for school-level practices in support of instructional uses of technology.

The first column of Table 2 lists commonly recommended teachers' classroom practices with respect to technology implementation.

These tables also show that, in most cases, the basis for recommending the implementation practices is expert opinion or a correlation between the practice and the observed extent of technology use. Only a handful of articles document a correlation between an implementation practice and student learning outcomes. Very few studies with a rigorous, controlled design have examined the effects of one of the recommended technology implementation practices on student learning outcomes. A formal search of the ERIC and PsychInfo databases to identify empirical studies using a control group design (either experimental or quasi-experimental) was conducted in support of a large research study (Dynarski et al., 2007) sponsored by the Institute of Education Sciences. Only a single published study meeting these criteria (Powell, Aeby, & Carpenter-Aeby, 2003) was identified through this search.[1] Powell, Aeby, and Carpenter-Aeby (2003) found that teacher presence during use of instructional software and teacher review of software reports of student performance on the software produced greater student learning. Hence, we are urging schools and teachers to implement technology with little or no empirically based guidance on how to do so in ways that enhance student learning.

An implication of the discussion above is that technology implementation practices need to be investigated in conjunction with studies of technology effects on student learning. Unfortunately, few large-scale studies have measured both effects of technology on student learning and technology implementation practices. A prominent exception is the congressionally mandated national experiment on the Effectiveness of Educational Technology Interventions (EETI), which examined the effects of reading software for students in grades 1 and 4 and of mathematics software for students in grade 6 and algebra classes (Dynarski et al., 2007). EETI found that, on average, the effect size for using reading or mathematics software was not statistically different from 0 at any of the four grade levels included in the study. Within each grade level and product, the classes using the software did better than those that did not at some schools, whereas the classes using their conventional approaches did better than those using the software at other schools. The only significant relationships between effect sizes and software implementation variables found in this study were larger effects in classes with more students per computer in grade 1 (contrary to a common recommendation for technology implementation) and a relationship between effect size and the amount of time students spent using the reading software in fourth grade (Dynarski et al., 2007).

In contrast, a study of a large urban district's implementation of the Waterford early reading software by Hansen, Llosa, and Slayton (2004) found that the amount of time students spent with the software was not correlated with measures of student learning. A randomized control trial of Accelerated Reader conducted by Nunnery, Ross, and McDonald (2006) found no relationship between the study's quality of implementation index and student achievement growth. In short, despite the existence and extensive dissemination of conventional wisdom concerning how technology should be implemented, the evidence base for recommending particular practices is neither deep nor internally consistent.

The research reported here was conducted with a subset of the EETI school sample to provide insights for those responsible for implementing

1 Subsequent work with the technology implementation research uncovered a quasi-experimental study (Cole, Simkins, & Penuel, 2002) that found student learning benefits associated with teachers' receipt of support from school-based technology integration specialists skilled in the design of project-based learning activities involving student use of multimedia technology.

reading and mathematics software by providing a closer look at school and classroom implementation practices. This study contrasts practices in schools whose students had above-average achievement gains in their first year of software use as part of the EETI study with those of schools where treatment classes had below-average gains. This correlational analysis used implementation data from the EETI study as well as data from a set of follow-up interviews and observations conducted with staff at 13 schools continuing to use the software they had implemented the prior year as part of the EETI study.

This study focused on two central questions:

- What classroom-level practices are associated with higher achievement gains in classrooms using reading or math software?
- What school-level practices are associated with higher achievement gains in classrooms using reading or math software?

To explore issues of software implementation, analysts identified those EETI schools where software-using teachers' students experienced above-average achievement gains and those whose students had below-average gains in the first year of the EETI software effectiveness study.[2] From these two school subsamples, 14 schools were selected for follow-up—7 in the above-average group and 7 in the below-average group. The 14 selected schools were using seven different software products (four reading products and three mathematics products) and included an above-average- and a below-average-gain school for each product. For each product, researchers looked for a high-gain school with a positive effect size and above-average use of the software for which a low-gain school matched on student demographic variables could be identified. For each product, schools were selected to be as similar as possible except for their differing levels of student gains.

The 14 schools selected for case study were contacted in April 2006 to ascertain whether they would be willing to participate in this follow-up data collection by completing phone interviews or hosting a site visit. All of the schools initially agreed to participate, but one of the low-gain schools subsequently dropped out of the data collection, resulting in a follow-up sample of 13 schools, as shown in Table 3 (p. 290).

By virtue of the selection process, the two groups of schools differed in average class standardized achievement gain (0.77 for the high-gain group versus -0.70 for the low-gain group). As intended, they were very similar in terms of variables related to their staff and student populations. The proportions of students eligible for free or reduced-price lunch, for example, were 57% and 56% in high- and low-gain schools, respectively.

The schools in the case study sample were using seven software products—four reading products and three mathematics products. Table 4 (p. 291) shows

2 Identification of the schools for case studies was based on information made available from the Effectiveness of Educational Technology Interventions (EETI) study (Dynarski et al., 2007).

Table 3. Characteristics of High- and Low-Gain Schools in the Follow-Up Sample

Variable	High-Gain Schools (n = 7)	Low-Gain Schools (n = 6)
Teacher experience level (years)	8.8	12.7
Teacher certification (percent)	79	83
Urban schools (percent)	71	50
Free/reduced-price lunch (percent)	57	56
African American (percent)	32	36
Hispanic (percent)	16	31
Special education (percent)	10*	3
Student-to-teacher ratio	18.0	16.0
Pretest score (standardized)	-0.14	0.21
Gain score	0.77*	-0.70

** Significant at p* < .05.

the number of classrooms using each product and the instructional features of those products, as judged by instructional design experts on the research team.[3]

Method

One pair of schools (a high- and a low-gain school both using the same product) at each grade level was designated for a site visit, which would involve interviews with the principal or other school leader and the school technology coordinator (if there was one), as well as with each teacher who had participated in the treatment condition in the EETI study. Site visits also involved observing each teacher twice—once while using the software with students and once while teaching the relevant subject (math or reading) without the software.[4] For follow-up schools that did not receive a site visit, researchers conducted phone interviews with the principal, technology coordinator, and teachers using the same interview protocols employed on the site visits. They used the same interview protocols for high-gain and low-gain schools, and site visitors and did not inform interviewers of the school's categorization as high or low gain.

Analysts blind to the level of gains a school or teacher had experienced during their first year of software use coded the data obtained through interviews and observations for descriptions of school practices (such as principal support), classroom practices (actions undertaken by individual teachers), conditions (demographic variables and other characteristics existing prior to software implementation), and perceived outcomes. Data coding began with two analysts independently coding each paragraph of

3 The coding team developed a set of instructional features, such as incorporation of practice opportunities, on which all software products could be judged. Two coders independently reviewed products, retaining feature categories for which intercoder agreement was 80 percent or better.

4 In some cases, this protocol had to be modified for elementary reading because the implementation model for the product was to have a portion of the students working independently on computers, whereas another portion worked with the teacher in a small group during all reading instruction.

Table 4. Instructional Features of Case Study Software Products

Product Type/ Code	No. Case Study Classes Using	Learning Opportunities		Individualization									Types Feedback to Teachers			Types Feedback to Students					
				Automatic			Teacher Input			Student Input						Immediate		Mastery		Diagnostic	
		Tutorial	Practice	T	P	A	T	P	A	T	P	A	Student Mastery	Learning Paths	Class Performance	P	A	P	A	P	A
Grade 1 Reading A	5	Many	Many	●	●	●	●	●	●		●		●	●	●	●		●	●	●	
Grade 1 Reading B	5	Many	Many	●	●		●	●	●				●		●	●	●		●	●	●
Grade 4 Reading A	4	Some	Many	●	●	●		●	●	●	●		●	●	●	●			●	●	
Grade 4 Reading B	2	Some	Many	●	●	●		●	●		●		●	●	●	●		●	●		
Grade 6 Pre-Algebra A	4	Many	Many	●	●	●	●	●	●	●	●	●	●	●	●	●				●	
Algebra A	4	Few	Many		●	●		●	●	●	●		●	●	●	●		●			
Algebra B	3	Many	Many	●	●	●	●	●	●	●	●	●	●	●	●	●				●	

Source: Staff review.

Key: T = Tutorial mode; P = Practice mode; A = Assessment mode

Definitions:

Immediate feedback: Learner is told whether response is correct immediately after completing module

Mastery feedback: Learner informed of number correct and whether or not a skills or concept has been acquired after completing a sequence of items

Diagnostic feedback: Learner receives hints or other information concerning probably source of error the data forms for two schools. Interrater agreement for the independent coding was greater than 75%. A single analyst conducted the remaining coding. The coded data was entered into a qualitative analysis software database (ATLAS.ti) to facilitate identification of examples of particular practices and analysis of differences between high- and low-gain schools in terms of both teachers' classroom practices and schoolwide supports for software implementation.

Results

The differences the analysts identified between high- and low-gain schools are reported below for teachers' classroom practices as they use the software and for schoolwide supports for software implementation.

Teacher Implementation Practices

Level of software use. Teachers participating in the EETI software effectiveness study received training on use of the software, which included specification of the amount of time they should give students on the software each week. Software vendors' recommendations for weekly use of their products ranged from 75 to 135 minutes. When each teacher's reported use was compared to the usage recommended for the product in that class, the proportion of teachers meeting or exceeding vendor usage specifications in high-gain schools, at 64%, was not significantly different from that in low-gain schools (50%). The average weekly number of minutes teachers reported in high- and low-gain schools was roughly equivalent (119 and 102 minutes, respectively). Teacher reports indicated that the great majority of teachers were making a good-faith effort to have their students spend a significant amount of time with the software, and thus it is possible that level of use would be more strongly associated with achievement in implementations where usage levels varied more widely.

Although the amount of time that teachers reported having their students use the software was not associated with student gains in the case study sample (or in three of four grades for the EETI sample as a whole), there was a significant relationship between student gains and the point in the school year when classes started software use. On average, teachers in the high-gain case study schools started software implementation 4.5 weeks after school started, whereas teachers in low-gain schools did not begin until 7.7 weeks into the school year. The later start in low-gain schools did not appear to decrease the total number of hours the average student received on the software, as logged by the six software products from which such record could be obtained. The average annual software exposure was 23.1 hours for students in high-gain schools and 23.3 for students in low-gain schools. It may be that the speed with which a school ramped up for software implementation was influenced by other factors that can also influence technology implementation, such as the quality of the school's technology infrastructure and support or the school's overall management efficiency.

Classroom management. In interviews, teachers talked about the need to develop classroom routines for moving onto and off the software. A number of the teachers said that students needed to learn how to execute this transition and log on and off the software independently for the class to run smoothly. When asked what advice they would give another teacher using the software for the first time, teachers were more likely to provide recommendations on classroom management than on any other topic.

For those teachers who were observed in the act of teaching, all of the teachers in high-gain schools were rated as effective in terms of classroom management compared to just 17% of observed teachers in low-gain schools.[5] Thus, effective classroom management routines for software use appear to be important. In observed classrooms, effective classroom management appeared to allow greater focus on the instructional activities of the software rather than the logistics of its use. Ironically, this aspect of implementation is seldom mentioned in the literature on educational technology "best practices."

Facilitation during software use. Software vendors recommend that the regular classroom teacher be present while their students use instructional software. In addition to managing classroom behavior and activity flow, teachers also provide more or less substantive support for students' learning during periods when they are using the software. Software products are typically designed so that students can use them independently, but technology advocates often make the case that by engaging all students in learning independently, the software provides the opportunity for teachers to interact one on one with those students needing the most help.

Nearly all of the case study teachers (25 of 27) reported being present in the room while their students used the software. Observed teachers varied, however, in the amount of substantive support they provided for students' learning during software use. Some of the case study teachers were observed rotating through the room of software-using students, identifying students who were experiencing difficulty and working with them one on one. For example, in one sixth grade mathematics class using software in a computer lab, the teacher circulated around the room, interacting not only with students who raised their hands but also with students she observed to be progressing slowly (Means et al., 2006):

> The teacher helped one student who asked, "When you have a + and - sign, which do you keep?"
>
> "Think about what the sign needs to be to get you to +2x," the teacher said as she directed the student's attention to what he had written on a piece of

5 Classroom management quality was judged on the basis of the proportion of time the class spent in learning and instruction, as opposed to moving around, preparing materials, or student disruptions.

> scrap paper. "Think about that. That gets you to -2x + x….There you go, look at that! Good."
>
> The student responded, "Right, right, thank you," and the teacher moved on to another student who had looked up for help.

In a sixth grade mathematics classroom at another school, the teacher was in the room as students worked with the software but spent about half of the class period on activities such as grading homework and talking on the phone that did not support students' work with the software.

The observed quality of teacher facilitation was measured for only the six teachers in the follow-up sample who could be observed teaching with the software during the school site visits, and two thirds of the observed teachers in both high- and low-gain schools engaged in facilitation of learning in the software sessions the researchers watched.

Articulation and integration of instruction with and without software. Coordination of learning done through the software with instruction in the same topic that does not involve software emerged as an issue in interviews with the case-study teachers. None of the classes did all of their reading or mathematics learning through software. Five of the seven software products in this study were designed as supplements to regular instruction rather than as the core reading or mathematics curriculum. Even in classrooms using a mathematics product intended as the core curriculum, the product included offline as well as technology-based activities and materials. For products intended as supplements, the software was not a component of the core curriculum, and therefore teachers were using software produced by one vendor and a textbook or other set of core-curriculum instructional materials from another source. This situation raised several challenges for the teacher. First, the teacher must coordinate the topics across the two sets of instructional materials. Most of the software products allow teachers flexibility in sequencing software modules so that the use of software on a given topic or skill can be fit into a logical place in the core curriculum. Although quite feasible, this effort does take time. Teachers at some of the case-study schools reported that they had not worked through the software themselves or compared its coverage to that of their core curriculum to identify areas of overlap prior to implementing the software with their students. In some cases, teachers were aware that they could change the sequence of the software modules to match what they were doing in class, but had not done so. As one teacher said, "A lot of times we just let it [the software] roll the kids into the next level."

Other teachers did take the time to become familiar with the software and think about how to articulate the software modules with classroom activities. A high school algebra teacher, for example, chose the software modules her students would use each week based on what she would be teaching in the classroom. In addition to instances of adapting the sequence of software activities to match what was happening in the core curriculum, there were also instances of teachers adapting what they did in class on the basis of insights gained from observing students working with the software.

This observation from a first grade class implementing reading software illustrates the way in which students' software-based activity can influence a teacher's core instruction (Means et al., 2006):

> The first grade teacher began by reviewing the vowels. In her interview, the teacher said she did this because she had heard one of the students singing an "a-e-i-o-u" song from the software during lunch. She said that she often listened to students humming to themselves or singing songs from the software and used that as an indication of where they were in the software and where their skills might need reinforcing.

A second issue related to integrating software use and other instruction is the way that concepts or procedures are presented. This appeared to be particularly troublesome in mathematics, when different terminology and different procedures for handling problems of the same type were likely to be conveyed in the textbook and in the software. Mathematics teachers at one school found this discrepancy to be so confusing to their students during the first year of using the software that they decided not to teach the same topic with the textbook and the software in close temporal proximity in the second year, reasoning that students would be less confused by the representation of something in the software if they had had time to forget how it was presented in the text.

Analysts coded teachers' observed practices as their students were using software (where available) for evidence that the teachers were helping students integrate ideas and representations covered by instruction with and without software so that students could make connections between what they learned through the two modalities.[6] A high school algebra class provided an example of a teacher bringing content from the software into her classroom instruction (Means et al., 2006):

> The high school algebra class returned from the computer lab and sat down in rows of desk chairs facing the blackboard. At 2:55 p.m. the class began with the teacher saying, "Some of you were looking at this in the computer lab." She then began talking about simplifying rational expressions and went through some problems on the board.

We also observed examples of teachers referring to what the students had experienced in class as the students were working with software in the computer lab, as illustrated by the observation below from a middle school mathematics class (Means et al., 2006):

6 Unless there was evidence of a lack of implementation of nonsoftware components, those teachers who used a core curriculum product with both computer-based and non-computer-based material were coded as having integrated software use and other instruction.

> As students worked with the math software in the computer lab, their teacher looked for students with raised hands or puzzled looks and provided individual assistance. The students were working with problems calling for them to do arithmetic operations with combinations of positive and negative integers. After noting that several of the students were struggling, the teacher addressed the class as a whole: "Remember when you add integers, use those algebra tiles we talked about in class. Red was for positive numbers and blue for negative numbers." (The software uses a number line depiction rather than algebra tiles, but it also uses red for negative numbers and blue for positive numbers.)

There were too few observations of software use during the follow-up study to support firm conclusions, but teachers' responses to interview items about integration of software-based and other instruction did suggest a relationship between integration and gains. Eighty-six percent of teachers in high-gain schools said that they had done this kind of integration, compared to 77% of teachers in low-gain schools.

Those teachers who actively facilitate their students' work with software are in a position to adapt their non-technology-based instruction by drawing on insights gained from interactions with the software. The software in essence provides the teacher with formative assessments, which research suggests can improve learning if the teacher uses them to guide future instruction (Black & Wiliam, 1998). Some of the case study teachers described this kind of practice. An algebra teacher, for example, reported that she finds that helping students individually while they are using the software is a good way of gauging their understanding and identifying areas to reteach. She said that students "who won't ask questions in the classroom will ask in the computer lab because they don't feel so much on the spot." She described her practice of taking the questions that students asked in the computer lab back into the classroom and reteaching concepts as needed.

Use of software data to inform instruction. Software vendors have long urged teachers to run the automated reports provided by their products and review them on a regular basis. Typically, these reports provide data on individual student progress through and mastery of the various software skill modules, as well as summary-level information for the class as a whole. Although the vendors' recommendation is rooted in concerns over teachers' support for software use and the desire to make sure the software is used appropriately, this practice appears to have broader benefit. Teachers at the high-gain schools in the follow-up sample reported doing frequent review of the student performance reports the software generates. Seventy-eight percent of the teachers in high-gain schools said they looked at software reports for all their students once a week or more, compared to 17% of teachers in low-gain schools. Thus, use of software-generated data reports was one of the largest differences between high-gain and low-gain implementations. Although it may be that achievement-oriented teachers implement many useful practices in addition to looking at data, our qualitative data are consistent with the hypothesis that the use of student performance information generated by software products helps teachers target their instruction to the things that students need to learn. Two examples illustrate teachers' use of the detailed student progress reports generated by software systems (Means et al., 2006):

> A fourth grade teacher reported that she looked at the software student performance reports on a monthly basis to monitor student progress and check what students were working on. She used the results of one report to group students during the core reading instruction time by topic mastery, allowing her to differentiate the pacing of her core instruction. "These kids are working on similes; these kids are working on context clues. I tried to coordinate it," she said. She also used software reports during parent–teacher conferences to emphasize or clarify a point she wanted to make with parents about their child's progress.
>
> A teacher at another elementary school said she looked at the software reports often and used the data to decide how to group students in her class. She said she also looked at the software "to help with words for class and give students individualized spelling words based on where they are in the software." The reports helped her decide what to teach, based on where students were in the software and how they were doing. "I love using those reports and being able to see exactly where kids are," she said. "I can sit down with a parent in a conference, and there's no guessing on my part."

Developing a system to motivate software use. Some of the software vendors recommend instituting a motivational system around software use—creating a visible chart showing modules completed, giving certificates for accomplishments on the software, or using software performance in grading. Some of the individual teachers in both the high-gain and the low-gain schools described setting up such systems, usually in the form of a public chart showing each student's record of software module completion. The difference between teachers in high-gain schools and those in low-gain schools in use of this technique was not significant. Moreover, when the correlation between this technique and gain score is computed for all EETI treatment classrooms, a negative relationship between this practice and student gains is found (perhaps because teachers whose students are not progressing resort to extrinsic rewards).

Table 5 (p. 298) summarizes the differences between teachers in high- and low-gain schools in terms of teacher-level software implementation practices.

Table 5. Teacher Implementation Practices in High- and Low-Gain Schools

Practice	Teachers in High-Gain Schools	Teachers in Low-Gain Schools
	Teacher-Reported Practices a	
Met vendor software weekly usage guideline	64%	50%
Reviewed software reports for all students weekly	78%	17%
Integrated software use with other instruction	86%	77%
Instituted motivational system	64%	46%
	Observed Practices b	
Managed classroom effectively	100%	17%
Facilitated learning during software use	67%	67%

a Number of teachers responding to interview item varied between 12 and 14 for the two sets of schools.

b Number of teachers observed and scored on a variable varied between 3 and 6 for the two sets of schools.

School-Level Implementation Practices

In addition to teacher behaviors and choices that teachers make about how to implement software with their students, the school as a whole provides supports for software implementation. The interviews that researchers conducted with school staff participating in the follow-up study addressed some broader school implementation issues that had not been covered in the EETI data collection. These include integration of technology use with a schoolwide instructional vision, principal support for use of the software, and teacher collaboration around software use. Additional schoolwide practices related to software implementation that were documented as part of the effectiveness study include the technology infrastructure, technical support, and receipt of additional formal training on software use or implementation. High- and low-gain schools were contrasted in terms of all of these schoolwide practices.

Consistent instructional vision. In schools with a consistent instructional vision, the principal and the treatment teachers expressed similar coherent views of how the subject (reading or mathematics) should be taught and the role that the software should play in implementing that instructional vision. Such consistency can be illustrated by reports from the staff of a large middle school serving a low-income student body that included many students who were not yet fluent in English (Means et al., 2006):

> All of the interviewed staff indicated that their top priority was to achieve the state/district content standards on the schedule designated in the district's instructional guide and pacing chart. The principal and both software-using teachers noted in separate interviews that many of their students did not come in with the skills that the district's instructional guide assumed and that, although they were supposed to be teaching the more advanced skills in the district instructional guide, they also needed to work on basic skills for students who had not yet mastered them. They

> all cited the software as useful for this purpose. They thought it would be better if students acquired basic skills before being moved to more advanced mathematics, but had concluded that they had to teach both together and saw the software as a useful tool for doing so.
>
> The majority of high-gain schools (four of seven) were coded as having a consistent instructional vision. In contrast, only two of six low-gain schools were judged to exhibit this kind of consistency. Lack of a consistent view of the software's role was illustrated by the staff in a low-gain school, as described below (Means et al., 2006):

The principal had little involvement with the study and was unsure how well the software fit with current schoolwide initiatives. One of the two teachers using the software taught low-skilled and English-language-learner students and said that the software would be good for honors students but not for his students because the language and concepts were too advanced. The other software-using teacher taught honors students and said that they got bored with it, but he expected that the software would be good for remediation.

Principal support. In addition to being instrumental in forging a consistent instructional vision, principals can provide support for use of instructional software, not just in the form of permission and supportive verbal statements but also in terms of concrete actions, such as giving the classes using the software priority access to computer resources and arranging for joint planning periods or other paid opportunities for teachers to gain proficiency with the software and to plan for its use. The majority of high-gain schools in the follow-up sample (five of seven) had principals who supported the software implementation in those ways; the majority of low-gain schools (four of six) did not.

Teacher collaboration. Beyond the support from the principal, support from one's colleagues appears to be another factor present in schools that achieve learning gains with technology. All seven of the high-gain schools that could be scored for this variable reported that their teachers collaborated and supported each other on use of the software product. Only one third of the low-gain schools (two of six) reported this kind of teacher collaboration.

Two teachers at an elementary school implementing the reading software illustrated the kind of teacher collaboration found in the high-gain schools (Means et al., 2006):

> Collaboration between the two teachers using the software at this elementary school was very close. The younger teacher, who was in her second year of teaching, "handles the technical side, does reports, registers kids." The older, veteran teacher mentored her younger colleague on instructional strategies for elementary reading. They planned together at the beginning of the year and got together throughout the year to look at software reports and discuss student progress. One of the teachers noted

Table 6. Proportion of Schools with Schoolwide Practices and Supports, by Gain Status

Practice or Support	High-Gain Schools (n = 7)	Low-Gain Schools(n = 6)
Consistent instructional vision	4 of 7	2 of 6
Principal support for software use	5 of 7	2 of 6
Teacher collaboration around software use	7 of 7	2 of 6
Satisfactory onsite technical support	6 of 7	3 of 6
Receipt of additional formal training	3 of 7	1 of 6
Receipt of informal face-to-face support	5 of 7	3 of 6
Access to help desk, e-mail, website	6 of 7	5 of 6

that they even "get in competition a little with the scores." The school's technology coordinator commented that "they work well together; they're both committed to the program."

A number of researchers have suggested that the presence of strong ties among teachers who view themselves as a learning community will facilitate the adoption of technology (Frank, Zhao, & Borman, 2004; Strudler & Hearrington, 2008). In these case studies, however, there was no difference between the proportions of high- and low-gain schools in the follow-up sample that were judged to emphasize teacher collaboration generally (five of seven high-gain schools and four of six low-gain schools described themselves as collaborative). This finding suggests that the focus of the collaboration, not just a generally supportive climate, is important.

Technology infrastructure and technical support. In implementing the EETI effectiveness study, the research team took steps to make sure that each school had the technology infrastructure needed to implement the software assigned to treatment classrooms. The study team worked with districts to identify hardware and software needs such as computers, headphones, memory, and operating system upgrades, and the study purchased the upgrades as needed. Thus, all of the schools in the case studies (as well as those in the larger EETI study) had technology infrastructures that were, at least in theory, adequate for running the assigned reading or mathematics software.

When we asked case study teachers about the technology support available to them, we found that high-gain schools nearly always had on-site technical support that teachers considered good (six of seven high-gain schools). Half of the case study low-gain schools (three of six) were similarly happy with their on-site support while half were not. Hence, the qualitative data suggest that the quality of on-site technology support, rather than its mere presence, is important and that good local support is not sufficient but may be necessary to ensure positive outcomes with technology.

Receipt of additional training and support. In a typical implementation of commercial software, the school or district purchasing the software has the option of obtaining training and support services from the vendor. In the

EETI study, these services were provided by vendors as part of the agreement around their participation. All of the commercial vendors with a product in the study conducted formal initial training for the teachers who would be implementing their software. In addition to this formal training, vendors were permitted to provide additional formal training sessions during the school year, face-to-face informal support as part of school visits, or assistance through a help desk, email or a web site. Somewhat larger proportions of the high-gain schools received additional formal training and face-to-face informal support from the software vendors, but the differences were not dramatic and the samples are small. A similarly large majority of teachers in both high- and low-gain schools reported having access to technical assistance in the form of a help desk, e-mail, or website supporting use of the software.

Table 6 summarizes the differences between high- and low-gain schools in terms of schoolwide implementation practices.

Changes in Implementation Practices from Year 1 to Year 2

Many changes in implementation practices in teachers' second year with the software appeared to reflect teachers' increased knowledge and confidence around software use. Nearly half of the teachers reported that technology problems were reduced in their second year of software implementation. Teachers at six of the 13 follow-up schools reported fewer technology problems in Year 2. One of these schools had gained a technology coordinator, and two schools that had had major start-up delays in Year 1 did not have this same problem in their second year of implementation. Teachers also credited their own increased familiarity with technology and with the programs for a decrease in technology problems. Technology problems do not always disappear with experience, however; two schools said that they had had more rather than fewer technology problems in Year 2. In both cases, a change in the school's technology infrastructure required reconfiguration of the technology for running the software.

One might expect teachers' increasing comfort with the technology to lead to more software use in their second year of implementation, but this was not the case. Nine teachers from five different schools reported using the software for less time in Year 2 than in Year 1, and only one teacher reported increased use. Time pressures and competition with other school improvement initiatives were the most frequently cited reasons for reducing the amount of time devoted to software use during the second year of implementation. Three of the schools where there was less software use in the second year had introduced a new core curriculum in the area covered by the software. Teachers said that the new curriculum required adjustment on their part and integrating the software with the new curriculum was difficult. At one of these schools, for example, teachers felt the new curriculum required them to do more whole-class instruction, making it more difficult to find time for software use.

Discussion

The findings from this study generally are consistent with the usual recommendations for school-level supports for technology in the education literature but are less similar to common recommendations for practices within classrooms implementing technology. The four school-level practices for which the study found support were:

- Establishment of a consistent instructional vision
- Principal support for software use
- Teacher collaboration around software use and
- Satisfactory on-site technical support.

These recommendations are among those commonly made in the educational technology literature (as shown in Table 1, p. 286).

The classroom-level practices receiving the strongest empirical support from this study were:

- Reviewing software reports for all students weekly and
- Managing the classroom effectively.

Similar practices can be found in Table 2 (p. 287; "Teacher reviews software reports" and "Efficient routines established for shifting in and out of technology use"), but there are fewer citations for them in the literature than there are for other practices, such as a low student-to-computer ratio, that did not receive empirical support either in the qualitative study of 27 classrooms reported here or in the large EETI study involving 132 classrooms.

One implication of this study for classroom practice and software implementation efforts is that teachers should be urged to capitalize on the assessment data that instructional software makes available. Most instructional software will adapt the learner's experience to the results of embedded assessments automatically. But teachers can use the software assessment reports also to identify specific areas where they can do more to support students during their regular classroom instruction, as was described by a number of case study teachers. Software reports can also bring to light individual students' motivational issues or learning disabilities that might have gone unnoticed during whole-class instruction.

A second implication is that training and support around instructional software should pay more attention to the details of classroom management. Teachers work with classes of different sizes, in different physical settings, and with different kinds of students. One of the teachers in the EETI study, for example, taught pre-Algebra to a large class of students in a space intended as a lecture hall. Students were widely spaced out in seats with small flip-up arms designed to hold a pad of paper. Distributing laptop computers and juggling papers and computers at the same time under such conditions is a challenge. Teachers also have different habitual routines for organizing and orchestrating class activities. All of these factors can influence the ease with which students can be transitioned into and out of technology-based activities. As with professional development on other aspects of teaching, it would be helpful for teachers to be able to observe examples of efficient routines for transitioning in and out of software use within the kind of setting in which they teach, and then to try out their transition strategy in their own classroom and school, with the opportunity to receive feedback and suggestions for improvement from experienced software-using coaches.

The study has implications also for future research. It raises but does not resolve questions about how teachers can best facilitate their students' work as students are engaging with software designed for independent individual use. The literature on classroom implementation of technology highlights the role of the teacher as a facilitator of students' technology use. This facilitative role is usually described as a move toward student-centered instruction and away from the more typical teacher role of directing classroom activities. However, other than giving students more responsibility, there is actually very little guidance in the literature about the most effective teacher facilitation practices when students are working with software. In these case studies, researchers categorized an identical percentage (67%) of observed teachers in high- and low-gain schools as "facilitating" students' use of software. It would be premature to suggest that teachers' facilitative behaviors do not affect student-learning gains, but this null result does suggest a need for a more precisely defined concept of teacher facilitation during software use. In interviews, teachers report gaining insights into their students' thinking by observing or working with students who are engaged with instructional software. But how should the teacher interact with the student to best support his or her learning with the software? When should teachers give answers and when should they give hints to students struggling with the online content? Should teachers attend primarily to motivational and behavioral issues or treat their students' software use as a "teachable moment" for individual students? Establishing an empirical basis for making recommendations in these areas requires theory development around facilitation, the development of reliable measures of different aspects of facilitation, and a program of systematic research.

Given the relatively small number of case study schools and of software-implementing teachers within those schools, findings from the present study should be interpreted with caution. Certainly failure to find significant differences between high-and low-gain schools in terms of an often-recommended implementation practice could be attributable to limited statistical power. But those implementation variables for which significant differences did emerge, especially in cases where the case study data and the larger EETI data set provide converging evidence, merit attention. Here we have evidence that the practice is associated with learning gains, not just more frequent use of technology.

The descriptive data presented in the appendixes also highlight larger issues having to do with the way teachers juggle the requirements of software implementation with everything else they are trying to do in the classroom.

Case study interviews and observations point to the need for more contextualized studies and a broader view of technology implementation. Rather than treating technology as a "thing" which is present or absent, researchers and educators need to look at instructional activity systems in context. Any piece of hardware or software is but a part of the instruction that students are exposed to in a given domain. The importance of teacher management of transitions onto and off of software, teachers' articulation of connections between online and offline instruction, and teachers' struggles to fit technology-based learning activities into schedules dominated by core curricula that are not technology-based underline the importance of taking this broader view.

Building on the concept of an instructional regime, as described by Cohen and Ball (1999), educators and policymakers need to stop thinking of learning software as an intervention in and of itself and to think instead of broader instructional activity systems (Roschelle, Knudsen, & Hegedus, 2009) defined by:

- Learning content
- Learning activities, only some of which are technology-based
- Articulation between a given learning activity system and other systems the student is exposed to
- Teacher professional development and collaboration around implementation of the instructional activity system
- Assessments for learning
- Use of data to refine the instructional activity on an ongoing basis.

Such a framework has obvious implications for intervention design and what may be less-obvious implications for research. We need to get beyond the simplistic "what works" view of learning technology as a "pill" that will have the same effect on outcomes for anyone in any context. We have ample evidence that implementation practices matter, and the instructional activity system framework suggests basic categories for the kinds of data that should be collected in any study of a technology-supported intervention in action.

The learning technology field needs implementation research contrasting the student outcomes produced by different implementation strategies and practices for the same intervention, not just comparisons of treatment versus no-treatment conditions. Education policymakers and practitioners need to think about the implementation of technology-supported interventions as a process of iteration and refinement rather than as a pill to be selected on the basis of "what works" evidence. Partnerships between the teachers, schools, and districts implementing technology-supported reforms and those who design and research such reforms can support a process of collaborative elaboration and adaptation of the intervention to fit local circumstances, followed by a cycle of implementation with monitoring of both the implementation process and outcomes for students. Findings of the implementation cycle can then inform another round of intervention refinement, again followed by implementation, monitoring, and improvement. Only by defining, measuring, and analyzing implementation variables and context along with student outcomes (Means & Penuel, 2005) can we gain the understanding that will support the implementation of technology-supported interventions in a way that optimizes student learning.

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