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The Digital Learning Classroom: Improving English Language Learners' academic success in mathematics and reading using interactive whiteboard technology

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ABSTRACT

This study presents the findings from the first-year evaluation of the Round Rock Independent School District's (ISD) Digital Learning Classroom project, an initiative focused on the improvement of English Language Learners' (ELL) learning using interactive whiteboard (IWB) technology. An objective of the evaluation was to determine the extent IWB technology could foster performance parity in academic achievement between ELL and regular students, that is, reduce the student achievement gap between these two student groups in 3rd and 5th grade mathematics and reading. These grade levels and subjects were the primary focus of the project because students in grades 3 and 5 that do not pass the state's standardized assessments in mathematics and reading cannot be promoted to the next grade level and therefore, these are "high stakes" tests for students. A second evaluation objective was to determine whether and the extent to which the Digital Learning Classroom could increase ELL students' academic learning relative to that of ELL students in traditional classrooms (i.e., without IWBs). Using a quasi-experimental design, the results strongly indicate that IWBs can foster performance parity thereby closing the achievement gap between ELL and regular students while increasing ELL student achievement. Pedagogical implications for teachers of ELL students within the context of Digital Learning Classroom project implementation are presented, as well as recommendations for future study of the Digital Learning Classroom in ELL classroom settings.

1. Introduction

Performance disparities in academic achievement between English Language Learners (ELL) and regular (non-ELL) students are thoroughly documented by the US National Assessment of Educational Progress (NAEP). For example, the 2005 NAEP results indicate that 54% of 4th grade ELL students scored at or above the basic achievement level in mathematics compared to 83% of 4th grade regular students, a performance gap of 29%. The results also show that 27% of 4th grade ELL students scored at or above the basic achievement level in reading compared to 67% of 4th grade regular students, a performance gap of 40% (NCES, 2005).

Similar performance disparities can be found in states with large populations of ELL students. Texas educates one the largest population of ELL students in the nation—second only to California. In school year 2005–2006, Texas public schools served 657,716 students in ELL programs, about 14.6% of the total student population (TEA, 2006). The 2006 Texas Assessment of Knowledge and Skills (TAKS) statewide test results indicate that 73% of ELL students in grades 3, 4, and 5 scored at or above the minimum passing standard in mathematics compared to 86% of regular students, a performance gap of 13%. The results also indicate that 77% of ELL students in these grades scored at or above the minimum passing standard in reading compared to 90% of regular students, also a performance difference of 13% (Lopez, 2008).

This study presents the findings from the first-year evaluation of the Round Rock Independent School District's (ISD) Digital Learning Classroom project, an initiative focused on the improvement of English Language Learners' (ELL) learning using interactive whiteboard (IWB) technology. The IWB technology consisted of a large, wall-mounted electronic board connected to both a ceiling-mounted LCD projector and a laptop computer that can connect to the internet via the school's wireless network. The LCD projector displays the image from the computer screen on the board. The laptop computer can then be controlled by touching the board with a wireless hand-held pen device that functions much like a PC mouse. An electronic slate also was a component of the district's Digital Learning Classroom. It is a wireless,

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Table 1
TAKS mathematics and reading performance—school year 2005–2006 for the three school-wide ELL campuses in Round Rock ISD.

	TAKS mathematics performance			TAKS reading performance		
Grade	ELL % passing	Regular % passing	Gap (±)	ELL % passing	Regular % passing	Gap (±)
3rd	60% (90)	81% (118)	−21%	89% (94)	95% (117)	−6%
5th	62% (78)	81% (134)	−19%	64% (77)	83% (135)	−19%

Note: Number of students tested in parentheses. *Source:* Lopez (2008).

fully integrated, mini-board that is small enough to sit on a student's desk and can be moved around the classroom. The electronic slate operates using the wireless pen-like device to communicate with the IWB.

Round Rock ISD is a growing urban district located in central Texas, educating over 38,000 students from early childhood programs through grade 12. About 2800 or 7.4% of these students are ELL in grades Kindergarten through grade 5. In school year 2005–2006, TAKS performance for ELL students in grades 3 and 5 was below that of regular students in the district's three school-wide ELL campuses, as shown in Table 1.

An objective of the evaluation was to determine the extent IWB technology could foster performance parity in academic achievement between ELL and regular students, that is, reduce the student achievement gap between these two student groups in 3rd and 5th grade mathematics and reading. These grade levels and subjects were the primary focus of the project because students in grades 3 and 5 that do not pass the state's standardized assessments in mathematics and reading cannot be promoted to the next grade level and therefore, these are "high stakes" tests for students. A second evaluation objective was to determine whether and the extent to which the Digital Learning Classroom could increase ELL students' academic learning relative to that of ELL students in traditional classrooms (i.e., without IWBs).

The article is divided into six main sections. In Section 2, a theoretical framework will be presented that supported the district's implementation of the Digital Learning Classroom project. Section 3 provides an overview of the district' implementation plan followed by the research design and methodology used to carry out the project evaluation. Section 4 presents the results from the evaluation by grade level per TAKS test area. Section 5 begins with a discussion of the findings organized by research question. Pedagogical implications for teachers of ELL students within the context of Digital Learning Classroom project implementation are then presented, as well as recommendations for future study of the Digital Learning Classroom in ELL classroom settings. Section 6 concludes the article with final insights regarding the use of IWBs in ELL classroom settings.

2. Theoretical framework

The peer-review literature is presently void of empirical studies that investigate the efficacy of IWB technology in affecting student learning. Rather, most evaluations of the technology have relied on classroom observations and surveys of teachers and students to investigate the impact of IWBs primarily as a tool for teaching and secondly, as a tool for enhancing student engagement. Higgins, Beauchamp, and Miller (2007) and Smith, Higgins, Wall, and Miller (2005) provide excellent reviews of this literature. Two more recent studies available on the internet did examine the impact of IWBs on student learning, as measured by standardized assessments. However, the researchers report either small effect sizes (Higgins et al., 2005), or they did not employ more rigorous experimental or quasi-experimental designs with comparison control groups to validate the effects from the IWB technology on student learning (Somekh et al., 2007).

In the review of the literature for the planning of the project in spring 2006, studies were found that investigated the efficacy of various technologies on student learning in the classroom. Such technologies included wireless laptops (Barak, Lipson, & Lerman, 2006; Varvel & Thurston, 2002); electronic decision boards (Zha, Kelly, MeeAeng, & Fitzgerald, 2006); hand-held computing and video devices (Margolis, Nussbaum, Rodriguez, & Rosas, 2006; Patten, Arnedillo-Sanchez, & Tangney, 2006; Segall, Doolen, & Porter, 2005; Swan, Van't Hooft, Kratcoski, & Unger, 2005); computer-assisted problem-solving systems (Chang, Sung, & Lin, 2006); electronic video games (Rosas et al., 2003); and web-based mediated instructional systems (Tuckman, 2002).

The positive results reported in these studies suggested that the IWB technology should make a contribution to ELL students' academic learning because these technology interventions were represented in some form or another in the Digital Learning Classroom. What these studies and the IWB literature could not provide to district staff was insight into how to implement an IWB classroom that would result in higher levels of student learning.

Given the lack of IWB empirical studies in the peer-review literature, the district's implementation of the Digital Learning Classroom project was guided by five principles of effective instructional practice identified by the National Research Council (NRC) in their synthesis of the research from the fields of cognitive, developmental and educational psychology, and brain research on how people learn.

NRC's (2000) first principle of effective instructional practice states that students' learning builds on their previous experiences. Studies have found that teachers can use IWBs to link students' prior experience with new learning, for example, by bringing their home culture, interests, and experiences into the classroom through digital images, music, and multimedia. The result is that teachers can use IWBs to create learning environments where students are able to construct their own knowledge as teachers scaffold students' learning with new content knowledge (BECTA, 2003; Burden, 2002; Miller & Glover, 2002).

NRC's (2000) second principle of effective instructional practice states that learning takes place in a social setting. In classroom assignments where students present and discuss their own work with other students, or become involved in class-wide activities, IWBs have technology features that allow students to annotate, conceal, manipulate, move and zoom in on or focus on images, including text (Bell, 2002; Edwards, Hartnell, & Martin, 2002; Levy, 2002; Thomas, 2003). This is the reason Kennewell (2001) argues that students must be allowed to use interactive whiteboards themselves. Such interactive group-settings motivate students because the students' interactions within the context of these technology features make lessons more enjoyable and interesting, resulting in improved attention, engagement, and student behavior essential to the learning process (Beeland, 2002).

NRC's (2000) third principle of instructional practice states that knowledge taught in a variety of contexts is more likely to support learning across students with diverse learning needs. One way that IWBs can promote student learning among diverse learners is by providing visual context through its multimedia and multi-sensory capacity. For example, teachers have reported that the IWB's capacity to present a range of multimedia resources efficiently helps students learn. This is not only because students have more information available to them. Students also benefit from access to a wider variety of information where they can explore their ideas and concepts within different contexts and thereby find new concepts easier to assimilate (Levy, 2002). Thus, teachers can more easily accommodate a wider range of student learning styles using IWBs when needed for particular students' needs (Bell, 2002; Billard, 2002).

NRC's (2000) fourth principle of instructional practice states that connected, organized and relevant information supports students' learning of knowledge but also helps them develop higher-order thinking skills. Project-based learning, thematic instruction, and cooperative grouping are examples of strategies that teachers use to engage students in such learning. These strategies give students opportunities to talk about shared learning experiences and to engage in hands-on, experiential learning experiences that promote learning of new material. IWBs can help students in this latter process by making available multimedia, simulations, and modeling (Bell, 2002; Levy, 2002; Thomas, 2003; Walker-Tileston, 2004).

NRC's (2000) fifth principle of instructional practice states that feedback and active evaluation of learning furthers students' understanding and skill development. Using IWB-based programs, teachers can incorporate short-cycle assessments into their lesson presentations to measure how students are progressing through the learning process (Miller & Glover, 2002; Richardson, 2002).

Students' response to these short-cycle assessments can occur in a number of ways using the IWB. At the simplest level, a student can provide a response directly through the board's interface, or with a hand-held radio controlled response system that allows students to select an answer from among a set of responses. IWB-based programs can give students instant feedback to questions or the computer can store and analyze student responses to questions for teachers to review with students to identify opportunities for re-learning that leads to student success (Miller & Glover, 2002; Richardson, 2002). With the advancement of speech synthesis and recognition technologies, students today can also carry on near natural conversations with an IWB-based computer program around pre-selected and programmed topics (Bell, 2002; Butler-Pascoe & Wiburg, 2003; Levy, 2002; Thomas, 2003).

3. Project implementation

In August 2006, the district's director of ELL programs asked principals at three school-wide ELL elementary schools to select teachers to implement the project. One principal selected four teachers, two each from grades 3 and 5. Another principal selected two teachers in 5th grade, while the third principal selected one 3rd grade teacher to implement the Digital Learning Classroom. The principals' primary selection criteria were based on their perceptions of the teachers, in terms of their willingness to undertake the intensive on-going technology training, ability to design new untried curriculum materials built around the IWB technology, and confidence to self-initiate changes in instructional practices, where needed. The principals were free to consider other criteria like the teachers' recent experience with ELL

Table 2
Prior Year TAKS mathematics and reading performance of selected Digital Learning Classroom (DLC) teachers and non-selected teachers per grade group.

Spring 2006 TAKS mathematics performance					Spring 2006 TAKS reading performance				
DLC	Teacher	Students	% Pass	% ELL	DLC	Teacher	Students	% Pass	% ELL
Elementary school A									
	3rd A	22	86.4	100		3rd A	22	100	100
3rd	3rd B	19	84.2	15.8		3rd C	11	90.9	7.7
	3rd C	11	81.8	9.1		3rd D	14	85.7	100
	3rd D	14	50.0	100	3rd	3rd B	19	84.2	15.8
	3rd E	12	25.0	100		3rd E	12	58.3	100
	4th A	13	92.3	38.5		4th C	19	94.7	100
	4th B	12	91.7	35.7		4th D	12	83.3	100
	4th C	19	84.2	100		4th A	13	76.9	38.5
	4th D	12	75.0	100		4th B	12	66.7	0.0
	4th E	9	66.7	0.0		4th E	9	66.7	0.0
3rd	4th F	8	12.5	87.5	3rd	4th F	8	37.5	87.5
	5th A	18	77.8	0.0		5th C	19	73.7	0.0
5th	5th B	20	70.0	0.0		5th A	18	72.2	0.0
	5th C	19	68.4	0.0	5th	5th B	20	70.0	0.0
5th	5th D	23	60.9	100		5th E	13	46.2	100
	5th E	13	30.8	100	5th	5th D	23	34.8	100
Elementary school B									
5th	3rd A	17	94.1	0.0	5th	3rd A	17	100	0.0
	3rd B	15	80.0	0.0		3rd C	13	100	100
	3rd C	13	76.9	100		3rd D	16	93.8	0.0
	3rd D	16	75.0	0.0		3rd B	15	86.7	0.0
5th	5th A	14	100	0.0	5th	5th A	11	100	0.0
	5th B*	79	62.0	25.3		5th C*	79	55.7	25.3
Elementary school C									
	3rd A	15	100	6.7		3rd C	16	93.8	0.0
	3rd B	14	71.4	0.0		3rd A	15	86.7	6.7
	3rd C	16	68.8	0.0		3rd E	12	83.3	100
	3rd D	19	57.9	100		3rd B	14	78.6	0.0
	3rd E	12	41.7	100		3rd D	19	63.2	100

* Teachers assigned to instruct in a specific subject area for the entire day. *Source:* Lopez (2009).

students and their students' prior year performance on the TAKS mathematics and reading assessments. Table 2 provides some insight into the extent that the principals' selection of teachers was influenced by these other criteria.

The table shows that the principal in elementary school (A) did not select teachers with the highest performing students based on their prior year's TAKS mathematics and reading assessments. Nor did this principal limit the selection of teachers to those with recent ELL experience, as indicated by the 0% of ELL students (% ELL) in the selected teachers' prior year classroom assignment (e.g., teacher 5th B). This principal even went so far as to re-assign a 4th grade teacher with the lowest performing students in both mathematics and reading to a "high stakes" 3rd-grade Digital Learning Classroom. Thus, the principal's selection of teachers was not significantly influenced by their students' prior year performance on the TAKS mathematics and reading assessments or entirely influenced by the teachers' recent experience with ELL students.

In comparison, the principal in elementary school (B) selected teachers with the highest performing students on the prior year's TAKS mathematics and reading assessments. However, this principal did not seriously consider the teachers' recent experience with ELL students, as indicated by the zero percentage of ELL students (% ELL) in the selected teachers' prior year classroom assignment. Furthermore, the principal also assigned a teacher from a "high stakes" 3rd grade classroom to a "high stakes" 5th grade Digital Learning Classroom suggesting the principal may have had great confidence or a belief that this teacher could transfer his or her teaching effectiveness from one grade to a higher grade level.

Similarly, the principal in elementary school (C) could have selected a high performing teacher like "3rd A" whose students in the prior year passed both the TAKS mathematics and reading assessments with a 100% and 86.7% pass rate, respectively. Furthermore, this teacher had some recent experience with ELL students (% ELL = 6.7%). Note in the table that there is no teacher in elementary school (C) with a grade in the "DLC" table columns which indicates the selected teacher's Digital Learning Classroom assignment. There is no selected teacher in the table for elementary school (C) because the principal chose instead to assign the Digital Learning Classroom to a third-grade teacher new to the school and the district and therefore, with no prior available record of performance based on students' results on the TAKS assessments. This suggests that the principal's selection of teachers for the Digital Learning Classroom project was not significantly influenced by their students' performance on the prior year's TAKS mathematics and reading assessments or by the teachers' recent experience with ELL students.

Taken as a whole, the teachers selected for the Digital Learning Classroom project may not have been the best candidates, as defined by *tangible* qualities like their recent experience with ELL students or their effectiveness in the classroom—as measured by their students' prior year performance on the TAKS mathematics and reading assessments. Nevertheless, the teachers selected were the best candidates to implement the Digital Learning Classroom because they possessed those *intangible* qualities, as defined by the primary selection criteria, that principals believed were essential to the project's success. The implication is that any lack of or negative results from the project could be attributed to the selected teachers' *tangible* qualifications. In comparison, any positive results from the project could be more attributed to the teachers' successful implementation of the Digital Learning Classroom project, which was guided by the five basic principles identified by the National Research Council (2000).

Meanwhile, the director of ELL programs assigned a curriculum specialist to support the select teachers in implementing the project. The IWB hardware components were not installed until late October; however, the software was installed on the curriculum specialist's computer at the start of school in mid-August. In this interim time period, an IWB technology consultant trained the curriculum specialist on how to use the board's software. Guided by the NRC (2000) framework, the curriculum specialist worked concurrently with the teachers to adapt their ELL curriculum and select instructional practices that would tap into the board's capabilities to enhance ELL students' learning. When the Digital Learning Classrooms became operational in late October, the teachers were ready to engage their students in using the IWB technology.

3.1. Research design

The quasi-experimental evaluation research design consisted of two sources of student-level data for 3rd and 5th grade students from the three participating elementary schools: the district's benchmark test data for mathematics and reading from fall 2006 and TAKS test data for mathematics and reading from spring 2007.

The district's benchmark test data contained mathematics and reading scale scores for each student tested. The TAKS test data contained the students' mathematics and reading scale scores and test results (pass or fail) at the Met and Commended standards. The Met standard represents the minimum performance level that students need to achieve to demonstrate they are ready for promotion to the next grade level, while the Commended standard represents a higher performance level indicating a student has mastered the entire curriculum for that grade level.

Both the TAKS and the benchmark data contained a unique 6-digit identifier for each student tested. Using this student identifier, the two sources of student-level test data were linked together to create the final data set for analysis. Table 3 shows the number of students with linked test records for each grade level and test area.

The final data set also contained a teacher identifier for each student, and these teacher-identifiers were flagged in the data records to indicate if the teacher taught in a Digital Learning Classroom with IWB technology, or in a traditional classroom without the technology. Furthermore, the final data set contained the students' status as either ELL or regular (non-ELL). Thus, three classroom types emerged from

Table 3
Number of Students with linked data in study by subject tested per grade.

	TAKS/benchmark linked data		
Grade	All students	Mathematics	Reading
3rd	213	204 (95.8%)	183 (85.9%)
5th	151	143 (94.7%)	113 (74.8%)

Note: Percent of all students with a test record in a subject area in parentheses.

Table 4
Number of students with linked data in study by classroom type and subject tested per grade.

Classroom Type	Students	Mathematics	Reading
3rd grade, n = 213			
Regular/traditional classrooms	76 [35.7%]	71 (93.4%)	61 (80.3%)
ELL/traditional classrooms	118 [55.4%]	116 (98.3%)	104 (88.1%)
ELL/Digital Learning Classrooms	19 [8.9%]	17 (89.5%)	18 (94.7%)
5th grade, n = 151			
Regular/traditional classrooms	81 [53.6%]	78 (96.3%)	55 (67.9%)
ELL/traditional classrooms	51 [33.8%]	47 (92.2%)	41 (80.4%)
ELL/Digital Learning Classrooms	19 [12.6%]	18 (94.7%)	17 (89.5%)

Note: Percent distribution of students within a grade level across the classroom types shown in brackets; percent distribution of students within a classroom type tested in mathematics or reading shown in parentheses.

Table 5
Students' language proficiency levels by classroom type per grade.

Classroom type	Students	L1-Bilingual	L1-ESL	L2-M1	L2-M2	Regular
3rd grade, n = 213						
Regular/traditional classrooms	76 [35.7%]			1 (1.3%)		75 (98.7%)
ELL/traditional classrooms	118 [55.4%]	113 (95.8%)	5 (4.2%)			
ELL/Digital Learning Classrooms	19 [8.9%]	15 (78.9%)	4 (21.1%)			
5th grade, n = 151						
Regular/traditional classrooms	81 [53.6%]			7 (8.6%)	9 (11.1%)	65 (80.3%)
ELL/traditional classrooms	51 [33.8%]	46 (90.2%)	5 (9.8%)			
ELL/Digital Learning Classrooms	19 [12.6%]	17 (89.5%)	2 (10.5%)			

Note: Percent distribution of students within a grade level across the classroom types shown in brackets; percent distribution of students within a classroom type across the language proficiency levels shown in parentheses.

the combination of this teacher and student data: ELL students in Digital Learning Classrooms which defined the treatment group; and two comparison control groups—regular students in traditional classrooms and ELL students in traditional classrooms. Table 4 shows the number of students in the final data set with linked test data in mathematics and reading for each of the three classroom types by grade level.

The TAKS test data further delineates the students' ELL status by their level of language proficiency. Table 5 provides a description of the students' language proficiency level for each of the three classroom types by grade level.

ELL students identified as L1-Bilingual are limited English proficient learning in state-approved bilingual programs where teachers are providing them with content matter instruction primarily in the students' native language and where possible, in English. In this study, the students' native language is exclusively Spanish. The district's bilingual program model is dual-language in that ELL students learn their core subjects (math, science, social studies, and reading) in both Spanish and in English with the goal of transitioning and exiting from the bilingual classroom to an English-only, non-ELL classroom.

Students identified as L1-ESL are limited English proficient learning in state-approved English as a Second Language (ESL) programs where teachers are providing them with content matter instruction in English. Observe in Table 5 that ELL classrooms have both L1-Bilingual and L1-ESL students. Because the state's bilingual certification also allows teachers to teach ELL students in ESL programs, bilingual and ESL students are found often in the same ELL classroom in Texas public schools.

Students identified as L2 met the state's criteria for bilingual/ESL program exit and therefore are no longer limited English proficient (LEP). Based on state law, however, the district must monitor their first-year and second-year academic progress after exiting a bilingual or ESL program to ensure the students' transition to an English-only, non-ELL classroom was successful. L2-M1 and L2-M2 students are those in their first-year and second-year of district monitoring, respectively. Students identified as Regular are English proficient in that their native language was English or they are post-L2-M2 students. Thus, L2-M1, L2-M2, and regular students are often found in the same classroom in Texas public schools that serve large populations of ELL students in bilingual/ESL programs.

3.2. Methodology

Given the project's goals of performance parity and increasing ELL student achievement, three research questions guided the project's evaluation:

- Was performance parity achieved between ELL and regular students in traditional classrooms?
- Was performance parity achieved between ELL students in Digital Learning Classrooms and regular students in traditional classrooms?
- Did student achievement increase for ELL students in Digital Learning Classrooms compared to ELL students in traditional classrooms?

Using the benchmark and TAKS test data, a pass rate comparison, chi-square test, and least-square means *t*-test were the primary methods used to address each research question. The pass rate comparison considered the magnitude of the difference noted in the TAKS Met pass rates between two classroom types against criteria that defined a performance status. To validate or confirm the pass rate comparison results, the chi-square test was used to determine if, for any two classroom types, students' TAKS test results (pass or fail) were related to their assigned type of classroom. The statistical outcomes were then compared against criteria that defined a performance status.

The third analysis consisted of using the least-squares means t-test to determine if the TAKS score means between classroom types were statistically different. In this analysis, the students' scores from the benchmark tests administered by the district in the middle of the fall 2006 semester were entered first into the regression model to statistically control for differences in their academic preparation at the start of the Digital Learning Classroom project in late October. Thus, any remaining statistical difference, or lack thereof, between the TAKS score means could be attributed to the effect from the three classroom types rather than to differences in students' prior academic preparation. The statistical result for any two classroom types was then compared against criteria that defined a performance status.

Table 6 provides a list of the variables and definitions used in the subsequent tables that present the criteria and performance status for each method used to address the research questions in this study.

Table 7 provides a framework for evaluating questions 1 and 2, related to the project's goal of performance parity. The framework consists of criteria that define a performance status of parity, disparity, or reverse disparity of ELL students in traditional classrooms or ELL students in Digital Learning Classrooms relative to regular students in traditional classrooms.

Parity indicates comparable test performance between ELL and regular students; disparity indicates that ELL students have performed significantly below that of regular students. *Reverse disparity* is the opposite of disparity—that is, a condition where ELL students have significantly outperformed regular students.

Table 8 provides a framework for evaluating question 3 related to the project's goal of increasing ELL student achievement. The framework consists of criteria that define a performance status of comparable, inferior, and superior for ELL students in Digital Learning Classrooms relative to ELL students in traditional classrooms.

In addition to the estimates, computations, and statistics from the chi-square and t-test procedures, an effect size construct was developed for the pass rate comparisons. For questions 1 and 2, the effect size was calculated by taking the ELL students' pass rate and subtract-

Table 6
Variable definitions for Tables 7–12.

Variable	Definitions
pELL	TAKS Met pass rate for ELL students traditional classrooms or Digital Learning Classrooms
pELL (t)	TAKS Met pass rate for ELL students in traditional classrooms
pELL (dlc)	TAKS Met pass rate for ELL students in Digital Learning Classrooms
pRegular (t)	TAKS Met pass rate for regular students in traditional classrooms
μELL	TAKS score mean for ELL students in traditional classrooms or Digital Learning Classrooms
μELL (t)	TAKS score mean for ELL students in traditional classrooms
μELL (dlc)	TAKS score mean for ELL students in Digital Learning Classrooms
μRegular (t)	TAKS score mean for regular students in traditional classrooms

Table 7
Framework for evaluating performance parity performance status criteria by evaluation method.

Evaluation method/criteria	Performance status
Pass rate comparison	
pELL = pRegular (t) *within a ± 5% threshold*	Parity
pELL < (pRegular (t) − 5%)	Disparity
pELL > (pRegular (t) + 5%)	Reverse disparity
Chi-square test	
No significant statistical difference between pELL and pRegular (t)	Parity
Significant statistical difference at $p < .05$ level when pELL < pRegular (t)	Disparity
Significant statistical difference at $p < .05$ level when pELL > pRegular (t)	Reverse disparity
Least-square means t-test	
No significant statistical difference between μELL and μRegular (t)	Parity
Significant statistical difference at $p < .05$ level when μELL < μRegular (t)	Disparity
Significant statistical difference at $p < .05$ level when μELL > μRegular(t)	Reverse disparity

Table 8
Framework for evaluating increase in ELL student achievement performance status criteria by evaluation method.

Evaluation method/criteria	Performance status
Pass rate comparison	
pELL(dlc) = pELL (t) *within a ± 5% threshold*	Comparable
pELL (dlc) < (pELL (t) − 5%)	Inferior
pELL (dlc) > (pELL (t) + 5%)	Superior
Chi-square test	
No significant statistical difference between pELL (dlc) and pELL (t)	Comparable
Significant statistical difference at $p < .05$ level when pELL (dlc) < pELL (t)	Inferior
Significant statistical difference at $p < .05$ level when pELL (dlc) > pELL (t)	Superior
Least-square means t-test	
No significant statistical difference between μELL (dlc) and μELL (t)	Comparable
Significant statistical difference at $p < .05$ level when μELL (dlc) < μELL (t)	Inferior
Significant statistical difference at $p < .05$ level when μELL (dlc) > μELL (t)	Superior

ing from it the regular students' pass rate. This resultant was then divided by 5 producing a measure (±) that defined the magnitude of the performance difference relative to the ±5% parity threshold shown in Table 7. Similarly, for question 3 the effect size was calculated by taking the pass rate of ELL students in Digital Learning Classrooms and subtracting from it the pass rate of ELL students in traditional classrooms. This resultant was then divided by 5 producing a measure (±) that defined the magnitude of the performance difference relative to the ±5% comparable threshold shown in Table 8. Thus, an effect size less than −1 is associated with disparity or inferior performance; between −1 and +1, inclusive, is associated with parity or comparable performance; and greater than +1 is associated with reverse disparity or superior performance. The following section presents the results from the analysis of the data organized by TAKS test area and grade level.

4. Results

4.1. 3rd grade TAKS mathematics performance

Table 9 summarizes the results from the pass rate comparison, the chi-square test, and the least-squares means *t*-test analysis used to evaluate the project's goals of performance parity and increasing ELL student achievement in 3rd grade mathematics.

The results indicate performance disparity in 3rd grade mathematics between ELL and regular students in traditional classrooms. The pass rate of ELL students (69.0%) is −15.5% below that of regular students (84.5%)—an effect size −3.1 times below the ±5% parity threshold. The chi-square test also validates this performance disparity in pass rates at the $p < .05$ level. Similarly, the *t*-test indicates significant statistical difference in the disparate score means between ELL and regular students at the $p < .05$ level.

In contrast, the results confirm that the Digital Learning Classroom achieved the project's goal of performance parity in 3rd grade mathematics between ELL students and regular students in traditional classrooms. The ELL students' pass rate (82.4%) is only −2.1% below that of regular students (84.5%)—an effect size of −0.4, well within the ±5% parity threshold. Performance parity was also validated in that the chi-square test indicated no significant statistical difference in the pass rates between these two classroom types ($p = 0.8273$). Likewise, the *t*-test indicates no significant statistical difference in the score means between ELL and regular students ($p = 0.1294$).

The results are mixed with regards to the Digital Learning Classroom attaining the project's goal of increasing ELL student achievement in 3rd grade mathematics. The performance of ELL students in Digital Learning Classrooms (82.4%) is +13.4% above that of ELL students in traditional classrooms (69.0%)—an effect size +2.7 times above the ±5% comparable threshold. Still, the chi-square test did not validate this pass rate performance difference ($p = 0.2575$) and, the *t*-test indicated no significant statistical difference in the score means between these two classroom types ($p = .7345$).

4.2. 5th grade TAKS mathematics performance

Table 10 summarizes the results from the pass rate comparison, the chi-square test, and the least-squares means *t*-test analysis used to evaluate the project's goals of performance parity and increasing ELL student achievement in 5th grade mathematics.

The results indicate performance disparity in 5th grade mathematics between ELL and regular students in traditional classrooms. The pass rate of ELL students (66.0%) is −18.6% below that of regular students (84.6%)—an effect size −3.7 times below the ±5% parity threshold. The chi-square test also validates this performance disparity in pass rates at the $p < .05$ level. Similarly, the *t*-test indicates significant statistical difference in the disparate score means between ELL and regular students at the $p < .001$ level.

In contrast, the results confirm that the Digital Learning Classroom achieved the project's goal of performance parity in 5th grade mathematics between ELL students and regular students in traditional classrooms. The ELL students' pass rate (88.9%) is +4.3% above that of regular students (84.6%)—an effect size of +0.9, well within the ±5% parity threshold. Performance parity was also validated in that the chi-square test indicated no significant statistical difference in the pass rates between these two classroom types ($p = 0.6433$). Likewise, the *t*-test indicates no significant statistical difference in the score means between ELL and regular students ($p = 0.0893$).

Table 9
3rd grade TAKS mathematics analysis results.

Analysis and parameters		Performance parity		
		ELL/traditional classrooms	ELL/Digital Learning Classrooms	ELL increased student achievement
Pass rate comparison				
pELL (dlc)	($n = 17$)		82.4%	82.4%
pELL (t)	($n = 116$)	69.0%		69.0%
pRegular (t)	($n = 71$)	84.5%	84.5%	
	Difference	−15.5%	−2.1%	+13.4%
	Performance status	Disparity	Parity	Superior
	Effect size	−3.1	−0.4	+2.7
Chi-square test				
	$\chi^2(df = 1)$	5.6535	.0476	1.2822
	p value	**<0.05**	0.8273	0.2575
*LS means t-test**				
μELL (dlc)	[30.3]		2192.1	2192.1
μELL (t)	[11.6]	2203.1		2203.1
μRegular (t)	[14.9]	2243.5	2243.5	
	μDifference	−40.4	−51.4	−11.0
	Pr > |t| for H0: LS means equal	**<0.05**	0.1294	0.7345

* Students in analysis: 204; model F value: 88.2; model F significance: <.0001; R-square: .570; Fall 2006 mathematics benchmark mean: 61.4; Fall 2006 mathematics benchmark F significance: <.0001; Classroom type F significance: .0739; 3rd grade TAKS mathematics score mean: 2216.2; Standard error (SE) in brackets.

Table 10
5th grade TAKS mathematics analysis results.

Analysis and parameters		Performance parity		
		ELL/traditional classrooms	ELL/Digital Learning Classrooms	ELL increased student achievement
Pass rate comparison				
pELL (dlc)	(n = 18)		88.9%	88.9%
pELL (t)	(n = 47)	66.0%		66.0%
pRegular (t)	(n = 78)	84.6%	84.6%	
	Difference	−18.6%	+4.3%	+22.9%
	Performance status	Disparity	Parity	Superior
	Effect size	−3.7	+0.9	+4.6
Chi-square test				
	$\chi^2(df = 1)$	5.8735	0.2144	3.4180
	p value	**<0.05**	0.6433	0.0645
LS means t-test[*]				
μELL (dlc)	[35.6]		2207.7	2207.7
μELL (t)	[21.3]	2178.6		2178.6
μRegular (t)	[16.4]	2275.1	2275.1	
	μDifference	−96.5	-67.4	+29.1
	Pr > |t| for H0: LS means equal	**<0.001**	0.0893	0.4911

[*] Students in analysis: 143; model F value: 63.3; model F significance: <.0001; R-square: .578; Fall 2006 mathematics benchmark mean: 63.0; Fall 2006 mathematics benchmark F significance: <.0001; Classroom type F significance: <.01; 5th grade TAKS mathematics score mean: 2234.9; Standard error (SE) in brackets.

The results are mixed with regards to the Digital Learning Classroom attaining the project's goal of increasing ELL student achievement in 5th grade mathematics. The performance of ELL students in Digital Learning Classrooms (88.9%) is +22.9% above that of ELL students in traditional classrooms (66.0%)—an effect size +4.6 times above the ±5% comparable threshold. Still, the chi-square test did not validate this pass rate performance difference (p = 0.0645), and the t-test indicated no significant statistical difference in the score means between these two classroom types (p = .4911).

4.3. 3rd grade TAKS reading performance

Table 11 summarizes the results from the pass rate comparison, the chi-square test, and the least-squares means t-test analysis used to evaluate the project's goals of performance parity and increasing ELL student achievement in 3rd grade reading.

The results indicate performance disparity in 3rd grade reading between ELL and regular students in traditional classrooms. The pass rate of ELL students (84.6%) is −10.5% below that of regular students (95.1%)—an effect size −2.1 times below the ±5% parity threshold. The chi-square test also validates this performance disparity in pass rates at the $p < .05$ level. Similarly, the t-test indicates significant statistical difference in the disparate score means between ELL and regular students at the $p < .01$ level.

The results are mixed with regards to the Digital Learning Classroom achieving the project's goal of performance parity in 3rd grade reading between ELL students and regular students in traditional classrooms. The ELL students' pass rate (77.8%) is −17.3% below that of regular students (95.1%)—an effect size of −3.5, well below the ±5% parity threshold. The chi-square test also validates this performance disparity in pass rates at the $p < .05$ level. However, the t-test indicates no significant statistical difference in the comparable score means between ELL and regular students (p = 0.9682).

Table 11
3rd Grade TAKS reading analysis results.

Analysis and parameters		Performance parity		
		ELL/traditional classrooms	ELL/Digital Learning Classrooms	ELL increased student achievement
Pass rate comparison				
pELL (dlc)	(n = 18)		77.8%	77.8%
pELL (t)	(n = 104)	84.6%		84.6%
pRegular (t)	(n = 61)	95.1%	95.1%	
	Difference	−10.5%	−17.3%	−6.8%
	Performance status	Disparity	Disparity	Inferior
	Effect size	−2.1	−3.5	−1.4
Chi-square test				
	χ^2 (df = 1)	4.1338	5.1535	0.5234
	p value	**<0.05**	**<0.05**	0.4694
LS means t-test[*]				
μELL (dlc)	[35.6]		2309.4	2309.4
μELL (t)	[14.5]	2232.9		2232.9
μRegular (t)	[18.9]	2311.0	2311.0	
	μDifference	−78.1	−1.6	+76.5
	Pr > |t| for H0: LS means equal	**<0.01**	0.9682	**<0.05**

[*] Students in analysis: 183; model F value: 20.1; model F significance: <.0001; R-square: .252; Fall 2006 reading benchmark mean: 63.4; Fall 2006 reading benchmark F significance: <.0001; Classroom type F significance: <.01; 3rd grade TAKS reading score mean: 2266.4; Standard error (SE) in brackets.

Table 12
5th grade TAKS reading analysis results.

Analysis and parameters		Performance parity		
		ELL/traditional classrooms	ELL/Digital Learning Classrooms	ELL increased student achievement
Pass rate comparison				
pELL (dlc)	($n = 17$)		100%	100%
pELL (t)	($n = 41$)	73.2%		73.2%
pRegular (t)	($n = 55$)	83.6%	83.6%	
	Difference	−10.4%	+16.4%	+26.8%
	Performance status	Disparity	Reverse Disparity	Superior
	Effect size	−2.1	+3.3	+5.4
Chi-square test				
	χ^2 ($df = 1$)	1.5599	3.1792	5.6284
	p value	0.2117	0.0746	**<0.05**
LS means t-test[*]				
μELL (dlc)	[33.5]		2183.5	2183.5
μELL (t)	[21.8]	2194.8		2194.8
μRegular (t)	[18.7]	2218.1	2218.1	
	μDifference	−23.3	−34.6	−11.3
	Pr > $\|t\|$ for H0: LS means equal	0.4248	0.3677	0.7801

[*] Students in analysis: 113; model F value: 11.4; model F significance: <.0001; R-square: .238; Fall 2006 reading benchmark mean: 67.8; Fall 2006 reading benchmark F significance: <.0001; Classroom type F significance: .5725; 5th grade TAKS reading score mean: 2204.4; Standard error (SE) in brackets.

The results are also mixed with regards to the Digital Learning Classroom attaining the project's goal of increasing ELL student achievement in 3rd grade reading. The performance of ELL students in Digital Learning Classrooms (77.8%) was −6.8% below that of ELL students in traditional classrooms (84.6%)—an effect size −1.4 times below the ±5% comparable threshold. However, the chi-square test indicated no significant statistical difference in the pass rates between these two classroom types ($p = 0.4694$). In comparison, the least-square mean estimate of ELL students in Digital Learning Classrooms (2309.4) was +76.5 scale score points above that of ELL students in traditional classrooms (2232.9), and the t-test confirmed significant statistical difference between these estimates at the $p < .05$ level. Thus, the Digital Learning Classroom attained the project's goal of increasing ELL student achievement in 3rd grade reading based on the t-test statistic.

4.4. 5th grade TAKS reading performance

Table 12 summarizes the results from the pass rate comparison, the chi-square test, and the least-squares means t-test analysis used to evaluate the project's goals of performance parity and increasing ELL student achievement in 5th grade reading.

The results are mixed with regards to performance disparity in 5th grade reading between ELL and regular students in traditional classrooms. The pass rate of ELL students (73.2%) is −10.4% below that of regular students (83.6%)—an effect size −2.1 times below the ±5% parity threshold. However, the chi-square test indicated no significant statistical difference in this pass rate performance disparity ($p = 0.2117$). Similarly, the t-test results show no significant statistical difference in the disparate score means between ELL and regular students ($p = 0.4248$).

Similarly, the results are mixed with regards to the Digital Learning Classroom achieving the project's goal of performance parity in 5th grade reading between ELL students and regular students in traditional classrooms. The ELL students' perfect pass rate of 100% is +16.4% above that of regular students (83.6%)—an effect size of +3.3, well above the ±5% parity threshold where *reverse disparity* is defined for the comparison analysis. However, the chi-square test indicated no significant statistical difference in the pass rates between these two classroom types ($p = 0.0746$). Likewise, the t-test showed no significant statistical difference in the score means between ELL and regular students ($p = 0.3677$).

The results are also mixed with regards to the Digital Learning Classroom attaining the project's goal of increasing ELL student achievement in 5th grade reading. The 100% perfect pass rate of ELL students in Digital Learning Classrooms is +26.8% above that of ELL students in traditional classrooms (73.2%)—an effect size +5.4 times above the ±5% comparable threshold. And the chi-square test confirmed significant statistical difference in the pass rates at the $p < 0.05$ level. However, the t-test indicated no significant statistical difference in the score means between these two classroom types ($p = 0.7801$).

5. Discussion

Table 13 summarizes the outcomes from the TAKS Met pass rate comparison, the chi-square test, and the least-squares means t-test analysis used to evaluate the project's goals of performance parity and increasing ELL student achievement. The outcomes are presented for each grade/TAKS test area, organized by the three guiding research questions.

5.1. Was performance parity achieved between ELL and regular students in traditional classrooms?

Performance parity was by and large not achieved between ELL and regular students in traditional classrooms. Based on the TAKS pass rate comparison, for example, ELL students had lower rates of passing the TAKS tests than regular students in each grade/TAKS test area evaluated for this project. Chi-square tests further validated these findings, with the exception of 5th grade reading. Here, the chi-square test indicated no significant statistical difference in the performance disparity between these two classroom types. Similarly, the t-test indicated no significant statistical difference in the 5th grade TAKS score means in reading between ELL and regular students in traditional classrooms—even though the ELL students' score mean (2194.8) was lower than that of regular students (2218.1).

Table 13
Summary results table.

Grade/TAKS test area	TAKS Met pass rate comparison	Chi-square test*	LS means *t*-test*
Was performance parity achieved between ELL and regular students in traditional classrooms?			
3rd grade/TAKS mathematics	No	No	No
5th grade/TAKS mathematics	No	No	No
3rd grade/TAKS reading	No	No	No
5th grade/TAKS reading	No	Yes	Yes
Was performance parity achieved between ELL students in Digital Learning Classrooms and regular students in traditional classrooms?			
3rd grade/TAKS mathematics	Yes	Yes	Yes
5th grade/TAKS mathematics	Yes	Yes	Yes
3rd grade/TAKS reading	No	No	Yes
5th grade/TAKS reading	R.D.**	Yes	Yes
Did student achievement increase for ELL students in Digital Learning Classrooms compared to ELL students in traditional classrooms?			
3rd grade/TAKS mathematics	Yes	No	No
5th grade/TAKS mathematics	Yes	No***	No
3rd grade/TAKS reading	No	No	Yes
5th grade/TAKS reading	Yes	Yes	No

* Statistical significance at $p < .05$ level.
** Reverse disparity (RD) indicated; parity surpassed.
*** Pass rate comparison result was validated by chi-square at $p < .10$ level.

5.2. Was performance parity achieved between ELL students in Digital Learning Classrooms and regular students in traditional classrooms?

In comparison, the results strongly suggest that performance parity was achieved between ELL students in Digital Learning Classrooms and regular students in traditional classrooms. Table 13 shows that based on the TAKS pass rate comparison, for example, the Digital Learning Classroom fostered performance parity between ELL students and regular students in traditional classrooms in 3rd and 5th grade mathematics, and produced *reverse parity* in 5th grade reading whereby the ELL students exceeded the performance of regular students. Chi-square tests validated performance parity in these pass rate comparisons. Moreover, the least-square means *t*-test of the TAKS score mean confirmed performance parity between these two classroom types at the $p < .05$ level.

With regard to 3rd grade students in reading, the Digital Learning Classroom did not result in performance parity between ELL students and regular students in traditional classrooms based on the TAKS pass rate comparison and the chi-square test. However, the *t*-test indicated no significant statistical difference in the comparable score means between ELL and regular students ($p = 0.9682$), which defines performance parity between these two classroom types. Thus, one can conclude that overall the Digital Learning Classroom fostered performance parity for ELL students in reading and mathematics at both the 3rd and 5th grades.

5.3. Did student achievement increase for ELL students in Digital Learning Classrooms compared to ELL students in traditional classrooms?

The evidence strongly suggests that the Digital Learning Classroom increased student achievement for ELL students compared to ELL students in traditional classrooms. Based on the TAKS pass rate comparison, for example, the Digital Learning Classroom contributed to increasing ELL student achievement relative to that of ELL students in traditional classrooms in 3rd grade mathematics and for 5th grade mathematics and reading. However, chi-square tests did not confirm these pass rate findings, except for 5th grade reading. Another exception was in 5th grade mathematics. The chi-square test did indicate that ELL students in Digital Learning Classrooms outperformed ELL students in traditional classrooms in 5th grade mathematics at the $p < .10$ level, but not the $p < .05$ level established for evaluating the project.

In comparison, the least-square means *t*-test of the TAKS score mean confirmed the absence of statistical differences in student achievement between ELL students in Digital Learning Classrooms and ELL students in traditional classrooms at the $p < .05$ level. The only exception was in 3rd grade reading where the TAKS pass rate for ELL students in the Digital Learning Classroom was lower than that of ELL students in traditional classrooms, 77.8% and 84.6%, respectively. Thus, the project's goal of increasing ELL student achievement was not achieved based on the TAKS pass rate comparison. Yet, the *t*-test analysis showed a higher TAKS mean score in reading of 2309.4 for ELL students in the Digital Learning Classroom compared to 2232.9 for ELL students in traditional classrooms. Furthermore, the *t*-test statistic indicated significant statistical difference in the score means between these two classroom types at the $p < .05$ level.

There is a plausible explanation for these conflicting results in 3rd grade reading. The 3rd grade ELL students in Digital Learning Classrooms did have a lower TAKS Met pass rate compared to ELL students in traditional classrooms. However, further analysis of the data showed that the 3rd grade ELL students in Digital Learning Classrooms had a higher TAKS pass rate in reading at the *Commended* level than ELL students in traditional classrooms, 33.3% and 23.1%, respectively. The result is that while the traditional classroom prepared proportionally more 3rd grade ELL students at the minimal performance standard in reading required for grade promotion, the Digital Learning Classroom prepared proportionally more 3rd grade ELL students at the higher performance standard that indicates a student has mastered the entire 3rd grade reading curriculum.

Thus, one can conclude based on the TAKS pass rate comparison that the Digital Learning Classroom contributed to increasing ELL student achievement in 3rd grade mathematics and in 5th grade mathematics and reading. Moreover, the *t*-test statistic verified that the Digital Learning Classroom contributed to increasing ELL student achievement in 3rd grade reading.

5.4. Pedagogical implications for teachers of ELL students within the context of Digital Learning Classroom project implementation

The author's classroom observations and conversations with district staff and teachers assigned to Digital Learning Classrooms provide the following insights with regards to pedagogical implications for teachers of ELL students within the context of the project's implementation. Please note the implications presented to the reader are without validation using qualitative methods designed to substantiate the findings or propositions. Combined with the quantitative findings in the study, however, the author believes these insights will provide the reader with a more complete picture of the Digital Learning Classroom project—and of the efficacy of interactive whiteboard (IWB) technology in ELL classrooms.

The author's first insight from the project is that *innovative technologies like the IWB must be introduced as a disruptive innovation, not by using it to directly compete with the teachers' current curriculum and instructional practices, but by letting it initially compete against teachers' "non-consumption" areas where the alternative is nothing at all.*

Christensen and Horn (2008) explain that a disruptive innovation is not a breakthrough improvement to an existing product or service in the marketplace. Therefore, consumers who use existing products or services do not receive any benefits from the disruptive innovation. Instead, the disruptive innovation extends its benefits to "non-consumers"—people who, for one reason or another, do not use existing products or services. They use the disruptive innovation because it is initially simpler and more affordable than existing products or services. However, disruptive innovations over time improve as non-consumers learn how to use them to handle more complex problems. Eventually, the disruptive innovation spreads from non-consumers to consumers displacing existing products or services of once-leading companies.

When the IWB was first introduced to teachers in late August 2006, they saw it simply as a new, more vibrant way to present their existing lesson units—a non-consumption area where an alternative did not exist. By late October when the Digital Learning Classroom became operational in the ELL classrooms, the teachers were familiar enough with basic IWB functions and features to augment their lesson units with simple web-based materials—like audio and visual files. By the end of the fall semester, the teachers were using the IWB's more advanced functions and features to effectively deliver *multi-sensory, highly interactive* curriculum to ELL students. The teachers had also transformed their teaching methods into instructional practices that exploited the technological benefits of the Digital Learning Classroom.

The author's second insight from the project is that the *Digital Learning Classroom promotes a learner-centered pedagogy where both teacher and ELL students are learners, which allows them to jointly produce a harvest of common themes and shared meanings.*

One instructional practice where this transformation was most observable was in the teachers' use of direct instruction. Direct instruction emphasizes the use of small-group, face-to-face instruction by teachers using carefully articulated pre-scripted lessons in which cognitive skills are broken down into small units, sequenced deliberately, and taught explicitly. It is based on the assumption that such instruction eliminates students' misinterpretations and therefore, greatly improves and accelerates their learning (Carnine, 2000; Traub, 1999).

As teachers became more familiar with advanced IWB functions and features, their direct instruction practice changed progressively in two fundamental ways. The first noticeable change was that teachers began sharing their direct instruction with the IWB. At times, ELL students even received direct instruction exclusively from this Digital Learning Classroom component. In this process, ELL students interacted with the IWB when they were prompted by the lesson unit. Teachers developed these lessons or selected them from sources readily available on the internet for use with IWB technology.

The second noticeable change in teachers' direct instruction came soon after when they realized that the ELL students were becoming adept in the Digital Learning Classroom's technologies—particularly in the use of the IWB. This moment of realization defines the "tipping point" in the teachers' ultimate transformation in their direct instruction practice.

Malcolm Gladwell (2002) in his book of the same title defines a "tipping point" as that "magic moment when an idea, trend, or social behavior crosses a threshold, tips, and spreads like wildfire." The "tipping point" in the teachers' direct instruction transformation followed the same pattern or characteristics identified by Gladwell (2002).

When the Digital Learning Classrooms became operational in late October, it soon became contagious—in particular, ELL students wanted to "play" with the IWB to see what it could do. As the teachers started to use the Digital Learning Classroom technologies in delivering the lesson units and activities, they made small changes in their lessons to provide ELL students with more opportunities to interact directly with the IWB. And the more the ELL students interacted with the IWB, the more they became adept in using its functions and features.

In turn, the teachers further extended their sharing of direct instruction to the ELL students by occasionally allowing them to use the IWB to instruct each other, with some teacher supervision where needed. Now ELL students were also using the IWB to locate other materials on the internet to complement the interactive lessons. By the end of the fall semester, the teachers' direct instruction transformation was complete and the Digital Learning Classroom and its centerpiece, the IWB, became the classroom-of-choice for both teachers and ELL students.

The author's third insight from the project is that *in spite of the promising findings shown in the study, the Digital Learning Classroom is not a "silver bullet" for improving ELL student academic success.* The Digital Learning Classroom cannot transform an average teacher into a master teacher, anymore than an electronic word processor can magically transform the typical clerical office worker into a Pulitzer Prize-winning author.

More specifically, the Digital Learning Classroom cannot compensate for the teacher's lack of subject content mastery, instructional competency, and classroom management skills. Nor can the Digital Learning Classroom serve as a substitute for the teacher's innate qualities important to ELL students' academic success: love for children, deep passion for the teaching craft, and higher-order emotional intelligence within the context of the learning needs of children.

The Digital Learning Classroom was simply a tool that augmented the teachers' innate and already developed teaching capacity to enact in the ELL classroom the five basic principles identified by the National Research Council (2000). However, this "tool", more than the basic computer and overhead projector, offered teachers a broader range of functions and features from which to: (1) build ELL students' learning on previous experience; (2) create social settings where ELL students' learning could prosper; (3) provide a variety of contexts for ELL students with diverse learning needs; (4) deliver content that was connected, organized, and relevant which supported ELL students' learning of knowledge but also helped them to develop higher-order thinking skills; and (5) integrate into lesson units feedback and active evaluation of learning that furthered ELL students' understanding and skill development.

If the teachers' teaching qualifications like subject content mastery, instructional competency, classroom management skills and innate qualities are paramount to ELL students' academic success, then the Digital Learning Classroom simply amplified their teaching effectiveness in modulating the classroom learning environment relevant to the five basic principles identified above.

The pedagogical implication is that the Digital Learning Classroom may conversely, in fact, illuminate and even exasperate teachers' deficiencies or lack of competency in classroom teaching. This is why the district's director of ELL students allowed the principals to personally select the teachers for the project. The principals' primary selection criteria were based on their perceptions of the teachers, in terms of their willingness to undertake the intensive on-going technology training, ability to design new untried curriculum materials built around the IWB technology, and confidence to self-initiate changes in instructional practices, where needed. Combined with their teaching qualifications noted earlier, these teacher characteristics provided a bedrock foundation on which to build and successfully launch the Digital Learning Classroom project.

What teachers do in the classroom is important—how they do it makes the difference in ELL students' academic success is the author's fourth insight from the Digital Learning Classroom project.

How teachers do what they do in the classroom is ultimately expressed in their teacher-student interactivities. These interactivities are based on teacher-student communication that from a student's perspective are either "dual-way" or "dull-way"—i.e., open, inclusive, exciting, and fun versus closed, exclusive, boring, and somber. Thus, for students the difference is more than just one letter in the word-spelling of these two forms of teacher-student communication.

Smith et al. (2005) cites that teacher-student interactivity is the primary benefit of the IWB. Based on teacher feedback and observations in Digital Learning Classrooms, teacher-student interactivity raised the ELL students' learning energy level in the classroom in terms of their attention to instruction, effort and persistence in completing classroom assignments, and participation in discourse with teacher and other students.

The challenge for teachers is that they must make decisions as to where, when, how, why, what, and for which students to integrate best the IWB into the curriculum and instructional practices. This has two pedagogical implications for teachers of ELL students.

First, teachers must make decisions where both teacher and ELL students can make mistakes in using the IWB without fear of ridicule or embarrassment. For example, during a scheduled tour by the district's school board members to a Digital Learning Classroom, a teacher was interacting with students on a math problem using the IWB. In the middle of the discourse, when the teacher could not implement one of the IWB features, an ELL student quickly ran to the IWB and proceeded to show the teacher how to recover from the IWB error to continue with the exercise. The teacher and ELL students were able to complete the IWB-based math exercise as though nothing out of the ordinary had happened.

Subsequent investigation revealed that it was quite common for this teacher and ELL students to help each other when technical difficulties arose in the use of the IWB. This example demonstrated a "safe" classroom learning environment where both teacher and ELL students could engage more openly and deeply in the learning process *because making and learning from one's technical mistakes were simply part of and not a distraction in the learning process itself.*

The second pedagogical implication when teachers make decisions to integrate the Digital Learning Classroom into the curriculum and instructional practices is how it changes the teacher's traditional roles in the classroom beyond that, for example, of instructor, coach, facilitator, and mediator to that of "servant teacher"—a concept similar to that of "servant leader".

AT&T executive, Robert K. Greenleaf (1970) first coined the term "servant leader" in a short essay titled: "The Servant as Leader". Greenleaf (1977) stated in a later publication that servant leaders are "servant-first", a natural feeling that serving others' needs is their highest priority or calling in life. He proposed that the best evidence of servant leadership is: "Do those served grow as persons? Do they, while being served, become healthier, wiser, freer, more autonomous, more likely themselves to become servants? And, what is the effect on the least privileged in society? Will they benefit, or, at least, not be further deprived?"

The teachers' decisions to integrate the Digital Learning Classroom into the curriculum and instructional practices transformed teachers into "servant teachers." As their experience with the Digital Learning Classroom grew, they become less concerned with their own teacher-needs and more focused on the learning needs of their ELL students. The result is that their ELL students acquired higher levels of academic achievement.

Teachers also reported more positive social behaviors in their ELL students as a result of the interactivities using the IWB in whole group sessions. This can have very interesting spill-over effects. In one classroom incident, for example, a teacher found a burned out light bulb in the LCD projector used with the IWB. The ELL students sat quietly and patiently at their desks until she found a light bulb replacement. For these ELL students, further investigation into this incident revealed that they desired from the teacher "*another exciting day at school, having fun learning with the IWB*" and they understood that a working light bulb—and good behavior—was required for this to happen.

As ELL students acquired the technical skills to use the IWB themselves, the teachers also saw how students wanted to be more autonomous—less reliant on the teacher, and more *self-reliant* on using the IWB and other ELL students to learn new knowledge and skills. By revising their lesson units to include more direct instruction from ELL students to each other, the teachers addressed their learning need for more learning autonomy. In this process, the teachers transferred a portion of their responsibility for classroom learning directly to the ELL students, which gave the students a sense of ownership in their academic success.

Simply stated, as teachers became "servant teachers", the more ELL students benefited from the Digital Learning Classroom. So much, that some ELL students outperformed non-ELL students on the state's 5th grade standardized test in reading. But it was through the process of learning how to make decisions to integrate the Digital Learning Classroom into the curriculum and instructional practices that these teachers became "servant teachers", stewards of the Digital Learning Classroom in trust for the ELL students they served, more attuned to the learning needs of the ELL students and committed to empowering them to academically succeed.

The author's fifth and final insight from the project is that *the teachers' success with ELL students did not happen in a vacuum—it was facilitated through the intervention of a curriculum specialist assigned to the Digital Learning Classroom project by the district's director of ELL students*.

The curriculum specialist entered the project already highly competent in curriculum and instructional practices, and through formal training in mid-summer through early fall, became adept in the IWB. When school started in late August, the curriculum specialist provided Digital Learning Classroom teachers with a series of professional development sessions in curricular, pedagogical, and technical areas relevant to the project.

The curriculum specialist's initial sessions focused on helping teachers to understand the inherent advantages of IWB functions and features which resulted in teachers moving up the technology learning curve until they became familiar and comfortable with using the Digital Learning Classroom components. In this process, the curriculum specialist introduced teachers to examples of lesson units that used

IWB functions and features. The sessions also provided teachers with time to share ideas and address concerns regarding the IWB in their ELL classroom.

In later sessions, the curriculum specialist assisted teachers to integrate IWB functions and features into their curriculum, explore new instructional practices relevant to the Digital Learning Classroom, and create feedback and active evaluations of learning that furthered ELL students' understanding and skill development. The curriculum specialist essentially shortened the amount of time needed for teachers to learn how to use the Digital Learning Classroom to enact in the ELL classroom the five basic principles identified by the National Research Council (2000). The result was that soon after the Digital Learning Classroom became operational in the ELL classrooms in late October, the teachers were involved in their own development of new materials using IWB functions and features.

To put this in perspective, consider that the overhead projector is perhaps one of the main technological features of the modern classroom. The curriculum specialist served as the catalyst in transforming teachers' pedagogy from simple and disconnected physical routine forms of instructional practice, to more highly complex and engaging visual, auditory, tactile forms of instructional practice based on IWB functions and features. Without this teacher transformation in pedagogy, the IWB's value to the ELL classroom would have been the equivalent of an overpriced "overhead projector".

The curriculum specialist's value to the teachers' success in the Digital Learning Classroom project: *Priceless*.

5.5. Recommendations for future research

The author recommends two lines of inquiry for future study of the Digital Learning Classroom in ELL classroom settings. The first line of inquiry should examine whether and the extent the Digital Learning Classroom is able to help ELL students learn *more* curriculum in the *same* unit of time than ELL students in traditional classrooms. This research is important because many ELL students are recent immigrants that may not have acquired in their prior schooling the necessary academic skills (e.g., reading) or content knowledge in a given subject area (e.g., mathematics) to transition and succeed academically in US public schools. The proposed research would investigate how the Digital Learning Classroom can provide teachers with the tools, instructional methods, and engaging curriculum that can help such ELL students learn the English language and concurrently "catch-up", i.e., accelerate their acquisition of these missing skills and knowledge, in the shortest, timely manner so that they can join their peers in mainstream coursework—taught in the English language.

The second line of inquiry should examine whether and the extent the Digital Learning Classroom is able to help ELL students learn a given unit of curriculum in *less* time than ELL students in traditional classrooms. This research is particularly important for ELL students entering US public schools on or above grade level, but that have no working knowledge of the English language or their English proficiency is not yet sufficient enough for academic learning in an English-taught course.

The teacher's ability to reduce the time needed for classroom instruction while achieving students' learning goals in the school's required curriculum means the saved time could be used by students and teachers in other learning activities or instructional modes. For example, ELL students could use the saved time to explore their own areas of interest and learn subjects outside the mainstream curriculum, thereby increasing students' engagement in the classroom. In contrast, teachers could also use the saved time to teach the required curriculum in a dual-language classroom setting where ELL students learn the initial material in their home language and then use the saved time to re-learn the material in the English language. The proposed research would investigate how the Digital Learning Classroom can help teachers create and implement such classroom settings where ELL students can learn the English language in the shortest, timely manner and concurrently, challenge them to continue their studies in advanced subjects so that they can join their peers in similar coursework—taught in the English language.

Meanwhile, further research of the Digital Learning Classroom is recommended to determine the extent that the positive results reported in this study are sustainable from year-to-year. Such research would investigate the effects on ELL student's learning from the teachers' instructional methods delivered using specific features and functions of the Digital Learning Classroom, and whether the positive effects on their learning persists after the novelty of using the IWB diminishes over time.

In 1983, Richard Clark first proposed the notion that students' learning is affected by the teacher's instructional methods delivered *using* technology—and not by the technology itself, and by the novelty effect created when a technology is first introduced to teachers and students. He drew these conclusions from his review of media comparison studies that compared student achievement when the teachers used two different media for instruction. Clark found that most media comparison studies resulted in no statistically significant differences regardless of the media studied. Moreover, he found in his review of the media research studies that because the research designs used did not have the *same* teacher deliver the content in both the treatment and control conditions, positive results could not be isolated from the use of the media, thereby confounding the findings (Clark, 1983).

Clark (1983) also found that the media research studies did not control for the novelty effects of the media. He contended that the teachers might have paid greater attention to the newer media possibly increasing their effort and thereby raising student achievement. His evidence for this novelty effect was found in several studies where the students' achievement gains diminished over time as they became more familiar with the media. This indicated the research was possibly confounded with the uncontrolled effect of novelty when the media was first introduced to the students (Clark, 1983).

The potential for novelty effects is present in this first-year evaluation study because the use of IWB technology in the Digital Learning Classroom was a new phenomenon for both teachers and ELL students. The novelty of the IWB technology may have motivated teachers to deliver instruction more effectively and students to work harder in the classroom and therefore, these factors—not the Digital Learning Classrooms—were the source of the positive effects on ELL students' learning reported in this study. Future research should examine the effects of the Digital Learning Classroom longitudinally to determine whether the positive effects on teachers' instructional practices and ELL students' learning diminish with increasing IWB experience.

Lastly, it should be noted that the district did not implement the Digital Learning Classroom in classrooms for regular students because the funding available for the IWBs came from federal monies that were exclusively designated for ELL students. Thus, the district was unable to implement the Digital Learning Classroom in regular classrooms. With the initial success of the project, the district plans to implement the Digital Learning Classroom in more 3rd and 5th grade ELL classrooms, and in ELL classrooms at other elementary grade levels.

The district also intends to use other funding sources to expand the Digital Learning Classroom to regular classrooms. When this occurs, the evaluation research design will include regular students in the treatment group. The project evaluation will then be guided by the three original research questions of this study, in addition to the question, "Did student achievement increase for *regular students* in Digital Learning Classrooms compared to *regular students* in traditional classrooms?"

Such research would add greatly to the findings of this study in two ways. The TAKS performance outcome measure used in the project evaluation was defined primarily by the *Met* standard, which represents the minimum performance level that students need to achieve to demonstrate they are ready for promotion to the next grade level. Based on the relatively high TAKS pass rates at the Met standard shown in Table 1 for regular students, the proposed evaluation research design would almost certainly have to be based on the TAKS performance outcome measure at the *Commended* standard, which indicates a student has mastered the *entire* curriculum for that grade level. A project evaluation using the Commended standard would contribute to the findings of this study because any positive effects found at this higher performance level would provide researchers and educators with insights into just how far the IWB technology can be used to deliver content and instruction that result in higher levels of learning for ELL and regular students.

Second, the evaluation of Digital Learning Classroom in regular classrooms would provide an opportunity to explore how well the findings from this study can be generalized to other classroom settings, thereby providing additional empirical evidence as to the efficacy of the IWB technology to students' learning.

6. Conclusions

Educators have for many years looked at computer technology as a potentially valuable resource for meeting the learning needs of ELL students. The findings from this project evaluation suggest the proposed lines of inquiry would be worthwhile to pursue in further understanding how the Digital Learning Classroom, based on interactive whiteboard technology, can best meet these learning needs that results in academic success for ELL students in US public schools.

Taken together, these findings indicate that the Digital Learning Classroom can significantly improve performance parity for ELL students—i.e., the extent to which they perform at similar achievement levels as regular students in traditional classrooms—in mathematics and reading at the 3rd and 5th grade. Even more so, there is evidence in the results that the Digital Learning Classroom can even surpass parity and perpetuate *reverse disparity* in performance—as in the case of 5th grade reading. Here, the TAKS Met pass rate for ELL students in Digital Learning Classrooms was 100% compared to 83.6% for regular students in traditional classrooms (See Table 12). In another case, one can also find ELL students in classrooms using IWB technology scoring more highly than ELL students in traditional classrooms, as shown on the 3rd grade TAKS reading assessment.

Based on these findings, the Digital Learning Classroom demonstrates the potential value of employing IWB technology to achieve performance parity between ELL and regular students while increasing ELL student achievement. Greater results should be expected for ELL students in subsequent years of implementation and beyond, as teachers gain still higher levels of proficiency in using the IWB's advanced functions and features in their instructional practices, learn how to identify and deliver their curriculum through IWB technology, and—guided by the NRC (2000) framework—find ways to engage ELL students in meaningful learning that results in higher levels of student academic achievement.

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