J Sci Teacher Educ
DOI 10.1007/s10972-011-9238-z

Science Achievement for All: Improving Science Performance and Closing Achievement Gaps

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Abstract This article addresses the serious and growing need to improve science instruction and science achievement for all students. We will describe the results of a 3-year study that transformed science instruction and student achievement at two high-poverty ethnically diverse public elementary schools in Texas. The school-wide intervention included purposeful planning, inquiry science instruction, and contextually rich academic science vocabulary development. In combination, these instructional practices rapidly improved student-science learning outcomes and narrowed achievement gaps across diverse student populations.

Keywords Vocabulary development · Professional development · Inquiry science · English language learners · High-stakes testing · Student achievement

Introduction

The United States is experiencing a profound demographic shift and the ethnic and racial composition of the nation's public classrooms reflect these changes. During the past 20 years, the proportion of White students enrolled in public schools declined from 68 to 55% while the proportion of Hispanic students doubled from 11 to 22%. During this same period, the number of Black students increased, but their share of enrollment decreased from 17 to 16%. The enrollment of Hispanic students in public schools surpassed Black enrollment for the first time in 2002 and remained higher through 2008. This shift in classroom composition mirrors an increase in

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Published online: 04 May 2011

school-age students who speak English as a second language. The number of K-12 students who speak a language other than English at home tripled between 1979 and 2008, resulting in 10.9 million or 21% of all public school students being classified as language minority. The majority of these students report Spanish as their first language. Examination of the ethnic and racial demographic distribution in public schools reveals that large percentages of Hispanic (46%) and Black (34%) students attend high-poverty public schools where more than 75% of the students are eligible for free or reduced-price lunch (National Center for Educational Statistics 2010).

Concurrent with these changes in student population demographics have been substantial revisions to the core science curriculum. In 1985, the American Association for the Advancement of Science (AAAS) launched *Project 2061*, a long-term reform initiative designed to transform science education in America by 2061, the year that Halley's Comet returns. In 1989, AAAS published *Science for all Americans*, a landmark report that defined science literacy and provided the groundwork for national science-education standards by outlining what students should know and be able to do in science by high school graduation. This pioneering report described a scientifically literate person as someone who has a broad and functional understanding of science and the natural world; is aware of the interdependence of mathematics, technology, and science; has a capacity for scientific thinking; and understands the coherence of science and society [American Association for the Advancement of Science (AAAS) 1989].

Moreover, *Benchmarks for Science Literacy* (AAAS 1993) provided a broad set of learning goals for students in grades K-12 that support the scientific literacy goals outlined in *Science for all Americans* (AAAS 1989). The benchmarks were specifically designed to help educators decide what to include in (or exclude from) a core curriculum and when to teach certain topics and why. Three years later, the National Research Council published the *National Science Education Standards* [National Research Council (NRC) 1996] to "spell out a vision of science education that will make scientific literacy for all a reality in the 21st century" (p. ix). The introduction to *National Science Education Standards* acknowledges the influence of *Science for all Americans* and *Benchmarks for Science Literacy* in the creation of standards regarding what students should know and be able to do in science. Inquiry, a prominent feature of the *National Education Science Standards*, is the instructional bridge that connects doing and learning science (NRC 2000). Inquiry science is emphasized in state and local science standards because they are based on the *National Science Education Standards*.

Coinciding with these efforts to create a more rigorous science curriculum designed to make scientific literacy in the twenty first century a reality, national legislation that mandates rigorous assessment of students' learning has been passed. The No Child Left Behind Act of 2001 (NCLB) drives the current educational system. It requires that educators measure students' yearly progress, encourages high academic standards, and implements greater accountability throughout the nation's school system. Of special interest to science educators is the requirement that schools must annually assess students' science knowledge and skills in elementary, middle school, and high school. As high-stakes testing moves into the realm of science, teachers of English-language learners (ELLs) must address English language fluency while simultaneously teaching science content

(Durón-Flores and Maciel 2006). For these reasons, identifying and implementing empirically sound and research-based practices that are effective in promoting solid science content and academic vocabulary for ELLs, as well as English literacy, are crucial (Echevarria et al. 2006).

Schools are under increasing pressure to meet accountability requirements and show growth in student achievement across tested content areas. Texas began testing science achievement in the 5th grade in 2004, and the Texas Assessment of Knowledge and Skills (TAKS) science test is administered to 5th grade students every April. Longitudinal analysis of statewide 5th-grade science test scores reveals that English language learners and economically disadvantaged students consistently underperform and post scores that are considerably below the state average [Texas Education Agency (TEA) 2011]. These students are at risk of falling and staying behind in science.

Research Purpose and Questions

Closing achievement gaps and improving science learning outcomes for all students are educational priorities. The pressing need to help ELL and economically disadvantaged student populations succeed in science prompted the following research question: Does the combination of purposeful planning, inquiry science instruction, and interactive multi-sensory vocabulary development impact the science achievement of English language learners and low SES elementary school students? We developed a professional-development initiative to test this question and implemented it at two high-poverty ethnically diverse public elementary schools located in Texas.

Professional Development Initiative

First, the professional development initiative provided opportunities for grade-level teams at Allen Elementary and Bell Elementary (both pseudonyms) to study state science standards and purposefully plan instructional activities based on the standards. Next, teachers designed 5-E inquiry science lessons that were tightly aligned with the state standards. Finally, multisensory interactive word walls were implemented to support key academic-content vocabulary.

Purposeful Planning

"While standards-based curriculum and instruction were called for and conceptualized by national reform efforts (AAAS 1993; NRC 1996), standards must be operationalized at the state, district, school, and classroom levels" (Bianchini and Kelly 2003). The Texas Essential Knowledge and Skills (TEKS) comprise the official curriculum in Texas public schools. To facilitate standards-based instruction, Texas school districts developed unique curriculum frameworks and pacing guides that they required their teachers to use to plan and pace instruction. These efforts typically begin with the "development of aligned curricula—what will be taught, followed by cultivating pacing guides that specified when particular content and skills would be covered" (Protheroe 2008, p. 38). Produced in-house by district personnel who may not fully understand the TEKS and the content being tested, the quality and rigor of these documents vary from district to district. As a result, classroom teachers shoulder the burden of translating these state standards into situated practice (Bianchini and Kelly 2003). Wallace et al. (2008) stated that positive outcomes in education are the product of effective innovations and effective implementation efforts, concluding that teachers are the critical piece of the standards-movement puzzle because teachers' actions and words deliver the intervention. Thus, teachers are the key players in standards-based educational systems.

Teachers are most likely to improve student learning when they address specific learning outcomes in their planning (Schmoker 1996). Purposeful planning provides teachers with opportunities to plan instructional activities that focus on the standards with fidelity while heeding district guidelines. It also provides time for teachers to understand the content vertically, answering the questions of what has been taught, what needs to be taught, and what will be taught in future grades. Finally, it provides structure that encourages teachers to identify essential academic vocabulary and plan how they will support targeted words during instruction. Thus, purposeful planning allows teachers to implement standards-based practices effectively and consistently in their classrooms.

In the professional development initiative, a focus on alignment of instruction with the TEKS underpinned all team planning activities. Grade-level teams at both elementary schools were given vertically aligned copies of the K-5 science TEKS and instructed to use this primary source document to plan instruction. Teachers were taught to look closely at TEKS verbs and science content in order to understand the rigor and intent of the standard. They were also instructed to review the vertical alignment of key science concepts. In addition, activities that had "always been taught" and commercial kit science programs were carefully reviewed for TEKS alignment. If these products were not aligned with specific grade-level TEKS, they were either discarded or revised to ensure that every aspect of instruction was aligned to the TEKS with fidelity. As the TEKS became the primary planning tool, the district-prepared curriculum and pacing documents moved into supporting roles. Allen Elementary grade-level teams met once a week during their scheduled planning period (40 min) to discuss science instruction and confirm TEKS alignment of planned activities. During the treatment phase at Allen Elementary and the replicability test at Bell Elementary, the researchers met with the K-5 grade-level teams monthly for an extended planning meeting (60–75 min) to look at concepts scheduled to be taught and consider any academic-content, TEKS-alignment, or rigor questions.

Inquiry Science Instruction: The 5-E Lesson Plan

The empirical nature of science supports contextual, multisensory learning. Most of the science content included in elementary science standards is immediately available through observation and experimentation. Research on how people learn (Bransford et al. 2000) suggests that learning is a dynamic and interactive process.

A powerful constructivist leaning tool, the 5-E lesson plan “capitalizes on hands-on activities, students’ curiosity, and academic discussions among students” (Carr et al. 2007, p. 4) while simultaneously supporting dynamic, interactive instruction.

Typical 5-E lesson plans are divided into phases with descriptive titles: Engage, Explore, Explain, Elaborate, and Evaluate. Engagement activities are designed to activate prior knowledge and capture students’ attention. This quick introduction sets the stage for the lesson and focuses students’ attention. Exploration gives students an opportunity to actively plan and engage in hands-on inquiry science activities and to make observations, gather evidence, and collect data. Explanation of key concepts is driven by teacher-guided questions focusing on analyzing and discussing student observations and data, sharing ideas, generating explanations, creating definitions, and connecting claims and evidence. Student understanding is constructed, clarified, and modified during this phase. Elaboration gives students the opportunity to expand and solidify their understanding of the science content by providing opportunities to apply their understanding in a new context. Evaluation includes both formative and summative assessments. Introductory 5-E inquiry lesson support was provided at fall faculty meetings. At planning meetings, grade-level teams were provided with sample 5-E TEKS-aligned lesson plans appropriate for use with their students. They were also given 5-E lesson planning templates to guide their own planning

Academic Content Vocabulary Development

“Researchers agree that teachers need to provide structured opportunities for students to encounter and use new words in authentic and engaging ways” (David 2010). Robust vocabulary instruction involves “directly explaining the meaning of words along with thought-provoking, playful, and interactive follow-up” (Beck et al. 2002, p. 2). Graves (2006) proposed that a balanced approach to vocabulary instruction includes rich and varied language experiences for students, as well as explicit instruction addressing a limited number of well-chosen words. In addition, Stahl and Fairbanks (1986) suggested that effective vocabulary programs provide multiple exposures to words that have been introduced in meaningful context and involve students in processing the meanings of the words.

Similarly, Cummins (1996) suggested that second language learners should receive instruction that is contextually rich and cognitively demanding. Contextually rich instruction builds basic language comprehension through the use of authentic pictures, illustrations, diagrams, and experiences. Cognitively demanding instruction requires students to simultaneously process different types of information. Furthermore, Husty and Jackson (2008) reported that ELL elementary students achieve a deeper understanding of science and enhanced vocabulary development in science when they were guided through inquiry-based, multisensory explorations that repeatedly exposed them to words and definitions in context.

Many elementary classrooms have word walls displaying the vocabulary that students have learned in class. Word walls serve as visual scaffolds and are a common classroom tool used to support reading and language arts instruction. Additionally, word walls that include visuals differentiate instruction for English language learners (Carr et al. 2007). To support vocabulary development in science, Husty and Jackson (2008) created interactive science word walls that strategically target academic vocabulary.

An interactive multi-sensory word wall is a way to present vocabulary to students while providing an ongoing visual representation and helps students develop "an understanding of, and fluency in, key unit vocabulary" (Douglas et al. 2006, p. 328). The type of word wall includes a visual representation of the word in a small (quart or pint) plastic bag and a vocabulary label. A color picture may be substituted if the actual item (realia) is not available or is too big or heavy to bag or display. Vocabulary definitions are optional. Cambourne (2000) asserted that student interaction with classroom wall print and displays support literacy and learning and teaching for all students. Therefore, student participation in creating and maintaining word walls is crucial. Students can supply the items to be bagged, create the labels, and suggest relevant connections. Teachers may also include visual artifacts from inquiry science activities to help students remember the learning activities and to connect labs to scientific concepts. This process supports deeper understanding of science because it provides opportunities for students to interact with the objects on display.

Research Setting

Our research project was driven by concerns about the low science achievement of ELLs and economically disadvantaged students. Allen and Bell Elementaries share a history of being rated Academically Acceptable by the Texas Academic Excellence Indicator System (AEIS) due to low scores on the 5th-grade science Texas Assessment of Knowledge and Skills (TAKS) test. Unless existing science achievement trends were reversed, participating schools were projected to become academically unacceptable. Both schools needed to improve their AEIS ratings. To meet this challenge, they needed to show growth in student achievement while closing achievement gaps across tested content areas, especially science.

Allen Elementary

A Pre-K-5 school, Allen Elementary is part of a large school district that encompasses high-tech manufacturing and urban retail centers, suburban neighborhoods, and farm and ranch land. Serving 45,000 students, this district has a diverse ethnic base. Over 50 years old, Allen Elementary has a history of serving ethnically diverse and economically disadvantaged children. Table 1 contains enrollment history and ethnic distribution data for Allen Elementary, collected by the Texas Education Agency (TEA) to determine the AEIS school ratings. (TEA and NCLB refer to students who are not fluent in English as *Limited English Proficient* [LEP] students; however, in practice, *ELL* is more common.)

Bell Elementary

Bell Elementary serves children in grades Pre-K-5 and is part of a fast-growth school district located in central Texas. This ethnically and culturally diverse

Table 1 Allen elementary enrollment history and ethnic distribution

School year	All	African American (%)	Hispanic (%)	White (%)	Native American (%)	Asian Pacific Islander (%)	Economically disadvantaged (%)	Limited English Proficient (LEP) (%)	At-risk (%)
2005–2006	655	5.3	81.7	12.1	0.0	0.9	83.8	58.9	74.5
2006–2007	587	5.6	80.9	12.1	0.2	1.2	84.0	58.1	78.2
2007–2008	582	5.5	82.8	10.3	0.0	1.4	77.3	56.9	75.6
2008–2009	467	8.1	73.9	16.7	0.2	1.1	81.8	43.7	70.4
2009–2010	573	11.9	65.8	20.2	0.0	2.1	81.3	41.7	62.0

Table 2 Bell elementary enrollment history and ethnic distribution

School year	All	African American (%)	Hispanic (%)	White (%)	Native American (%)	Asian Pacific Islander (%)	Economically disadvantaged (%)	Limited English Proficient (LEP) (%)	At-risk (%)
2005–2006	743	17.2	66.1	10.6	0.3	5.8	73.5	49.4	65.7
2006–2007	783	14.4	71.6	9.1	0.1	4.7	76.4	56.8	64.6
2007–2008	626	17.4	67.4	8.0	0.2	7.0	75.2	49.7	59.4
2008–2009	630	12.5	72.7	9.8	0.0	4.9	80.8	54.0	70.3
2009–2010	613	13.7	74.2	8.3	0.2	3.6	84.2	54.5	72.9

school district encompasses approximately 95 square miles and includes all or part of six communities. Over 22,000 students are currently enrolled and enrollment is expected to double over the next 10 years. Table 2 shows the enrollment history and ethnic distribution of students at Bell Elementary across a 5-year period.

Method

Timeline

This tiered study was implemented over 3 years. The treatment elementary school, Allen Elementary, engaged in science professional development for 2 years and during Year 3 did not receive any science professional development so as to test sustainability. Bell Elementary tested replicability and began science professional development during Year 3. Table 3 shows the tiered implementation timeline.

Both schools enroll pre-k students but only K-5 teachers participated in the professional development and associated study. Table 4 includes a summary of the number of teachers who participated as well as their grade level distribution.

Table 3 Tiered science professional development timeline

Location	2007–2008 Year 1	2008–2009 Year 2	2009–2010 Year 3
Allen elementary	Science PD	Science PD	Sustainability test
	31 teachers K-5	25 teachers K-5	26 teachers K-5
	521 students K-5	415 students K-5	471 students K-5
Bell elementary			Science PD replicability test
			32 teachers K-5
			531 students K-5

Table 4 Summary of participants

School	Participant total	K	First	Second	Third	Fourth	Fifth
Allen 2007–2008 (treatment)	31	5	6	5	6	5	4
Allen 2008–2009 (treatment)	25	5	4	5	5	3	3
Allen 2009–2010 (sustainability)	26	5	4	4	5	5	3
Bell 2009–2010 (replicability)	32	5	6	5	6	5	5

Data Collection and Analysis

Multiple data sources were used throughout the 3-year professional-development initiative. Allen Elementary and Bell Elementary 5th-grade science TAKS scores were collected and analyzed using difference-in-proportions tests to determine whether students showed positive achievement gains as a result of the treatment. Difference in proportions tests utilize both the percentages and sample sizes for two groups, and calculate the probability level associated with the difference in proportions evidenced between the two groups. Based on the results of this test, the difference in the proportions, or percentages, between two groups of respondents can either be determined as statistically significant or non-significant. An end-of-year questionnaire provided a snapshot of teachers' perspectives regarding the impact the project had on science learning and instruction during Year 1. Classroom artifacts were also collected throughout the project.

The end-of-year questionnaire was adapted from Lee et al. (2008). The questionnaire was divided into five sets of questions to organize feedback. The first question set examined how effectively the project addressed project objectives. Teachers rated the effectiveness of standards-based science learning, preparation of students for the statewide science assessment, English language development, scientific reasoning, inquiry instruction, and teacher science-content knowledge. A 4-point Likert-type scale was used to rate responses, with 1 indicating "very ineffective" and 4 indicating "very effective." Sections "Professional Development Initiative" to "Data Analysis and Results" required open-ended written responses. The second question set addressed the impact of the study on teacher knowledge of grade-level science topics, how they teach science, how English language development in science instruction was promoted, planning science instruction, and attitude toward teaching science. The third set of questions focused on the impact of the study on students. Section "Professional Development Initiative" asked teachers to rate project activities for effectiveness, and section "Data Analysis and Results" addressed activities of the project that needed improvement.

Descriptive statistics were used to analyze teacher responses to the first set of questions. Qualitative methods were used to analyze the open-ended written responses to questions sets two through five. Two researchers reviewed all of the written responses, and emergent themes were identified and coded. The data analysis results section of this paper includes lists of emergent themes and supporting quotes.

Data Analysis and Results

Fifth-Grade Science TAKS Score Analysis

Difference-in-proportions tests were used to determine whether the percentage of students who were passing and the percentage who were commended significantly changed on the basis of the science professional-development treatment. At Allen Elementary, 2 years of baseline were followed by 2 years of treatment, which was followed by a single year to determine whether the effects of treatment were sustained.

The results of the analyses focusing on the percentage of students found to be passing within Allen Elementary are shown in Table 5, which compares the state, district, and Allen Elementary percent of students passing the 5th-grade science TAKS test. A TAKS score of 70 or better is considered passing. As shown in the table, the percentage of White students passing was found to be greater than 99%. This indicates a ceiling effect, meaning that in this case, there is no substantial room for improvement in regard to the passing rate for White students.

Table 5 Percent passing Allen 5th-grade state science assessment scores compared to state and district

Year	State Avg (%)	District Avg (%)	Allen (%)	African American (%)	Hispanic (%)	White (%)	Native American (%)	Asian Pacific Islander (%)	Eco Dis (%)	LEP (%)
2005–2006	70	85	51	*	46	67	*	*	45	33
2006–2007	71	85	51	*	48	*	*	*	52	41
2007–2008 (treatment)	74	85	74	*	68	>99	*	*	73	58
2008–2009 (treatment)	78	89	98	*	97	*	*	*	97	>99
2009–2010 (sustainability)	83	91	98	*	97	>99	*	*	97	>99

* Fewer than 30 test takers, so the subgroup was not evaluated separately

Table 6 Allen school baseline compared to treatment—students passing

Ethnicity	Base *N*	Base %	Treatment *N*	Treatment %	*z*
Hispanic	149	46.96	106	81.85	5.64*
White	22	67.00	17	99.50	2.57*
Economically disadvantaged	154	48.55	106	85.06	6.01*
LEP	107	37.17	69	78.17	5.32*

* $p < 0.05$

Table 7 Allen school treatment compared to sustainability check—students passing

Ethnicity	Base *N*	Base %	Treatment *N*	Treatment %	*z*
Hispanic	106	81.85	43	97.00	2.43*
White	17	99.50	13	99.50	0.00
Economically disadvantaged	106	85.06	53	97.00	2.27*
LEP	69	78.17	27	99.50	2.57*

* $p < 0.05$

In the case of Allen Elementary, two sets of analyses were conducted: one to test whether the change in the percentage of students passing was significantly different between the 2-year baseline period and the 2-year treatment period and the second to test whether there was a significant change in the percentage of students passing between the 2-year treatment period and the single following year of nontreatment used to determine whether the effects of treatment were found to be sustained. Table 6 shows the results of the analyses conducted between the 2-year baseline period and the 2-year treatment period.

This set of analyses found the percentage of students passing to significantly increase during the treatment phase among all four groups examined. Among Hispanic students, the percentage of those passing increased from 46.96% to 81.85%. In regard to White students, the percentage of those passing increased from 67.00% to 99.50%. Among students who were economically disadvantaged, 48.55% were passing during the baseline phase while 85.06% were found to be passing during the treatment phase. Finally, among LEP students, the percentage found to be passing increased from 37.17% to 78.17%.

The second set of analyses conducted on Allen Elementary data focused on differences in the percentage of students passing between the 2-year treatment period and the single year in which treatment was not conducted to test whether the effects of treatment were found to be sustained over time. The results of these analyses are presented in Table 7.

Of these four analyses, three were found to be statistically significant. While the percentage of White students who were found to be passing did not change between these two time periods, the percentages of Hispanic, economically disadvantaged, and LEP students found to be passing were found to increase significantly between the treatment phase and the final phase of nontreatment. Specifically, the pass rate for Hispanic students increased from 81.85% to 97.00%, and the pass rate for

Table 8 Allen 5th-grade state science assessment scores—% commended students

Allen elementary 5th grade state science assessment scores—% commended										
Year	State Avg (%)	District Avg (%)	Allen (%)	African American (%)	Hispanic (%)	White (%)	Native American (%)	Asian Pacific Islander (%)	Eco Dis (%)	LEP (%)
2005–2006	16	31	9	*	8	17	*	*	6	<1
2006–2007	19	34	16	*	15	*	*	*	15	16
2007–2008 (treatment)	22	38	21	*	16	40	*	*	20	10
2008–2009 (treatment)	26	45	51	*	51	*	*	*	44	40
2009–2010 (sustainability)	28	46	54	*	49	69	*	*	47	55

* Fewer than 30 test takers, so the subgroup was not evaluated separately

Table 9 Allen school baseline compared to treatment—students commended

Ethnicity	Base *N*	Base %	Treatment *N*	Treatment %	*z*
Hispanic	149	12.35	106	39.50	5.03*
White	22	17.00	17	44.00	1.60
Economically disadvantaged	154	12.21	106	35.02	4.40*
LEP	107	15.47	69	30.64	2.40*

* $p < 0.05$

economically disadvantaged students increased from 85.06% to 97.00%. In addition, the percentage of LEP students found to be passing increased from 78.17% to 99.50%. These results may suggest that treatment has both an immediate as well as a delayed effect and, within this context, may have led to the increase in the pass rate for these students in the year following the end of treatment. In regard to White students, the lack of significant results can be explained through a ceiling effect: as the percentage of White students passing was already 99.5%, there was really no room for scores to substantially increase during treatment.

Table 8 shows the percentages of students who were commended because they scored 90 or better on the 5th-grade science TAKS test.

Analyses were conducted to determine whether there was a significant change in the percentage of students who were commended between the 2 initial years in which there was no treatment and the 2 years of treatment. These results are presented in Table 9.

In these analyses, significant increases in the percentage of students who were commended were found in all cases with the exception of White students. In regard to White students, this nonsignificant effect can be explained through the small sample size. In terms of Hispanic students, the percentage of students commended was found to increase from 12.35% to 39.50% while, in regard to economically disadvantaged students, the percentage of students commended increased from

Table 10 Allen school treatment compared to sustainability check—commended students

Ethnicity	Base *N*	Base %	Treatment *N*	Treatment %	*z*
Hispanic	106	39.50	43	49.00	1.06
White	17	40.00	13	69.00	1.58
Economically disadvantaged	106	35.02	53	47.00	1.46
LEP	69	30.64	27	55.00	2.22*

* $p < 0.05$

Table 11 Percent passing Bell 5th-grade state science assessment scores compared to state and district

Year	State Avg (%)	District Avg (%)	Bell (%)	African American (%)	Hispanic (%)	White (%)	Native American (%)	Asian Pacific Islander (%)	Eco Dis (%)	LEP (%)
2005–2006	70	74	66	61	56	85	*	99	56	41
2006–2007	71	76	71	63	69	83	*	83	69	66
2007–2008	74	73	67	35	73	*	*	*	62	60
2008–2009	78	77	62	46	60	67	*	>99	54	61
2009–2010 (replicability)	83	84	92	80	92	>99	*	*	90	98

* Fewer than 30 test takers, so the subgroup was not evaluated separately

12.21% to 35.02%. Additionally, the percentage of LEP students commended was found to increase from 15.47% to 30.64%.

Next, an additional set of analyses were conducted in order to determine whether there was a significant change in the percentage of students commended between the treatment phase and the final year of nontreatment. These results are presented in Table 10.

Significant differences in the percentage of students commended were found in the case of LEP students. Among LEP students, the percentage found to be commended increased from 30.64% to 55.00%. This result further supports the possibility of the effect of treatment increasing in the year following its termination. While the percentages of students commended also increased among the three other groups included in the analysis, these results were not statistically significant. These non-significant findings are likely due to the small sample sizes included here. Additionally, while differences in percentages of students commended was not significant among the three other groups, this finding is not negative in the sense that this simply indicates that the percent commended did not decrease after the termination of treatment.

The next set of analyses focused on Bell Elementary. Table 11 shows a 5-year history of the passing rates of Bell Elementary 5th-grade students on the 5th-grade science TAKS test. Four years of baseline data was used to enable a comparison using a broader and more stable set of data. A test score of 70 or better is required for a student to pass.

Table 12 Bell school baseline compared to treatment—students passing

Ethnicity	Base *N*	Base %	Treatment *N*	Treatment %	*z*
African American	62	54.55	13	80.00	1.70
Hispanic	278	65.38	70	92.00	4.38*
White	38	79.98	8	99.50	1.35
Economically disadvantaged	306	61.23	80	90.00	4.88*
LEP	211	58.99	52	98.00	5.35*

* $p < 0.05$

Table 13 Bell 5th-grade state science assessment scores—% commended

Year	State Avg (%)	District Avg (%)	Bell (%)	African American (%)	Hispanic (%)	White (%)	Native American (%)	Asian Pacific Islander (%)	Eco Dis (%)	LEP (%)
2005–2006	16	18	23	6	16	62	*	40	15	<1
2006–2007	19	20	18	<1	18	33	*	33	18	18
2007–2008	22	22	20	12	16	*	*	*	19	8
2008–2009	26	26	29	31	11	58	*	>99	16	18
2009–2010 (replicability)	28	29	41	50	35	71	*	*	35	31

* Fewer than 30 test takers, so the subgroup was not evaluated separately

At Bell Elementary, two phases were conducted in total: 4 years of baseline followed by 1 year of treatment. The results of the analyses conducted on passing rates at Bell are summarized in Table 12.

Overall, three significant effects were found in this analysis: a statistically significant increase in the percentage of Hispanic, economically disadvantaged, and LEP students found to be passing between the 4-year baseline period and the single year in which treatment was conducted. Among Hispanic students, the percentage of those passing increased from an average of 65.38–92.00%. In regard to economically disadvantaged students, the percentage of those passing increased from 61.23% during the baseline period to 90.00% during treatment. Finally, the percentage of LEP students found to be passing increased from 58.99% during the baseline period to 98.00% during treatment. While the increase in the percentage of African American and White students found to be passing was also very substantial, these two analyses were not found to be statistically significant due to the small sample sizes for both of these groups of students during the treatment period.

Next, additional analyses were conducted focusing on the percentage of students who were commended. The percentages of Bell 5th-grade students commended on the state science test over a 5-year period are presented in Table 13. A test score of 90 or better is required for a student to be commended in science.

These analyses served to test the effect of treatment as well as whether the effect of treatment was sustained over time. The results of the analyses conducted on the

Table 14 Bell school baseline compared to treatment—students commended

Ethnicity	Base *N*	Base %	Treatment *N*	Treatment %	*z*
African American	62	18.99	13	50.00	2.37*
Hispanic	278	15.88	70	35.00	3.59*
White	38	54.23	8	71.00	0.87
Economically disadvantaged	306	12.75	80	35.00	4.68*
LEP	211	15.42	52	31.00	2.59*

* $p < 0.05$

Bell school, comparing baseline and treatment periods, are presented in the Table 14.

These analyses indicated that the percentage of students commended increased significantly for students in all categories with the exception of White students. First, the percentage of African American students commended increased from 18.99% to 50.00% while the percentage of Hispanic students commended increased from 15.88% to 35.00%. Additionally, the percentage of economically disadvantaged students commended increased from 12.75% to 35.00% while the percentage of LEP students commended increased from 15.42% to 31.00%. The non-significant finding in regard to White students was likely due to the very small sample size of only eight respondents in regard to the treatment sample.

End-of-Year Questionnaire Analysis

During the second week of May 2008, thirty-one Allen Elementary teachers were asked to complete a Science Initiative End-of-Year Teacher Feedback Questionnaire (see “Appendices 1 and 2”). Twenty-four teachers returned the questionnaires (77% return rate), and their perceptions are described in the following sections. Questionnaire data were only used in year 1. The use of descriptive teacher perceptions is a limitation of this study. Although questionnaire responses were anonymous, teachers may not have been completely forthcoming in their comments.

Effectiveness of Science Initiative

Teachers indicated the overall effectiveness of the project using a 4-point Likert-type scale and rated standards-based science learning, teacher science-content knowledge, English language development, scientific reasoning, and inquiry instruction as very effective. The mean rating for standards-based science learning was 3.92 (SD = 0.282), teacher science-content knowledge was 3.83 (SD = 0.381), English language development, scientific reasoning, and inquiry instruction were all 3.63 (SD = 0.495). Teachers reported that preparation for statewide science assessment was somewhat effective ($M = 3.46$, SD = 0.509).

Table 15 Impact of participation in science initiative on teachers ($N = 24$)

Topic	Common themes	Number of responses
Knowledge of grade level science topics (TEKS)	Knowledge of specific grade-level TEKS were refined and focused	21
	Increased understanding of the vertical alignment of science topics across different grade levels.	20
How they teach science	More hands-on	21
	Use the 5-E model	19
	Better teacher	4
Promote ELL development in Science instruction	Importance of vocabulary instruction	15
	Increased focus on vocabulary explanations and uses	14
	Use of science word walls	13
Planning of science lessons	Work more closely as a team	16
	Teams shares more ideas together	13
	Activities across the board are more focused on TEKS and the appropriate cognitive level of application	12
	Think vertically	10
	Use the 5-E model	7
Attitude toward teaching science	Increased confidence	12
	It is fun and exciting	9
	Generally more positive	6

Impact of Participation on Teachers

Teachers at Allen Elementary reported that the project influenced the way they approached and taught science. Their perceptions are organized with regard to knowledge of grade-level science topics (TEKS), how they taught science, how they promoted ELL development in science instruction, planning of science lessons, and their attitudes toward teaching science (see Table 15).

When describing the impact the project had on learning grade-level science topics, 21 teachers reported that the professional development refined and refocused their knowledge of science TEKS. A first-grade teacher wrote, “Having to analyze our grade level TEKS in-depth really helped me understand more clearly our TEKS and what exactly the TEKS were asking for.” A second-grade teacher noted, “I learned to look at the TEKS more closely and understand and identify exactly what my students are to be learning and doing for each science concept.” Teachers also described a new or heightened awareness of the vertical alignment of science topics. One teacher said, “It made our team own and use the TEKS vertical alignment with fidelity and look at the rigor up the line to determine whose responsibility it was to teach different concepts.”

The way teachers taught science was also affected by the project. The amount of inquiry science instruction increased: “I teach more inquiry and allow the students to explore concepts first and figure out for themselves instead of just telling and lecturing.” Another noted, “It made me increase the number of hands-on activities in science." One teacher stated, "Each year I continue to grow as a science teacher. The project has increased my science content knowledge and how I teach science. I am a better science instructor."

As a result of the project, teachers promoted English language development during science instruction by increasing the focus on content vocabulary and implementing interactive science word walls. As one teacher said, "I am focusing more on vocabulary and making sure the students are understanding the vocabulary and are using it and applying it correctly." Another teacher indicated, "The interactive word wall was a great resource in building English language science vocabulary. Having it up all year was a good visual support. Not only did it help the students but it helped me as well!"

Lesson planning was a main feature of the professional-development initiative, and 13 commented that the team planning structure provided opportunities for teachers to share ideas and strategies: "I am taking more time in planning for science." Another teacher wrote, "We now plan as a team." Similarly, another noted, "Our team got together and looked at the TEKS. We planned our labs together. We also worked together to share ideas for the classroom."

Participation in the project transformed teachers' attitudes toward teaching science. Teachers reported they had more confidence teaching science and increased content knowledge. Nine reported that the project changed how they felt when teaching science. Teachers mentioned that "science is now fun to teach" and they were "more excited about teaching science" and "enjoyed teaching science more this year." One teacher commented, "All of a sudden, I finally enjoyed it!"

Impact of the Science Initiative on Students

Teachers reported that the science initiative affected how students learned science and student attitudes toward science (see Table 16). One teacher stated, "They enjoy using the science vocabulary, they love the labs and everything hands-on."

Table 16 Impact of science initiative on students ($N = 24$)

Topic	Common themes	Number of responses
How students learn science	Enjoyed participating in hands-on activities	22
	Vocabulary activities	9
	See science in their everyday lives	5
	Writing	4
How students learn English language and literacy during science instruction	Reading more science informal literature	16
	Vocabulary activities and focus	15
	Interactive science word walls	11
Students' attitude toward science	They were engaged and excited	18
	Look forward to science	7
	Science is everywhere, no longer thinking about it as a single subject	6

Table 17 Effective project activities ($N = 24$)

Common themes	Number of responses
Help planning science lessons	15
Examples of TEKS aligned 5-E lesson plans	14
Sharing science resources	12
Alignment of instruction with grade level TEKS	9

The fifth-grade team commented that their students "see science in their environment and are aware that their actions affect science daily".

This project also influenced how students learn English language and literacy in science. Sixteen teachers reported an increase in students' desires to read informal science literature. A fourth-grade teacher reported, "My students are reading more informal science literature. One library day every student checked out a book about a science topic. That was a first!" First-grade teachers noticed that their students enjoyed "the great books that we used to support the science and literacy connection." Vocabulary activities also supported English language and literacy development. Fifteen teachers reported an increased focus on vocabulary instruction, and 11 specifically mentioned using the interactive science word wall: "We really focus on the vocabulary and how it relates to the science concept and what it means to the students. They aren't just hearing the vocabulary, they are applying it and using it."

Teachers reported that their students' attitudes toward science became more positive as well: "My students enjoyed the hand-on science experiments." Another wrote, "My students always looked forward to going into the science lab. They also liked ongoing experiments that they had to check daily to see the progress." Finally, one teacher indicated, "My students see science everywhere, they no longer think of it as a separate subject… They realize that is it at their level, friendly and exciting."

Effective Project Activities

Participating teachers believed that the most effective aspects of the project included opportunities to exchange ideas, 5-E lesson plans that they could use as examples to write their own lessons, and alignment of instruction with grade-level TEKS (see Table 17). As one noted, "I enjoyed and found very beneficial just having someone to discuss TEKS related science topics with. The resulting suggestions and ideas regarding what activities to use with specific topics were very effective."

Areas for Improvement

Areas targeted for improvement included requests for more assistance and support for the lower elementary grades (K-2), continued help planning and implementing hands-on inquiry activities, money to purchase additional science equipment and

Table 18 Areas for improvement ($N = 24$)

Common themes	Number of responses
More science assistance and support for lower grades	8
Continued help planning and implementing 5-E lessons	8
Money to purchase consumable items and lab equipment	8
Continued clarification of grade level TEKS	2

consumable items, and continued clarification of grade level TEKS (see Table 18). Teacher requested "continued help planning meaningful inquiry labs."

Conclusion

The demographics of American classrooms reflect the diverse ethnic, racial, social, and economic backgrounds of our changing communities. Effective pedagogical practices that meet the needs of diverse students are in demand. This present research revealed that the combination of purposeful planning, inquiry science instruction, and multisensory vocabulary activities significantly improved the performance of English language learners and economically disadvantaged students on a high-stakes 5th grade science test in Texas. During the treatment, sustainability, and replicability phases of this project, English language learners and economically disadvantaged students significantly improved their passing and commended test scores. The empirical evidence produced by this study provides rigorous support for replicability and sustainability. We believe these finding are important because science is a challenging academic subject for students who are learning English and who are economically disadvantaged. Additionally, the science scores of these student populations frequently determine school performance ratings. As a result, these findings may inform the curricular decisions of diverse, Title I elementary schools struggling to raise student test scores and close achievement gaps to comply with the high expectations for student learning mandated by NCLB.

Teachers reported that this project positively affected the way they planned and delivered science instruction. Professional development activities provided opportunities for teachers to work in grade-level teams to purposefully plan standards-based lessons. This collaborative team planning structure enabled content discussions and the exchange of teaching ideas and strategies. Teachers reported that aligning instruction with state science standards was a powerful element of the project. Their heightened awareness of the vertical alignment of K-5 science content and increased familiarity with specific grade-level topics changed the way they selected instructional materials and delivered instruction.

This study illustrates that student scores on high-stakes tests are positively affected when classroom teachers are trained to translate state standards into situated practice. In addition, the 5-E lesson-plan model affected the way participating teachers planned and delivered instruction. Teachers reported enjoying delivering inquiry lessons. They also reported that students were engaged in the inquiry science activities and looked forward to science lessons. Thus, the results of this study support the National Science Education Standards call for an increased focus on inquiry instruction (NRC 2000).

"Academic success requires a command of academic language" (Walqui 2002 p. 1). Participating teachers used interactive-multisensory activities to enhance academic content-vocabulary development. Teachers observed that their students achieved a deeper understanding of content, as well as enhanced vocabulary development, when they were guided through inquiry-based, multi-sensory explorations that repeatedly exposed them to words and definitions in context. Multi-sensory word walls allowed students to informally see, hear, touch, manipulate, name, and discuss content vocabulary. Acting as visual scaffolds, these interactive word walls provided semantic links between key science vocabulary and concepts as well as related pictures and objects. Thus, this study supports the findings of Carlo et al. (2004) in that vocabulary instruction was effective when taught in context, exposing students to new words in novel ways and providing opportunities for repeated exposure to key vocabulary.

Appendix 1: Science Initiative End-of-Year Teacher Feedback Questionnaire May 2008

Grade Level Taught

Part I Please indicate how effectively the project has addressed each of the following areas:

	Very ineffective	Somewhat ineffective	Somewhat effective	Very effective
a. Standards-based science learning (TEKS)	1	2	3	4
b. Preparation for statewide science assessment (TAKS)	1	2	3	4
c. English language development	1	2	3	4
d. Scientific reasoning (asking questions)	1	2	3	4
e. Inquiry instruction	1	2	3	4
f. Teacher science content knowledge	1	2	3	4

Part II What impact has your participation in the project had on

a. Your knowledge of your grade level science topics (TEKS)?
b. How you teach science?

c. How you promote English language development in science instruction?
d. How you plan science instruction?
e. Your attitude toward teaching science?

Part III What impact has the project made over the school year with regard to

a. How your students learn science?
b. How your students learn English language and literacy in science instruction
c. Their attitude toward science?

Part IV What aspects or activities of the project have been most effective? (What have we done well?) Please rate three in order of effectiveness.

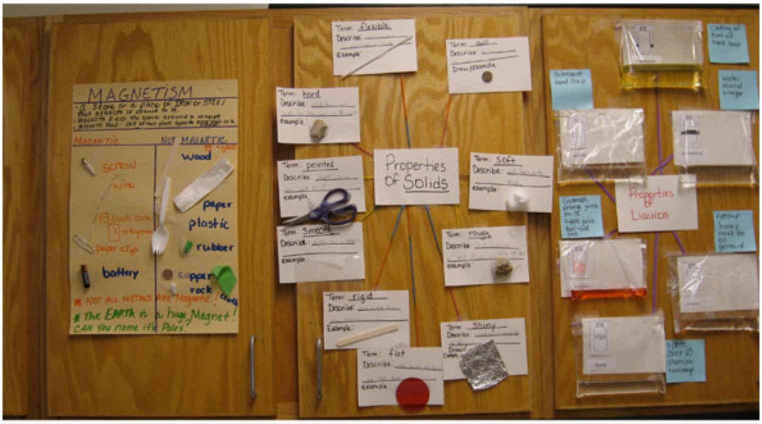
1.
2.
3.

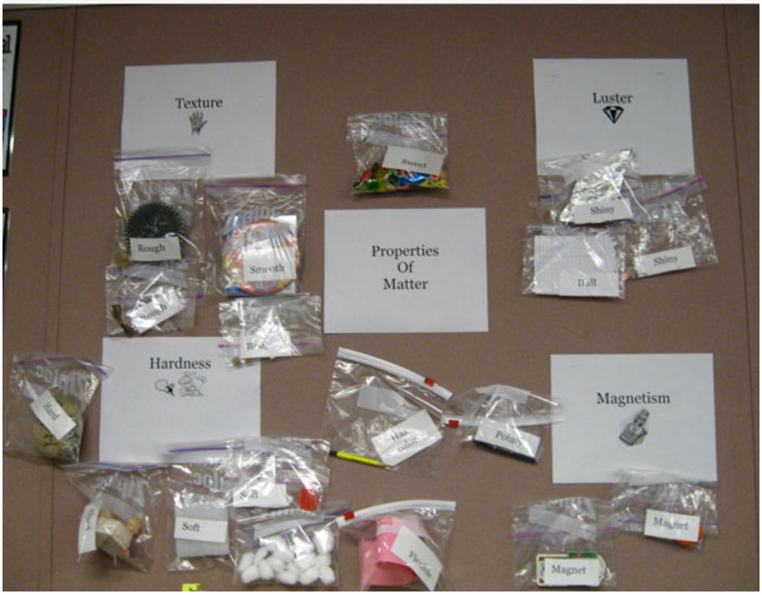
Part V What aspects or activities of the project need improvement? (What can we do better?) Please rate three in order of improvement needed.

1.
2.
3.

Reference: Lee, O., Adamson, K., Maerten-Rivera, J., Lewis, S., Thornton, T., & LeRoy, K. (2008). Teachers' perspectives on a professional development intervention to improve science instruction among English language learners. *Journal of Science Teacher Education, 19*, 41–67.

Appendix 2: Interactive Multi-Sensory Word Wall Photos from Allen Elementary 2007–2008 School Year





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