The Journal of Educational Research

ISSN: 0022-0671 (Print) 1940-0675 (Online) Journal homepage: https://www.tandfonline.com/loi/vjer20

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To cite this article: Julie K. Jackson, Margarita Huerta & Tiberio Garza (2020) A promising science and literacy instructional model with Hispanic fifth grade students, The Journal of Educational Research, 113:2, 79-92, DOI: 10.1080/00220671.2020.1728734

To link to this article: https://doi.org/10.1080/00220671.2020.1728734

THE JOURNAL OF EDUCATIONAL RESEARCH
2020, VOL. 113, NO. 2, 79–92
https://doi.org/10.1080/00220671.2020.1728734

A promising science and literacy instructional model with Hispanic fifth grade students

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ABSTRACT

This study evaluated the Science and Literacy Instructional Model aimed at helping primarily Hispanic bilingual/English Learners (ELs) and economically disadvantaged fifth grade students with science achievement as measured by high-stakes standardized science achievement scores. The model combined purposeful planning, innovative academic vocabulary instruction, and a Lesson Design Lab. Difference-in proportions tests were used to determine if students at two school campuses showed positive achievement gains on a state science test. This study found statistically significant results with medium to large effect sizes at both campuses. Findings contribute to much needed research, practice, and policy in the area of effective models to assist both teachers and students in an era of high-stakes testing.

ARTICLE HISTORY
Received 26 February 2019
Revised 5 October 2019
Accepted 30 January 2020

KEYWORDS
Bilingual students; high-stakes tests; Hispanic students; English learners; professional development; science achievement; interactive word walls

Science education is important for individuals to be able to succeed in scientifically and technology driven societies. Science education should also be accessible to *all* students, including English Learners (ELs) who are students in the process of learning English (National Research Council [NRC], 1996; NGSS Lead States, 2013). Students who are classified as Hispanic – many who are also classified as English Learners (ELs) and economically disadvantaged – score significantly below other students on national measures of science achievement (McFarland et al., 2017). For example, Hispanic elementary aged students scored 27 points lower than White elementary aged students, ELs scored 37 points lower than native English-speaking students, and economically disadvantaged students scored 29 points lower than non-economically disadvantaged students on the most recently reported national measures of science achievement (National Assessment of Educational Progress [NAEP], 2015).

Problem

The aforementioned statistics are problematic from two different though interrelated viewpoints. From a social justice viewpoint, science education practices may be failing to provide equitable learning experiences for ELs and/or students who are economically disadvantaged (Dawson, 2017; Leonard, Chamberlin, Johnson, & Verma, 2016). Researchers concerned with EL science achievement report teachers in intervention studies receiving professional development training do not always reach the level of reform-oriented practices needed to promote ELs' science learning. For example, researchers have noted teachers in their intervention were not able to engage students in argumentation and inquiry as specified by the *Next Generation Science Standards* (Lee, Lewis, Adamson, Maerten-Rivera, & Secada, 2008; NGSS Lead States, 2013; Santau, Secada, Maerten-Rivera, Cone, & Lee, 2010). These are processes requiring written and oral language production which are closely tied to academic language and vocabulary use and could be closely tied to ELs achievement on high-stakes standardized tests.

From a statistical viewpoint, an educational disservice exists for a large percentage of the population – arguably, the future of the nation. The latest data from the National Center of Educational Statistics concerned with racial and ethnic group trends in the United States notes the following: 24% of the national student population is Hispanic, and this group represents 27% of all students considered economically disadvantaged. Moreover, 4.6 million public school students are considered ELs, of which Hispanics make up the majority at 78.4% (Musu-Gillette et al., 2016).

Context and terminology

The present study is situated in the context of a high-Hispanic population in the state of Texas. In the state, 52.4% of public-school students are classified as Hispanic, 18.9% are classified as English Learners (ELs), and 59% are classified as economically disadvantaged (Texas Education Agency [TEA], 2017). In the present context (1) "At-risk" is

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defined as a student under the age of 26 who is at-risk of dropping out of school who also meets one or more of thirteen criteria such as not having advanced from one grade level to the next, being EL, and being homeless; (2) "EL" is defined as a student who lives in a home where a language other than English is primarily used and whose English language proficiency is determined as limited by the Language Proficiency Assessment Committee (LPAC) or by an English proficiency test; and (3) "Economically disadvantaged" is defined as a student who is eligible for free or reduced-priced meals under the National School Lunch Program (Texas Education Data Standards, 2019).

From here on, we use the terms bilingual and EL because our context includes mostly bilingual Hispanic students who are Spanish and English speakers. However, the term EL acknowledges a more inclusive corpus of students discussed in the science education literature who may be multilingual and/or still in the process of learning English (United States Department of Education; TEA).

Purpose

The present study addressed issues related to state trends reflective of larger, national issues related to science education for Hispanic students. In doing so, the purpose of the study was to evaluate the Science and Literacy Instructional Model intended to help primarily Hispanic bilingual/ELs and economically disadvantaged students succeed in science as measured by standardized science achievement scores.

Theoretical framework

The present study is based on sociolinguistic and sociocultural theory which views language as critical to learning in the content areas such as science (Gee, 2004; Halliday, 1993; Lemke, 1990). Discipline specific language, including vocabulary, is important for student comprehension (Wright & Domke, 2019), especially for English learners (Fang, 2006; Schleppegrell, 2001). For example, words such as "volume" can take on different meanings such as how loud something is or how much space is taken up by an object. Students therefore need opportunities to learn discipline-specific language in ways which facilitate comprehension. In a recent systematic review, Wright and Cervetti (2017) noted that vocabulary instruction based on theory related to actively engaging students with words and their meanings (e.g., McKeown & Beck, 2014), was more impactful for supporting student comprehension than teaching students vocabulary through definitions or dictionaries. The implications for the science classroom, or any content-area classroom, are that students may benefit from actively engaging in using vocabulary in context rather than being directly taught vocabulary words. For this type of instruction to happen teachers need to be able to facilitate simultaneous language and content learning for all students, including ELs.

The present study is also based on theory linking changes in teacher practices to improved student learning. We align our work with Guskey and colleagues work on professional development (e.g., Guskey, 1985; 2002; Guskey & Sparks, 1996). The premise of this body of work is that teacher changes in beliefs and attitudes come after teachers have implemented instruction (based on professional development) and seen the instruction affect student learning outcomes (Guskey, 2002). This model was recently adapted in a study investigating the effect of professional development on science teachers' instructional practices, beliefs, and their students' achievement in a middle school (Zamback, Alston, Marshall, & Tyminksi, 2017). The researchers found that teachers' focus on discourse and curriculum were important components of teachers' inquiry-based instruction and teacher beliefs. While the purpose of the present study did not include analyzing teacher beliefs and attitudes, it did consider student learning outcomes as the most important evaluative measure for the quality of the Science and Literacy Instructional professional development model and the instructional practices it espoused (Guskey, 2013).

Literature review

Standardized science testing

Students' success on standardized tests is critical to school accountability as set by national education policy (Every Student Succeeds Act [ESSA], 2015; No Child Left Behind [NCLB], 2001). Standardized tests are considered high-stakes because their results are used to make decisions regarding issues such as school and district ratings, school closures, teacher compensation, and student graduation. At the state level, for example, Texas began testing science achievement in fifth grade in 2004. The state standardized science test, previously the *Texas Assessment of Knowledge and Skills* (TAKS) and now (since 2012) the *State of Texas Assessments of Academic Readiness* (STAAR), is administered to students every spring. Longitudinal state data shows trends parallel to national trends. That is, Hispanic, EL, and economically disadvantaged students do not fare well on the state science test compared to their peers (Texas Education Agency [TEA], 2016).

Clearly, standardized tests are difficult for diverse students and the reasons for these difficulties are closely tied to language (Abedi, 2002; Kieffer, Lesaux, Rivera, & Francis, 2009; Noble, Rosebery, Suarez, Warren, & O'Connor, 2014). At the same time, the reality of educational policy and school accountability remain (Every Student Succeeds Act [ESSA], 2015), prompting researchers and educators to find ways to promote all students' science achievement reflected by standardized science achievement scores.

Previous science education research with bilingual/ELs

In the United States efforts have been made though teacher professional development interventions to close overall achievement gaps between ELs and their peers. Based on theory and research, these efforts have anchored themselves on the importance of building students' language alongside content understanding, especially when students come from culturally and linguistically diverse (e.g., Hispanic and/or EL) and economically disadvantaged backgrounds (Bravo & Cervetti, 2014; Lara-Alecio et al., 2012; Maerten-Rivera, Ahn, Lanier, Diaz, & Lee, 2016). In what follows we considered the work of Lee and colleagues which dominates the field of science and EL education in terms of quantity and impact. We also consider other notable studies concerned with the science education of ELs.

Lee and colleagues

Lee and colleagues conducted a series of national grant-funded projects evaluating the effects of a professional development intervention in the southeastern United States focused on improving the science and literacy achievement of EL elementary students (3rd-5th) ELs. The studies included the following key elements: (1) curriculum units to guide teachers on how to teach science concepts effectively alongside key vocabulary words, (2) student booklets to promote science inquiry and the integration of reading and writing, and (3) teacher workshops to guide them through the science content and pedagogy with emphasis on teaching the state science content standards (e.g., Lee, Adamson, et al., 2008).

Overall, their work has shown the positive impact of inquiry and standards-based curriculum, science and literacy integration with language scaffolding, and targeted teacher professional development. The researchers reported positive effects for in-service teachers' development in terms of knowledge and practices (Adamson, Santau, & Lee, 2013; Lee, Adamson, et al., 2008; 2008; Lee, Llosa, Jiang, O'Connor, & Haas, 2016; Lee, O., Llosa, L., Jiang, F., Haas, A., O'Connor, C., & Van Booven, et al., 2016; Santau et al., 2010) and positive effects for overall student achievement on science and literacy measures (Lee, Deaktro, Hart, Cuevas, & Enders, 2005; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008; Lee, Mahotiere, Salinas, Penfield, & Maerten-Rivera, 2009; Llosa et al., 2016; Maerten-Rivera, Ahn, Lanier, Diaz, & Lee, 2016).

Demographics. The population demographics reported in Lee and colleagues' studies included notable percentages of Hispanic, EL, and economically disadvantaged students. For example, in their first major project, the researchers focused on results from the first year of their professional development intervention (2004–2005; 3rd grade; 6 treatment and 8 control schools within the same district) during which the district was comprised of 60% Hispanic, 24% EL, and 72% economically disadvantaged students (Lee, Adamson, et al., 2008; Lee, Lewis, et al., 2008; Lee, Maerten-Rivera, et al., 2008; Lee et al., 2009; Santau et al., 2010). In their second major project, the researchers scaled up their previous professional intervention study to include 33 treatment and 33 control schools across three school districts in the same state, focused on 5^{th} grade students. During this three-year scale-up project, the researchers reported that approximately 65% of the students were Hispanic, 12–13% of the students were ELs, and 77–82% of the students were economically disadvantaged (Maerten-Rivera et al., 2016).

Student achievement impact. Throughout the two decades of their research, Lee and colleagues have acknowledged the high-stakes nature of standardized tests but their studies have only begun to find effects of their interventions on high-stakes test measures. They reported standardized high-stakes test measures in only three of their studies (Lee, Maerten-Rivera, et al., 2008; Llosa et al., 2016; Maerten-Rivera et al., 2016), and only one (Maerten-Rivera et al., 2016) found effects on science achievement on ELs. For example, Lee, Maerten-Rivera, et al. (2008) reported 3rd grade treatment students as having higher scores on state-wide math tests than comparison students (science was not tested in 3rd grade). Llosa et al. (2016) reported positive effects for 5th grade former ELs and non-ELs on the state high-stakes science assessment but not for ELs or recently reclassified ELs after one year of the intervention. Maerten-Rivera et al. (2016) did, however, find statistically significant effects for all treatment students, including ELs, in year 2 and 3 of the intervention noting that "… there may be a lag in improved student achievement as teachers gain familiarity with the new curriculum and adjust their teaching practices over time" (p. 600). It is important, however, that more research find effects on high-stakes standardized tests than is presently reported.

Proximal vs. distal assessments. In these aforementioned studies and in their other work reporting student achievement (Lee, Maerten-Rivera, et al., 2008; Lee et al., 2005; 2009; Llosa et al., 2016; Maerten-Rivera et al., 2016), the researchers noted positive effects based on researcher-made proximal assessments, meaning they were assessments closely aligned to the researcher-created curriculum vs. distal assessments such as standardized tests that are arguably further removed from the curriculum (Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002). While the work is valuable in understanding what works for diverse students in science education, the reality is that policy-makers and researchers consistently refer to the achievement gap based on high-stakes, standardized tests.

Other studies

Other groups of researchers have also considered the impact of science and literacy instruction on Hispanic, EL, and/or economically disadvantaged students. For example, Bravo and Cervetti (2014) explored the effect of creating and giving teacher guides which explicitly helped teachers integrate language – reading and vocabulary – into their science lessons. They found that 4th and 5th grade ELs in their treatment condition to outperform ELs in their control condition on measures of vocabulary but not reading (pre-post, researcher-created tests). Their sample came from five high-poverty schools in one western and one southern state and included 115 ELs of which 98% were Spanish-speaking.

In the present study's state of interest, Lara-Alecio et al. (2012) conducted their research in one southeast Texas school district with 6 treatment (116 students) and 8 comparison schools (80 students). They reported over 45% of the students to speak Spanish as their first language and

Table 1. Enrollment history and ethnic distribution data for Rio Grande School 1.

Campus Ethnic Distribution	Total Students	African American	Hispanic	White	American Indian	Asian	Pacific Islander	Economically Disadvantaged	EL*	At-Risk
2016–2017	777	0.10%	99.50%	0.40%	0.00%	0.00%	0.00%	88.90%	59.20%	80.70%
2015–2016	770	0.00%	99.10%	0.80%	0.10%	0.00%	0.00%	90.10%	59.70%	84.20%
2014–2015	775	0.00%	99.40%	0.50%	0.00%	0.10%	0.00%	89.50%	60.30%	83%

**Note*: Publicly available reported data uses the term "LEP". We have changed the term to "EL" to be in line with the terminology used in this manuscript.

85% of the students were considered economically disadvantaged. The researchers explored the impact of their multifaceted professional development intervention on 5th grade students' achievement measures. The intervention included science inquiry, direct and explicit vocabulary instruction, and reading/writing integration. The researchers reported statistically significant positive treatment effects on district benchmark science and reading tests but not on the state standardized test (Lara-Alecio et al., 2012). These findings are similar to those of Lee and colleagues after one year of intervention — that is, the researchers found effects for proximal measures of science achievement but not for distal, high-stakes measures. Again, more work needs to consider interventions focused on increasing students' distal, high-stakes assessment outcomes and helping teachers to accomplish that goal alongside students.

Research purpose and questions

The purpose of the study was to evaluate the Science and Literacy Instructional Model intended to help primarily Hispanic bilingual/ELs and economically disadvantaged students succeed in science as measured by standardized science achievement scores. The Science and Literacy Instructional Model included elements noted by previous research to be effective for addressing the needs of diverse learners in science. In specific, it included professional development focused on pedagogy aligned to state standards and an emphasis on literacy-integration – including vocabulary instruction – to promote diverse students' learning (e.g., Lee, Adamson, et al., 2008; Lara-Alecio et al., 2012; See: "Science and Literacy Instructional Model" below). We therefore asked: What changes on Hispanic and bilingual/EL students' standardized achievement passing rates, if any, are evident on two school campuses implementing the Science and Literacy Instructional Model?

Method

Context

The school district in which the Science and Literacy Instructional Model was implemented is situated on the United States – Mexico border. Stretching thirteen miles north of the Rio Grande River it encompasses more than 226 square miles of the Rio Grande Valley in South Texas. The school district was established in the early 1800's when a rock and adobe building was repurposed to serve as a schoolhouse. At the time of the study, the district supported 29,500 students in twenty-three elementary schools, eight middle schools, four high schools, five academies, and three early-college high schools. The student population was 99.7% Hispanic, 93.8% economically disadvantaged, 53% English Learners, and 79.3% At-Risk. The school campus implementing the Science and Literacy Instructional Model the first year (from here on known as Rio Grande School 1), the oldest elementary school in the district, has historically served economically disadvantaged, Hispanic students. Table 1 contains enrollment history and ethnic distribution data for Rio Grande School 1 collected by the Texas Education Agency (TEA) across a three-year period.

A school campus similar to Rio Grande School 1 was selected to implement the Science and Literacy Instructional Model one year later to evaluate the Science and Literacy Instructional Model in a second school. The second school, or Rio Grande School 2, was selected based on enrollment history and ethnic distribution data collected by the Texas Education Agency (TEA) across a two-year period. Rio Grande School 2 was built in 1997 and also served economically disadvantaged, Hispanic students. Table 2 contains enrollment history and ethnic distribution data for Rio Grande School 2.

Measures

As noted, our research project was driven by concerns about the low science achievement of Hispanic bilingual/EL's, economically disadvantaged students and At-Risk students on high stakes tests. Rio Grande School 1 was rated "Improvement Required" (IR) on the 2014 – 2015 school year Texas Academic Performance Report due to low scores on State of Texas Assessments of Academic Readiness (STAAR) fifth grade science exam. IR indicates unacceptable performance and is assigned to campuses and districts that do not meet established Texas Education Agency (TEA) targets on a range of indices for which data is available. Eight percent of Texas public schools were rated IR in 2014–2015. Rio Grande School 2 was rated "Met Standard" on the 2015–2016 school year Texas Academic Performance Report. School campuses that receive an accountability rating of "Met Standard" must meet three of four indices: Student achievement on the STAAR, student progress, closing performance gaps, and postsecondary readiness. Ninety-four percent of Texas public schools were rated "Met Standard" in 2015–2016.

The fifth-grade science STAAR is a distal high-stakes state exam administered to all fifth-grade students in the spring. Retesting is not allowed so the students have one opportunity to pass. The fifth-grade science STAAR passing criteria for 2015 – 2016 were Unsatisfactory (scores below 60%, considered not passing), Satisfactory (scores between

Table 2. Enrollment history and ethnic distribution data for Rio Grande School 2.

Campus Ethnic Distribution	Total Students	African American	Hispanic	White	American Indian	Asian	Pacific Islander	Economically Disadvantaged	EL*	At-Risk
2016–2017	517	0.00%	99.60%	0.40%	0.00%	0.00%	0.00%	94.60%	72%	84.30%
2015–2016	586	0.00%	100%	0.00%	0.00%	0.00%	0.00%	94.50%	73.5%	86.20%

**Note*: Publicly available reported data uses the term "LEP". We have changed the term to "EL" to be in line with the terminology used in this manuscript.

60−89%, considered passing) and Advanced (90% or better, considered passing). STAAR performance standards have been scheduled with incremental improvements toward a final recommended level of performance in 2021−2022. In 2017, two STAAR reporting categories were renamed. "Satisfactory" became "Approaches" and "Advanced" became "Masters." The passing criteria were also adjusted. The fifth-grade science STAAR passing criteria for 2016−2017 were Unsatisfactory (scores below 58%, considered not passing), "Approaches" (scores between 58% and 87%, considered passing) and "Masters" (88% or better, considered passing). Additionally, the test had to be completed within a two hour window and the number of test questions was reduced from 44 to 35.

STAAR passing rates are one of four indices used to determine campus and district accountability ratings. As a result, improving fifth grade science STAAR passing rates was a high priority for both campuses and the district. For these reasons we developed the Science and Literacy Instructional Model based on theory and previous research, with the intent of helping improve students' fifth grade science STAAR passing rates at the Satisfactory (Approaches) level, and with the intent of seeing changes at the Advanced (Masters) level as well.

Science and literacy instructional model

The Science and Literacy Instructional Model included three major components: (1) Innovative vocabulary instruction - interactive word walls, (2) Purposeful planning, and (3) Lesson design labs. Each component is elaborated in the following section, but we first make explicit connections between the components and previous theory and research.

The first component, innovative vocabulary instruction - interactive word walls was based on previous theory and research regarding the importance of actively engaging students in using vocabulary in context to aid their comprehension (McKeown & Beck, 2014; Wright & Cervetti, 2017). Elements of Michael Grave's *Comprehensive Vocabulary Program* were used to create a *Vocabulary Planning Document* that underpinned the selection of essential academic vocabulary (Graves, 2006; Graves, August, & Mancilla-Martinez, 2013). Vocabulary instruction was also based on previous research concerned with ELs and science noting that science and literacy integration promotes all students science learning (Saul, 2004), and is important for ELs' science learning (Bravo & Cervetti, 2014; Lara-Alecio et al., 2012; Maerten-Rivera et al., 2016). For ELs in particular, academic vocabulary is critical to their ability to perform on standardized tests (Kieffer et al., 2009).

The second and third components - purposeful planning and lesson design lab are based on theory noting the importance of teacher agency on quality professional development (e.g., Guskey, 2002). They are also based on the premise of the importance of quality and sustained professional development, as noted in previous literature in science education with ELs (Adamson et al., 2013; Santau et al., 2010). Last, they are based on research noting the importance of teacher engagement with a focus on student discourse and curriculum when planning science inquiry lessons (Zamback et al., 2017). The details of each component of the Science and Literacy Instructional Model, when it was introduced, how it was supported, and how implementation was monitored are listed in Figure 1 and discussed as follows.

Innovative vocabulary instruction – interactive word walls

Word walls can be found in many elementary school classrooms. Teachers use word walls to visually display vocabulary that students will learn or have learned during instruction. The structure and usefulness of word walls varies. Many word walls are static lists of words or word banks posted on classroom walls, arranged alphabetically, and created by teachers. Hilden and Jones (2012) label these word walls "word wallpaper" (p. 9) because they decorate classroom walls with words and are seldom used or referenced by students to support learning. Researchers have found that word walls become instructional tools when they are conceptually organized, include student-generated materials, link academic vocabulary with concepts, include visual cues, and support oral and written discourse (Cunningham, 2000; Jackson & Ash 2011; Pinnell & Fontas, 1998). Furthermore, word walls that are organized by theme, include pictures or illustrations, and example sentences or sentence frames differentiate instruction for ELs as they learn to speak and write English (Carr, Sexton, & Lagunoff, 2007). To support academic language development in science, we replaced traditional teacher-generated word walls or "word wallpaper" with interactive word walls that are created and used by students. The interactive word walls created during this study strategically targeted academic vocabulary, visually displayed connections between inquiry science activities and academic vocabulary, were created by students during class, and they supported oral and written discourse. Teachers were taught how to select vocabulary for interactive word walls, plan, build, and use interactive word walls to support oral and written discourse during the professional development meetings. Implementation was monitored via bi-monthly classroom visits conducted by the district science specialist and school principals (see Table 3 and Figure 1).

First Component	Second Component	Third Component
Innovative Vocabulary Instruction Interactive Word Walls	Purposeful Planning	Lesson Design Labs
Introduced during professional development meetings and supported during Purposeful Planning and Lesson Design Labs. Monitored via bi-monthly classroom visits	Introduced during professional development meetings and implemented during team planning and Lesson Design Labs.	Monthly after school meetings that provided planning and implementation support.
• Highlighted connections between science investigations, in class activities, and science concepts, • Connected science concepts and essential academic vocabulary, • Resembled graphic organizers, • Included artifacts or visual representations from science investigations and in class activities, • Built/organized by students during science lessons, • Included sentence frames or scientific discourse patterns, • Used by students to frame oral and written discourse, • District and school level support.	• Reinforced during team planning and Lesson Design Lab activities, • Reviewed state science standards, • Used the *Vocabulary Planning Documen*t to identify essential academic vocabulary, • Discussed and clarified science content, • Planned the structure of interactive word walls, • Identified or created lessons aligned to standards, • District and school level support.	• Held after-school on a monthly basis and functioned as just-in-time planning, • Reviewed state science standards, • Used the *Vocabulary Planning Documen*t to identify essential academic vocabulary, • Discussed and clarified science content, • Planned the structure of interactive word walls, • Identified or created lessons aligned to standards, • Prepared materials for use during instruction, • District and school level support.

Figure 1 . Components of the Science and Literacy Instructional Model.

Table 3. Tiered professional development timeline.

Timeline	Rio Grande School 1	Rio Grande School 2
January 2016 Professional development (1day)	Three 5th grade teachers, campus principal, district science specialist	
January – May 2016 Monthly lesson design labs	Three 5th grade teachers, district science specialist	
August 2016 Professional development (1day)	47 K-5 teachers, campus principal, district science specialist	36 K-5 teachers, campus principal, district science specialist
August 2016 – May 2017 Monthly lesson design labs	Three 5th grade teachers, district science specialist	Three 5th grade teachers, district science specialist
January 2017 Professional development (1day)	47 K-5 teachers, campus principal, district science specialist	36 K-5 teachers, campus principal, district science specialist

Effective interactive word walls resemble graphic organizers or data tables. To determine the best way to represent information, teachers were taught to consider: Can the science concept be divided into categories and subcategories? Is it a cycle? Cause and effect? Structure and function? Is there a hierarchy? This process ensured that interactive word walls visually represented the patterns and connections between academic vocabulary and science concepts. Interactive word walls functioned as unit organizers that students referenced to help them connect science concepts and academic vocabulary during lessons.

Interactive word walls also showcase connections between concepts and artifacts (realia – the real thing) from science activities while connecting scientific concepts and academic vocabulary. Interactive word walls include visual representations of specific vocabulary words and labels. When appropriate, they highlight prefixes, suffixes, root words, multiple meaning words, and cognates. Definitions are optional (Jackson & Durham, 2016). Figure 2 includes a completed interactive word wall illustrating the flow of energy within a food web including the roles of the Sun, producers, consumers, and decomposers. Students constructed interactive word walls in class following inquiry science experiences. Building interactive word walls allowed students to have multiple encounters with new and familiar academic vocabulary in context as they actively processed the meaning of academic vocabulary and connected vocabulary to classroom science activities. Sentence frames or scientific discourse patterns were frequently used to scaffold students' as they practiced speaking and writing sentences that included academic vocabulary. Figure 2 illustrates how claims and evidence sentence frames were embedded in an interactive word wall to structure oral and written discourse regarding producers, consumers, and decomposers. Student participation in

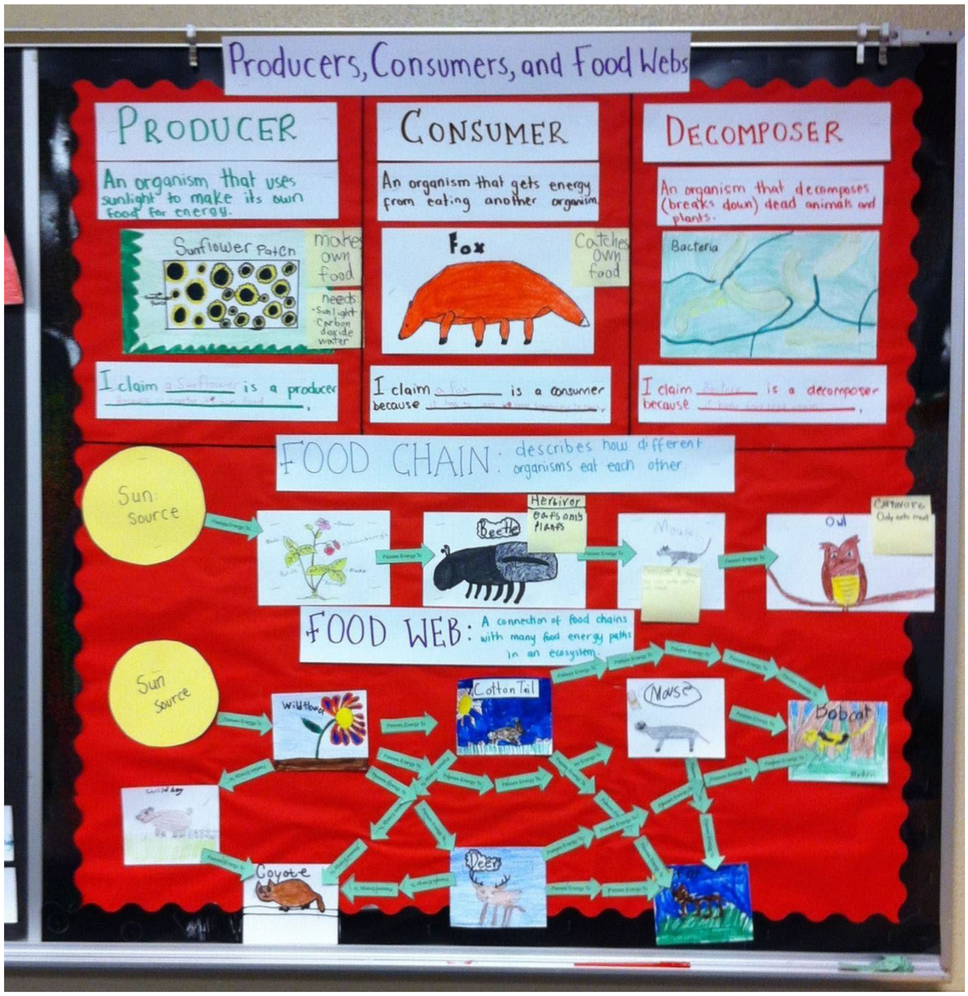

Figure 2. Completed interactive word wall illustrating the flow of energy within a food web including the roles of the Sun, producers, consumers, and decomposers.

constructing and then using interactive word walls to frame discourse was a critical factor that cannot be overemphasized.

Purposeful planning

Interactive word walls were constructed by students, but planned and organized by teachers. As a result, planning was the keystone to successful implementation of the Science and Literacy Instructional Model. Teachers were taught how to plan interactive word walls during the professional development meetings. Implementation occurred during team planning and Lesson Design Labs, and monitored during monthly Lesson Design Labs (see Table 3 and Figure 1). The first step in planning interactive word walls was to use content standards to identify the academic vocabulary students needed to learn. Standards-based instruction has been called for and conceptualized by national science education reform efforts (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996; NGSS Lead States, 2013). Teachers are a critical piece in standards-based instruction because they are the front-line providers of instruction. Therefore, it was essential that teachers implementing the Science and Literacy Instructional Model understood and used state science standards to select academic vocabulary and plan interactive word walls.

Lesson planning preceded instruction and required teachers to consider the standards-based content they would teach and select relevant academic vocabulary. Based on the 1996 National Science Education Standards, the Texas Essential Knowledge and Skills (TEKS) are the standards used in Texas schools. Teachers at Rio Grande School 1 and Rio Grande School 2 were given K-6 vertically aligned copies of the science TEKS and instructed to use this primary source document to select academic vocabulary and plan interactive word walls. Learning how to align instruction with state science standards (TEKS), how to select academic vocabulary, and planning the structure of interactive word walls underpinned all of the Science and Literacy Instructional Model activities. The selection of essential academic vocabulary was driven by state science standards and teachers used the *Vocabulary Planning Document* (see Figure 3) to select “target” academic vocabulary that would be included in upcoming lessons and placed on the interactive word wall. The *Vocabulary Planning Document* (see Figure 3) structures Grave’s four-part *Comprehensive Vocabulary Program*: Pre-teach a few well selected words, teach word learning strategies, provide rich and varied language experiences, and foster word consciousness (Graves, 2006; Graves et al., 2013). Teachers reviewed the science standards they were scheduled to teach and considered the rigor of the verbs and the science process skills or practices of science associated with the concept. Teachers reviewed the standards vertically to determine the science concepts that their students needed to learn, what concepts they had already learned, and what they would learn in future grades. Finally, they considered the science tools their students would use during science activities. The results of this review were included on the *Vocabulary Planning Document* under the heading "Teach a few well-selected words directly" (see Figure 3).

Next, teachers were taught to consider word-learning strategies. They reviewed science standards looking for any affixes that should be taught or reviewed. Using word parts to help unlock the meaning of unknown words is a widely accepted practice. Understanding and using prefixes, suffixes, and roots (morphemic analysis) helps EL's unlock the meaning of academic and common vocabulary words (Graves, 2006). We also looked for words with multiple meanings. Many familiar words have different meanings in science. To rotate, spin on an axis, does not describe moving stations in a classroom. The more frequent the word, the more likely it is to have multiple meanings (Graves, 2006). Conceptual understanding was enhanced when teachers openly addressed words with multiple meanings, provided authentic context for one or more of the meanings, and created opportunities to use them. We also considered English–Spanish cognates. Cognates are words from two different languages that have the same or similar meanings, spellings, and sometimes, similar pronunciations (Graves et al., 2013). A list of English/Spanish science cognates is available at http://www.thesciencetoolkit.com/wp-content/uploads/2015/10/04_Cognates-for-Science.pdf.

To foster word consciousness, we selected the target vocabulary that HAD be included on the interactive word wall and structured ways that students could become aware of and interested in these words and their meanings. Finally, we planned for rich and varied language experiences and created or identified sentence stems to support oral and written discourse. Then teachers sketched interactive word walls making sure that all target vocabulary words were included. Interactive word wall sketches resemble graphic organizers or data tables. To determine the best way to represent the science concepts, teachers considered the nature of the content: Does the concept have a hierarchical structure that can be divided into categories and subcategories? Is this concept a cycle? Do students need to compare and contrast topics? Explore cause and effect? Examine structure and function? Recognize scale, proportion, and quantity? Text structures, connections, and concepts related to the science standard helped teachers organize interactive word walls. For example, fishbone graphic organizers, arrows, and pie charts were used to represent cause and effect. Structure and function was displayed as a tree map with one column labeled organism, another column labeled structure, and another column labeled function. A web concept map illustrated the effects of interactions between living and non living organisms in an ecosystem. (Jackson & Narvaez, 2013). A flow concept map illustrates the flow of energy in Figure 2.

Teachers also planned ways the interactive word wall could be used to support classroom discussions, writing, vocabulary games, and other vocabulary enrichment activities. They looked for ways students could speak and write about science concepts with a purpose in mind and for an audience – their classmates/peers (Graves et al., 2013). Teachers reported that interactive word walls were frequently referenced by students when they needed to obtain, evaluate, and communicate information. Monthly Lesson Design Labs provided teachers with opportunities to apply elements of the Science and Literacy Instructional Model.

Lesson design lab

The district science specialist organized and facilitated monthly after school Lesson Design Lab activities that were structured to review/reinforce innovative vocabulary instruction and purposeful planning. Teachers at each school were invited to attend (See Table 3). Lesson Design Lab activities included using the *Vocabulary Planning Document* (see Figure 3) to identify essential vocabulary for upcoming lessons and units, reviewing state science standards, discussing and clarifying science content, planning and sketching the structure of interactive word walls, planning how to integrate building interactive word walls during lessons, identification of standards aligned lesson materials, and preparation of materials for use during lessons.

Timeline and summary of participants

The Rio Grande School 1 fifth grade team (three self-contained teachers), the district science specialist, the principal, and researchers met for one day of professional development in early January 2016 to create the Science and Literacy Instructional Model that would guide science instruction January – May 2016. The Science and Literacy Instructional Model included innovative vocabulary instruction, purposeful planning, and attending monthly Lesson Design Labs (See: "Science and Literacy Model" section above). To support the Science and Literacy Instructional Model and provide a channel for clear and timely communication, the district science specialist regularly communicated with the research team and school principals. He also worked with fifth grade teams during monthly after school Lesson Design Labs and provided feedback following bi-weekly classroom visits.

All of the kindergarten-fifth grade teachers at Rio Grande School 1 (47 teachers) and Rio Grande School 2 (36 teachers), campus principals, and the district science specialist met with researchers for one day of professional development in August 2016 and another day in early January 2017. The professional development meeting agendas included purposeful planning and innovative vocabulary instruction. During the 2016-2017 school year, the district science specialist was in frequent contact with the research team and

Science Standard:

Teach a few well-selected words directly Prior knowledge Science processes Science Tools	**Teach word learning strategies** Are there any affixes that should be taught? Words with multiple meanings? Cognates?
Provide "rich and varied" language experiences Word wall, vocabulary strategies, vocabulary games and enrichment ideas	**Foster "word consciousness"** Student awareness of and interest in words and their meanings TARGET Vocabulary

Figure 3. Vocabulary planning document.
Source: Graves (2006).

school principals, he facilitated monthly after school Lesson Design Labs for fifth grade teachers at both campuses, and provided feedback following bi-weekly classroom visits (see Table 3).

Data collection

We accessed publicly available Texas Education Agency online databases after the Science and Literacy Instructional Model implementation was completed. We used this data because it best aligns to our research question regarding the evaluation of student achievement from a high-stakes testing perspective. In specific, we collected fifth grade science STARR passing rates for the Rio Grande School 1 across three years (see Table 4).

We also collected fifth grade science STAAR passing rates for Rio Grande School 2 across two years (see Table 5).

Analysis

To evaluate the Science and Literacy Instructional Model, we analyzed state standardized high-stakes scores. In specific, we determined whether student scores showed positive achievement gains on school campuses before and after the Science and Literacy Instructional Model implementation. Because the state data does not match students at an individual level, we used a difference-in proportions test. This statistical test allowed us to analyze our data because it uses both the percentages and sample sizes for two groups (data publicly available in the state) to calculate the probability level associated with the difference in proportions evidence between the two groups (Ryan, 1960). This probability level is then determined to either be statistically significant or nonsignificant. We also calculated effect sizes (i.e., d = the standard mean difference) to determine the magnitude of any noted changes. In doing so, we gaged the magnitude of the effects with $0.2 = \text{small}$; $0.5 = \text{medium}$, and $0.8 = \text{large}$

Table 4. Fifth grade STAAR passing rates for Rio Grande School 1.

5th grade science STAAR	State passing rate	Number of students tested	Campus Score on 5th grade science STAAR Satisfactory*	Campus Score on 5th grade science STAAR Advanced**	Economically Disadvantaged	Current EL***	At-Risk
2017 ImplementationRating system changed	74%	106	62%	11%	61%	45%	51%
2016 ImplementationMet Standard	74%	108	69%	5%	68%	61%	65%
2015 Baseline Improvement Required	78%	103	45%	4%	39%	27%	36%

*Satisfactory (Approaches) *scored 60% or better 2015 & 2016 and 58% or better 2017*
**Advanced (Masters) *scored 90% or better 2015 & 2016 and 88% or better 2017*
****Note*: Publicly available reported data uses the term "LEP". We have changed the term to "EL" to be in line with the terminology used in this manuscript.

Table 5. Fifth grade STAAR passing rates for Rio Grande School 2.

5th grade science STAAR	State passing rate	Number of students tested	Campus Score on 5th grade science STAAR Satisfactory*	Campus Score on 5th grade science STAAR Advanced**	Economically Disadvantaged	Current EL***	At-Risk
2017 Implementation Rating system changed	74%	83	78%	5%	77%	74%	75%
2016 Baseline Met Standard	74%	90	48%	2%	48%	42%	43%

*Satisfactory (Approaches) *scored 60% or better 2015 & 2016 and 58% or better 2017.*
**Advanced (Masters) *scored 90% or better 2015 & 2016 and 88% or better 2017.*
****Note*: Publicly available reported data uses the term "LEP". We have changed the term to "EL" to be in line with the terminology used in this manuscript.

(Cohen, 1969). For the difference in proportions test, the assumption is that all individuals within the group have the same probability for taking the test and that the test responses for each individual is independent of that from any other individual. Because we examined a standardized test, the above assumptions are met for the analysis.

We first analyzed the data for Rio Grande Campus 1 by comparing 2015 passing rates (the baseline year before exposure to the model) and 2016 and 2017 passing rates (the two years during which the Science and Literacy Instructional Model was implemented). To detect any changes among the highest performers, we compared the "Satisfactory" and "Advanced" passing rates separately. We then analyzed the data for Rio Grande School 2 by comparing 2016 passing rates (the baseline year before exposure to the Science and Literacy Instructional Model) and 2017 passing rates (the years during which the Science and Literacy Instructional Model was implemented). In addition to analyzing specifically EL and economically disadvantaged students, we also analyzed the "overall" passing rate. We also looked specifically at the category of "At-Risk" students. English learning and economically disadvantaged students often fall into this category, meaning they are at risk of not graduating from high school in the long term, did not perform satisfactorily on a readiness test or assessment instrument administered during the current school year, or were not advanced from one grade level to the next for one or more school years (Texas Education Agency, 2010).

Results

As noted, in order to answer our research question – *What changes on Hispanic and EL students' standardized achievement passing rates, if any, are evident on two school campuses implementing the Science and Literacy Instructional Model?* – we conducted difference in proportion tests comparing to determine whether student scores showed positive achievement gains on two school campuses before and after implementing the Science and Literacy Instructional Model.

As can be noted in Table 6 (Rio Grande School 1 Year 1), the passing rate percentages (i.e., "Satisfactory") from 2015 to 2016 were substantially larger after the school implemented the Science and Literacy Instructional Model. In addition, statistically significant differences were noted for students in all categories (i.e., overall, economically disadvantaged, EL, and At-Risk). Effect sizes were of medium magnitude, with the EL effect size notably close to large magnitude ($d = .795$). In the "Advanced" category, all percentages increased in the intervention year, but only the economically disadvantaged category was statistically significant.

As can be noted in Table 7 (Rio Grande School 1 Year 2), the passing rate percentages (i.e., "Satisfactory") from 2015 to 2017 were substantially larger after the school implemented the Science and Literacy Instructional Model and notably larger in the "Advanced" category. In addition, statistically significant differences were noted for students in all categories at the "Satisfactory" level (i.e., overall, economically disadvantaged, EL, and At-Risk). Effect sizes were close to medium magnitude. In the "Advanced" category, all percentages increased after the intervention years, with statistically significant effects for the economically disadvantaged and EL category. Notably, the effect size for the other two categories (i.e., overall and At-Risk) were of large magnitude.

As can be noted in Table 8 (Rio Grande School 2), the passing rate percentages (i.e., "Satisfactory") from 2016 to 2017 were substantially larger after the school implemented the Science and Literacy Instructional Model and notably larger in the "Advanced" category. In addition, statistically significant differences were noted for students in all

Table 6. Rio Grande School 1 year: one year (2015–2016) comparison of satisfactory and advanced passing rates within Rio Grande School 1 before and after science and literacy model implementation.

					Confidence Intervals	
	2015 Baseline	2016 Implementation Year 1	*z*	*d (effect size)*	Lower 95%	Upper 95%
Satisfactory						
Overall	45%	69%	−3.523***	.552	.241	.862
Economically Disadvantaged	39%	68%	−4.224***	.662	.350	.974
EL	27%	61%	−4.968***	.795	.474	1.120
At-Risk	36%	65%	−4.212***	.659	.348	.970
Advanced						
Overall	4%	5%	−0.350	.129	−0.594	0.852
Economically Disadvantaged	0%	4%	−2.051*	–	–	–
EL	0%	1%	−1.018	–	–	–
At-Risk	1%	2%	−0.595	.388	−0.915	1.690

Notes. d = standard mean difference; 2015 $N = 103$; 2016 $N = 108$; *$p < .05$, **$p < .01$, ***$p < .001$; Publicly available reported data uses the term “LEP”. We have changed the term to “EL” to be in line with the terminology used in this manuscript.

Table 7. Rio Grande School 1 year 2: two year (2015 – 2017) comparison of satisfactory and advanced passing rates within Rio Grande School 1 before and after science and literacy model implementation.

					Confidence Intervals	
	2015 Baseline	2017 Implementation Year 2	*z*	*d (effect size)*	Lower 95%	Upper 95%
Satisfactory						
Overall	45%	62%	−2.464**	.381	.076	.685
Economically Disadvantaged	39%	61%	−3.180***	.493	.187	.800
EL	27%	45%	−2.708**	.438	.118	.757
At-Risk	36%	51%	−2.186*	.339	.034	.645
Advanced						
Overall	4%	11%	−1.915	.600	−.039	1.238
Economically Disadvantaged	0%	11%	−3.464***	–	–	–
EL	0%	7%	−2.734**	–	–	–
At-Risk	1%	6%	−1.957	1.016	-.141	2.174

Notes. d = standard mean difference; 2015 $N = 103$; 2017 $N = 106$; *$p < .05$, **$p < .01$, ***$p < .001$; Publicly available reported data uses the term “LEP”. We have changed the term to “EL” to be in line with the terminology used in this manuscript.

categories at the “Satisfactory” level (i.e., overall, economically disadvantaged, EL, and At-Risk). Effect sizes were all of large magnitude. In the “Advanced” category, all percentages increased after the intervention years, though there were no statistically significant effects. Still, effect sizes were of medium magnitude for all categories except At-Risk, which was a large effect size.

Discussion

The purpose of this study was to evaluate the Science and Literacy Instructional Model aimed at helping primarily Hispanic bilingual/ELs and economically disadvantaged students with science achievement as measured on high-stakes standardized science achievement tests. The Science and Literacy Instructional Model included elements noted by previous research to be effective for addressing the needs of diverse learners in science. Professional development activities promoted a research-based innovative vocabulary instructional strategy designed to help ELs and economically disadvantaged students simultaneously learn the academic language and content of science, purposeful planning, and monthly Lesson Design Labs. Our results indicate that, overall, implementing the Science and Literacy Instructional Model was beneficial to the fifth-grade students at both schools. Major findings are summarized below, with discussion based on previous literature, consideration of limitations, and recommendations for future research, practice, and policy.

Rio Grande school 1 findings

After one year of implementing the Science and Literacy Instructional Model at Rio Grande School 1, student passing scores on the high-stakes state standardized fifth grade STAAR exam increased. Notably, statistically significant results and medium size effects were detected for the Satisfactory passing rate for students in all categories. In the Advanced passing rate category (i.e., the highest passing rate), only the economically disadvantaged category was statistically significant. Findings were similar after two years of implementing the Science and Literacy Instructional Model, with two large magnitude effects in the Advanced category. Statistically significant differences were noted for students in all categories at the Satisfactory level and effect sizes were close to medium. All percentages increased in the Advanced category with statistically significant effects for the economically disadvantaged and EL categories. The effect size for overall and At-Risk were of large magnitude. These changes indicate that focus on teaching students’ academic language within the context of standards aligned science experiences and providing time for teachers to hone practice, review content, and prepare lessons are important factors in increasing the magnitude of the effect of an intervention.

Table 8. Rio Grande School 2 year 1: one year (2016 – 2017) comparison of satisfactory and advanced passing rates within the replication campus before and after science and literacy model implementation.

	2016 Baseline	2017 Implementation Year 1	*z*	*d (effect size)*	Confidence Intervals	
					Lower 95%	Upper 95%
Satisfactory						
Overall	48%	78%	−4.070***	.742	.376	1.108
Economically Disadvantaged	48%	77%	−3.924***	.710	.348	1.073
EL	42%	74%	−4.252***	.755	.399	1.110
At-Risk	43%	75%	−4.265***	.761	.403	1.119
Advanced						
Overall	2%	5%	−1.082	.522	-.457	1.501
Economically Disadvantaged	2%	5%	−1.082	.522	-.457	1.501
EL	2%	6%	−1.355	.629	-.326	1.583
At-Risk	1%	5%	−1.561	.910	-.358	2.178

Notes. d = standard mean difference; 2016 $N = 90$; 2017 $N = 83$; $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; Publicly available reported data uses the term "LEP". We have changed the term to "EL" to be in line with the terminology used in this manuscript.

These findings are different from previous work which only found significant changes in ELs science scores on benchmark or researcher-created tests rather than high-stakes state assessments (Lara-Alecio et al., 2012; Lee, Maerten-Rivera, et al., 2008; Llosa et al., 2016). At the same time, the present study's findings are in line with more recent studies which have found science and literacy professional development interventions to benefit ELs on measures of high-stakes state over time (Maerten-Rivera et al., 2016). However, these comparisons must be made with caution as this study is focused on overall evaluation of school campus scores and not on treatment/control individual student data analysis.

As previous researchers in the field of ELs and science have noted, professional development initiatives designed to close achievement gaps between ELs, economically disadvantaged students and their peers should be anchored in building students' language alongside content understanding (e.g., Bravo & Cervetti, 2014; Lara-Alecio et al., 2012; Maerten-Rivera et al., 2016). Research in the field of teacher professional development reveals that teachers need time to learn and become proficient in implementing new strategies presented during professional development (Adamson et al., 2013; Santau et al., 2010). The substantially larger passing rates at the highest Advanced rate for all students (EL, economically disadvantaged, At-Risk) could be, in part due to the professional development structure used in the present study provided equitable learning experiences that benefited all students and met the national policy goal of moving students toward desired outcomes by making education accessible to all students (National Academy of Sciences, National Academy of Engineering, and the Institute of Medicine, 2011; National Research Council, 2013).

Rio Grande school 2 findings

After one year of implementing the Science and Literacy Instructional Model at Rio Grande School 2, statistically significant differences were noted for students in all categories at the Satisfactory level and effect sizes were all of large magnitude. In the Advanced passing rate category (i.e., the highest passing rate) all percentages increased after the Science and Literacy Instructional Model was implemented but there were no statistically significant results. However, the effect sizes were of medium magnitude in the overall, economically disadvantaged and EL categories and large for At-Risk students. The findings reinforce the overall advantage of anchoring academic language development alongside content understanding as previous studies have found (e.g., Bravo & Cervetti, 2014; Lara-Alecio et al., 2012; Maerten-Rivera et al., 2016). We did see improvement at the Advanced level and medium and large effect sizes, but it would have been more promising to see statistically significant results. Significant movement of scores at the highest passing rate occurred during year two at Rio Grande School 1 indicating that time might influence positive changes at this level. This finding is in line with Maerten-Rivera et al. (2016) work who found a time "lag in improved student achievement as teachers gain familiarity with new curriculum and adjust their teaching practices over time" (p. 600).

Limitations

Though this study considered longitudinal changes on carefully matched school campuses before and after their implementation of the Science and Literacy Instructional Model, the study cannot infer causality. Future work should consider a randomized design as well as matching individual student scores. What can be inferred, nonetheless, is that implementing the Science and Literacy Instructional Model based on theory and research with a strong professional development component has promising effects for schools when it comes to students' scores on high-stakes standardized science tests. Moreover, the findings complement findings from science and literacy interventions concerned with samples of elementary EL and economically disadvantaged, at-risk students and their outcomes in high-stakes standardized tests (e.g., Lara-Alecio et al., 2012; Lee, Maerten-Rivera, et al., 2008; Llosa et al., 2016; Maerten-Rivera et al., 2016). The study also advances knowledge regarding effective professional development within science and literacy models.

Recommendations for future research, practice, and policy

Given the small number of studies that have considered high-stakes science achievement scores for ELs in science (Lara-Alecio et al., 2012; Lee, Maerten-Rivera, et al., 2008;

Llosa et al., 2016; Maerten-Rivera et al., 2016), and the even smaller number that have found significant outcomes in their interventions (Maerten-Rivera et al., 2016), future researchers should continue to explore variables (i.e., teacher professional development, instructional practices, student variables), that close the achievement gaps between racially diverse (e.g., Hispanic), English learning, and economically disadvantaged students. Certainly, researchers would do well to continue to implement and analyze longitudinal studies as well as replications of successful interventions. In addition, future research would do well to include qualitative analysis to examine the impact of the model on teachers and their practices including changes in teacher attitudes and beliefs.

The implications of this particular study include an affirmation that combining purposeful language and science content teaching is generally good for ELs' science achievement. In addition, the findings point to the importance of professional development practices which provide teachers with training and tools for how to integrate language in the science classroom easily and effectively, a challenge repeatedly noted by previous researchers in the field (Adamson et al., 2013; Maerten-Rivera et al., 2016; Santau et al., 2010). Furthermore, the study confirms studies and reviews illustrating the critical role language support plays in disciplinary areas such as science (Wright & Domke, 2019) and how teaching vocabulary in a manner which involves active processing (i.e., when students actively engage with a word and its meaning) is impactful for student comprehension of subject matter (Wright & Cervetti, 2017).

These findings are important because they add to the literature on science and literacy integration practices with ELs. As noted, previous work with ELs in science has found science and literacy interventions to help student achievement (Lee, Maerten-Rivera, et al., 2008; Lee et al., 2005; 2009; Llosa et al., 2016; Maerten-Rivera et al., 2016), but only one study has reported effects for students on high-stakes science achievement tests (Maerten-Rivera et al., 2016). This study illustrates how the Science and Literacy Instructional Model can positively affect high-stakes results in school communities.

These findings should prompt policy makers to promote quality professional development initiatives for teachers that provide a focus on standards-based, engaging, and language integrated science instruction. In addition, policy would do well to consider the central importance that language instruction plays across content areas as a way to promote all students' learning and success on high-stakes tests (Kieffer et al., 2009). Last, policy should also note that learning is a developmental process which takes time on both the teachers and students' part and consistency in implementation and learning is important. In these ways, research, practice, and policy can work together to implement small changes which have the potential for large impact on all students' achievement in science.

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