The Journal of Educational Research
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/vjer20

Integrating Literacy and Science for English Language Learners: From Learning-to-Read to Reading-to-Learn

Fuhui Tong[a], Beverly J. Irby[b], Rafael Lara-Alecio[a] & Janice Koch[c]
[a] Texas A&M University
[b] Sam Houston State University
[c] Hofstra University
Published online: 22 Apr 2014.

The Journal of Educational Research, 00:1–17, 2014

ISSN: 0022-0671 print / 1940-0675 online
DOI:10.1080/00220671.2013.833072

Integrating Literacy and Science for English Language Learners: From Learning-to-Read to Reading-to-Learn

FUHUI TONG
Texas A&M University

RAFAEL LARA-ALECIO
Texas A&M University

BEVERLY J. IRBY
Sam Houston State University

JANICE KOCH
Hofstra University

ABSTRACT. The authors examined the impact of 2 subsequent, longitudinal interdisciplinary interventions for 58 Hispanic English language learners (ELLs): (a) Grade 5 science with English language/reading embedded (i.e., science intervention) and (b) K–3 English language/reading with science embedded (i.e., language/reading intervention). Results revealed that (a) in the science intervention treatment ELLs outperformed their counterparts in English-reading fluency, knowledge of word meaning, and science and reading achievement; (b) in the language/reading intervention treatment ELLs continued to develop faster than their peers in English oracy, reading fluency, and comprehension; (c) ELLs benefited more from the science intervention if they received the prior language/reading intervention. We conclude that for ELLs, the integration of science and English language/reading should primarily focus on reading in elementary grades and science in Grade 5.

Keywords: English language learner, English language/reading literacy, interdisciplinary, science achievement, science/literacy integration

Over the past 3 decades, the population o English language learners (ELLs) has steadily grown in the United States, with an increase from 4.7 to 11.2 million between 1980 and 2009 (National Center for Education Statistics [NCES], 2011a). Unfortunately, primarily due to the limited proficiency of English, these ELLs are reported to be underperforming academically. For example, the recently released National Assessment of Educational Progress (NAEP) data indicate that at Grade 8, 26% of ELLs achieved at or above basic level in reading, compared to 78% of non-ELLs. The pattern is similar in science, with 14% ELLs and 66% non-ELLs achieving at or above basic level, and such a gap remains unchanged in Grade 12 (NCES, 2009, 2010, 2011b). Among the limited disaggregated reports that are available for former ELLs[1] are data indicating that they are still lagging behind monolingual English-fluent students in reading (Cawthon, 2010) and in the content reading area of science (e.g., California Department of Education, 2001; de Jong, 2004; Florida Department of Education, 2001; Texas Education Agency, 2010), particularly at the middle and/or secondary level. Furthermore, a decade ago, Stoddart, Pinal, Latzke, and Canaday (2002) indicated there was a limited availability of published research on any type of integration of science, particularly inquiry-based science curriculum, with reading for ELLs and former ELLs from economically disadvantaged families; we determined, based on our review of literature, this is still the case in 2012 (Lara-Alecio et al., 2012).

Purpose, Data Sources, and Research Questions of the Study

The overarching purpose of our study was to investigate the joint impact on students' science and literacy achievement of two interdisciplinary interventions: (a) an intervention where science instruction was embedded in English-reading literacy among fifth-grade former and current Hispanic ELLs and (b) an intervention where English language/reading literacy instruction was embedded in science instruction from kindergarten to Grade 3. We compared students' science and English literacy achievement between those who participated in these two interventions and those students who did not receive such interventions.

Based on our extensive review of the literature, this appears to be the only study that has included the same group of ELL students followed longitudinally from kindergarten to the end of Grade 5 who were randomized to participate in

Address correspondence to Fuhui Tong, Texas A&M University, Educational Psychology, 1071 Harrington MS 4225, College Station, TX 77843-4225, USA. (E-mail: fuhuitong@tamu.edu)

two subsequent interdisciplinary interventions of integrating English language and science. *Interdisciplinary science-embedded English language and literacy* is defined as a curriculum in which oral English language and reading proficiency is of primary focus, with science being secondary focus to establish context so as to support the learning in the primary domain. *Interdisciplinary English literacy–embedded science* is defined as a curriculum in which the learning of science is of primary focus, with reading and writing being secondary focus so as to support the learning in the primary domain. Therefore, this study furthers the understanding of the relationship between learning to read and reading to learn in science for ELLs.

Data on literacy skills and science achievement were collected from 56 fifth-grade students from four intermediate schools in a large urban school district in the Southeast United States. Gender was a variable while ethnicity and economic level were not included as variables because all students in the study were Hispanic/Latino and were classified as economically disadvantaged. Specifically, we examined the following research questions:

Research Question 1: Did students' performance on district curriculum-based benchmark assessments in science differ due to participation in these two interventions? (These data were disaggregated by gender.)

Research Question 2: Did students' performance on state standardized tests in science and English reading differ due to participation in these two interventions? (These data were also disaggregated by gender.)

Research Question 3: Did students' English literacy development in reading fluency, oral proficiency, and reading comprehension, measured by standardized English proficiency tests differ due to participation in these two interventions? (These data were also disaggregated by gender.)

Significance of the Study

The study is significant in several ways. First, we present two interdisciplinary interventions that were intended to assist ELLs and former ELLs in acquiring the academic language of science (and in the Grade 5—science achievement) while also learning a second language of English. As O. Lee (2005) critiqued, "[i]t must be acknowledged that current educational policies and practices do not generally support desired science outcomes with ELLs. Policies and practices do not . . . substantially engage or incorporate the knowledge and practices that ELLs bring to science classrooms" (p. 493).

Second, the study examines the effect of infusion between English literacy and science instruction among ELLs and former ELLs from low socioeconomic status (SES) families who, according to Muller, Stage, and Kinzie (2001), are more susceptible to underachievement in reading and science. In their review, Pearson, Moje, and Greenleaf (2010) listed the most recent studies of successful science literacy projects that show promise of students learning in both science and literacy at various grades. However, none of them specifically addressed the needs of ELLs and non-ELLs or economically disadvantaged students. Pearson et al. underlined the fact that this body of research is quite new, and it is yet unknown as to which core ingredients are common in these projects that promote students' learning.

Third, existing studies on science achievement primarily have been focused on a specific grade level without including a rigorous experimental design with a continuous cohort of economically disadvantaged, language minority students, and, according to O. Lee and Luykx (2006), such studies lack concrete results. This study follows participating students' academic development longitudinally from early elementary to middle school level. That type of transitional, longitudinal analysis is significant in that inclusivity of ELLs at the intermediate and secondary level is lacking in the body of empirical integration on vocabulary and science education research (Fang & Wei, 2010; C. Snow, 2006; Stoddart et al., 2002).

Finally, gender difference has received the least attention in research of second-language development (Brantmeier, Schueller, Wilde, & Kinginger, 2007), and the findings are inconclusive as to which gender group acquires a second language more rapidly (Ehrlich, 1997; Tong, Irby, Lara-Alecio, Yoon, & Mathes, 2010), because gender difference in second-language attainment is not solely associated with neurobiological characterization, but also with sociocultural particularities (Polat, 2011). Yet gender is a critical individual and social variable in language learning (Brantmeier et al., 2007; Cook, 2001; Shehadeh, 1999) that should be taken into account when teaching and programming for a second language. Of significance in this study is the analysis of performance data by gender among current and former ELLs.

Theoretical Framework

Our study was conceptualized within the theoretical framework of curriculum integration between literacy practice and scientific inquiry for ELLs. We adapted the concept of interdisciplinary curriculum from Huntley's (1998) and McComas and Wang's (1998) work regarding the infusion of two content domains (i.e., mathematics and science) at middle school mainstream classrooms. According to Huntley and McComas and Wang, in an interdisciplinary curriculum, there is one discipline that is of primary focus, with one or more other disciplines that is of secondary focus to establish context so as to support the learning in the primary domain. We further applied the concept in our study with ELLs, and we purport that the integration between English language and reading literacy and science should be interdisciplinary at different grade levels. It is reasonable to integrate English language and reading literacy with science, because at a basic level science is content-area reading. At elementary grade levels, English language/reading literacy should be the primary focus and with science embedded to support ELLs' acquisition of reading skills and comprehension. In such an environment, ELLs (a) learn complex language forms and functions through access to science texts, (b) engage in contextualized use of language in science inquiry, and (c) enhance their conceptual capacity of the content topic of science (Pearson et al., 2010; Santu, Maerten-Rivera, & Huggins, 2011). This process of *learning to read* is deemed critical to subsequent, specific content area learning (Genesee & Riches, 2006).

In higher grades, particularly at the intermediate level, the focus of instruction should shift to science, which is inclusive of English-reading literacy strategies. This focus requires the accurate use of academic language so that students can conduct scientific inquiries, construct theoretical explanations of the natural phenomenon, and communicate scientific principles and procedures (Fang & Wei, 2010). At this stage, while still developing English proficiency, ELLs rely on their English language and reading literacy skills acquired during the elementary grades to comprehend dense and cognitively challenging concepts in content areas. This concept is *reading to learn*, which promotes academic achievement that enables a student to succeed in school and society (Lindholm-Leary & Borsato, 2006).

Carrier (2005) suggested that literacy objectives should support the content objectives of science learning for ELLs, and science educators have claimed that reading instruction is a powerful vehicle for engaging students' minds, fostering the construction of conceptual understanding, supporting inquiry, and cultivating scientific habits of mind (Fang & Wei, 2010). Therefore, science or other content-based subjects provide ELLs with a context-enriched setting for the learning of language structure and functions, and the expansion of students' vocabulary (Fang & Wei 2010; Stoddart et al., 2002).

Integration of Literacy Practice and Scientific Inquiry for Elementary ELLs

August and Shanahan (2008), as well as Saunders and O'Brien (2006), noted extensive literature related to the daunting challenges ELLs face in acquiring both academic English language and knowledge and skills in content areas such as math and science. The term *academic language*, or mostly commonly known as *cognitive academic language proficiency* (CALP), was proposed by Cummins (1979, 1984) as language that occurs in context-reduced academic situations where higher order thinking skills are required in the curriculum. It takes 5–7 years for ELLs to acquire a level of such proficiency in academic language that is comparable to native English speakers. CALP includes not only the understanding of content area vocabulary but also skills such as comparing, classifying, synthesizing, evaluating, and inferring. Seminal work of Krashen (1985) is still followed, particularly his work related to comprehensible input hypothesis and acquisition learning hypothesis for second-language learners. Further, his concept of academic language still is generally in place as it promulgated that academic language is learned most effectively through meaningful and purposeful communication in academic contexts. Specifically for our study, we further defined academic language related to science. Based on observations from a previous learning to read study at Grade 3 level (Project English Language and Literacy Acquisition-ELLA, R305P030032, funded by the U.S. Department of Education; principal investigator: Rafael Lara-Alecio), we determined that academic language in science for ELLs yielded positive outcomes if the following activities were included: (a) making inferences from incomplete evidence, (b) clarifying ambiguities, (c) making and recording predictions and observations, (d) designing experiments, (e) creating perspective-based writing/postcards/newspaper articles/journals/reports, (f) reflecting on science concepts, and (g) synthesizing information.

Some researchers have found that a traditional approach to teaching young ELLs is the separation of language skills from content area academic language (M. A. Snow, Met, & Genesee, 1989). As a result of such separationist thinking in curriculum, ELLs are placed at a disadvantage for academic progress (Stoddart et al., 2002). However, other researchers found that such a separationist approach prevents ELLs access to rigorous subject matter instruction and specialized academic language (O. Lee, Lewis, Adamson, Maerten-Rivera, & Secada, 2008). Similarly, reading instruction in early grades that focuses on isolated language skills, instead of accelerating literacy achievement, may, with low-performing students, actually perpetuate little growth (Allington & McGill-Franzen, 1989; Greenleaf & Hinchman, 2009; Haycock, 2001; C. D. Lee & Spratley, 2010) and deprive students' opportunities to learn in other academic subjects, particularly, in science (McMurrer, 2007; Rentner et al., 2006). Furthermore, Collier (1987) suggested that that ELLs need to develop academic language that is context-reduced and cognitively demanding in order to function successfully in the classroom.

School districts are under increased pressure to address the No Child Left Behind Act of 2001 (NCLB; 2002) 100% proficiency rate on state tests by 2014. If a school fails to meet annual yearly progress for 2 consecutive years, either as a whole or for any single subgroup (e.g., ELLs), then the school is labeled “in need of improvement” (NCLB, 2002). It would seem critical, therefore, for districts to be placing struggling readers into intervention programs and to be offering literacy practices that include and emphasize building ELLs' academic English vocabularies which may be abstract and sophisticated (C. Snow, 2010), because these vocabularies “seem to occupy an important middle ground in learning to read” (Kamil, 2004, p. 215).

Further, Linan-Thompson and Hickman-Davis (2002), as well as Tong, Lara-Alecio, Irby, Mathes, and Kwok (2008), recommended that effective literacy practice for ELLs should begin in early elementary grades for the development of specific skills in learning to read. Thus, according to these researchers, reading interventions for ELLs should be systematic, structured, intensive, content-oriented, and interactive with the following components: (a) after skills are introduced sequentially in isolation, students are provided opportunities to practice them in context; (b) redundancy is embedded in the intervention allowing guided and independent practice; (c) students are engaged in student-directed activities, and encouraged to discuss their learning content; (d) scaffolded inquiry and hands-on activities and direct and explicit vocabulary instruction are integrated throughout the instruction; and (e) continued English learning support is provided with strategies including graphic organizer, vocabulary extensions, visual aids, and partner reading.

Integration of Literacy Practice and Science Learning for Intermediate ELLs

When students reach intermediate grades, academic language tasks become more complex, context-reduced, and specialized that requires elaborate language skills in learning content areas (Greenleaf et al., 2011). For example, learning science involves learning to observe, predict, analyze, summarize, and present information in various formats such as orally, in writing and drawing, and through tables and graphs (Hines, Wible, & McCartney, 2010). M. A. Snow et al. (1989) in their conceptual framework of integrating content area and second/foreign language instruction suggested that the primary objective for content classes should target the mastery of the subject; however, there remains potential for language teaching, which should be planned and considered carefully. As hypothesized by Kieffer, Lesaux, Rivera, and Francis (2009),

> learning of content knowledge and skills is largely mediated by language and academic language skills and content knowledge overlap with one another to a great degree, such that there are very few "language-free" content skills—virtually all sophisticated academic tasks . . . are mediated by language and literacy skills. (p. 1188)

It is, therefore, reasonable to consider that advanced literacy skills can facilitate science learning.

Developing science learning and literacy includes learning the language, concept, and culture of science. The new conceptual framework for the Next Generation Science Standards (2012) stated that in classroom science discourse, "students must read, write, view, and visually represent as they develop their models and explanations. They speak and listen as they present their ideas or engage in reasoned argumentation with others to refine their ideas and reach shared conclusions" (p. 3). According to Bybee (1996), the notion of scientific literacy consists of the following: science achievement and vocabulary (the knowledge of the concepts of a discipline), conceptual scientific literacy (connecting concepts in schemes according to the structure of the discipline), and procedural scientific literacy (employing conceptual literacy to solve problems and make new discoveries). On the other hand, Ruiz-Primo, Shavelson, Hamilton, and Klein (2002) promoted the use of science achievement as opposed to scientific literacy because the former is "always related to educational experiences and carries the connotation of accomplishment" and therefore, "more widely used than 'literacy' to refer to what students know and can do" (p. 373).

For ELLs, we propose that achievement in science is related to the educational experience in language learning classrooms such as bilingual/English as second language (ESL); therefore, we infer that instruction and curriculum matter. We also suggest that science achievement for ELLs is grounded on the student's understanding and acquisition of vocabulary and scientific language and the student's ability to transpose that understanding and apply it in a meaningful manner. Vocabulary instruction with a science focus typically has received minimal instructional attention in kindergarten through Grade 12 classrooms across the nation (Scott, Jamieson-Noel, & Asselin, 2004; Watts, 1995). The situation is more alarming in secondary science classrooms where there has been a widespread reduction of language-based learning activities due to teachers' limited knowledge of how to integrate literacy instruction into hands-on scientific exploration (Greenleaf et al., 2011; Rivard, 2004).

Successful Instructional Practice Integrating English Literacy and Science

Researchers have recommended effective strategies on how to integrate literacy and science for ELLs (e.g., Amaral, Garrison, & Duron-Flores, 2006; Klentschy, 2005; Palumbo & Sanacore, 2009; Watkins & Lindahl, 2010). We identified a few empirical studies and share those that are science and English language/literacy focused as follows: (a) interdisciplinary science-embedded English language and literacy intervention and (b) interdisciplinary literacy-embedded science intervention. Our intervention and how we have defined it is most closely aligned to those research studies that report these two types of instructional integration. We include as our intervention two interdisciplinary foci: (a) a science-embedded English language and literacy intervention and (b) an English-reading literacy-embedded science intervention.

Interdisciplinary science-embedded English language and reading literacy intervention. An evidence-based approach of science-embedded English language and reading literacy intervention can be found in Concept-Oriented Reading Instruction (COPI) developed and refined by Guthrie et al. (2004) with the objective to promote literacy through life science learning for third-grade children. In the COPI program, explicit instruction in reading strategies is provided to students including questioning, activating background knowledge, information seeking, summarizing, and synthesizing for communication. Further, the instruction also involves hands-on and inquiry-based learning, establishing collaborative working environment for students, and engaging them in writing, drawing, and presenting findings. The model has shown promise in advancing students' science concept learning, comprehension skills (Guthrie et al., 2004; Pearson et al., 2011), and motivation (Guthrie, McRae, &

Klauda, 2007), as compared to students in control classrooms with separate science and literacy instruction.

In the Reading Apprenticeship model, developed and implemented by Greenleaf et al. (2001) and Schoenbach, Greenleaf, Cziko, and Hurwitz (1999), in addition to the research-based instructional approaches on direct and explicit comprehension strategies, academic development techniques, and extended discussion of the meaning of texts read, the instruction was also closely aligned with science learning goals, and the science was integrated, "rather than being an instructional add-on or additional curriculum" (Greenleaf et al., 2011, p. 657). This model has been utilized in several studies that resulted in improved English proficiency, reading comprehension, and academic engagement in science across a diverse group of students (Greenleaf et al., 2011; Greenleaf, Schoenbach, Cziko, & Mueller, 2001; Schoenbach et al., 1999).

Another example of a successful model for academic reading literacy instruction is reported by Morrow, Pressley, Smith, and Smith (1997), who found that third-grade students in the literature/science group scored significantly higher on all literacy measures (e.g., vocabulary, writing narratives) than did their peers in the literature-only group. Similar findings were reported from a 2-year (Grades 1–2) intervention of storybook retelling and higher order thinking among Spanish-speaking second-grade ELLs (Quiros, 2008). Students in benefited from participating in a learner-centered, structured reading instruction in story reading and retelling, which served as a bridge that connected and integrated science, and demonstrated improved vocabulary knowledge and comprehension in English literacy acquisition.

Interdisciplinary literacy-embedded science intervention. To answer the call for well-designed science instructional models, in particular, inquiry-based science practice has been promoted as a practical and effective approach integrating literacy and science development. For example, *Hapgood* and Palinscar (2007) noted the following benefits of inquiry-based science: (a) it encourages students to develop their capacities to express, digest, and critique ideas in written and oral forms through critical thinking, which is especially beneficial for building students' vocabularies and their ability to use complex sentence structures; (b) it actively engages students in the intellectual work of inquiry; (c) it provides students opportunities for communicating in different genres and forms with learning to appropriately represent ideas in multiple ways; and (d) reading texts to explore science topics, combined with first hand investigations and discussions, can help students acquire reading strategies even better than the direct instruction of those strategies. Similar conclusions were drawn from a 3-year longitudinal professional development intervention on inquiry-based science instruction among fourth-grade ELLs with varied level of English proficiency (Santau, Maerten-Rivera, & Huggins, 2011).

In the research on inquiry-based science plus reading, Fang and Wei (2010) argued that even a modest amount of reading infusion could exert a positive impact on middle school students' science literacy. The researchers focused on sixth-grade students' science literacy development in the fundamental and derived senses, and reported that the infusion with explicit reading instruction and a weekly-based home science reading program led to more effective inquiry-based science than the science-only curriculum. The study concluded that students need to be engaged in more reading in science where they can apply reading strategies, increase vocabulary knowledge, and learn subject content.

In addition to inquiry-based science instruction, researchers have continued to explore other effective methods that bring hands-on contextual learning experience to students with diverse backgrounds. For example, Connor et al. (2010) questioned inquiry-based instruction, and argued that a one-size-fits-all approach to the use of such instruction may not help students with poor literacy skills in the classroom. Specifically, they found that even students in second grade who held low science and literacy skills at the beginning could make comparable gains in content learning as other students who did not have low skill initially when receiving instruction built upon the 5-E model of Engage, Explore, Explain, Elaborate, and Evaluate (Bybee, 1997).

Gender Difference in Reading and Science Literacy for ELLs

While little is known on the integration of reading and science, literature on student characteristics that influence academic achievement in these two areas is not scarce. For example, in a large-scale study Maerten-Rivera, Myers, Lee, and Penfield (2010) found that student background factors, including gender, minority status, ELL status, and disability status significantly predicted fifth-grade students' science achievement as measured by a high-stakes state test. More specifically, female students scored significantly lower than did male students, when controlling for other variables. In addition, national data show that females may struggle more with the discourse of science than male students as they progress through grade levels because in Grade 8, the percentages of male students performing at or above the basic, proficient, and advanced levels were higher than the percentages of female students and such gap increased as students reach Grade 12 (NCES, 2011). In the area of English literacy skills, studies show mixed findings among ELLs. Duursma et al. (2007) confirmed an advantage for girls in expressive English vocabulary acquisition among Spanish-speaking fifth-grade students who received initial instruction in their native language. To the opposite, Uchikoshi (2006) identified kindergarten male ELLs' superiority on expressive and receptive English vocabulary. In empirical studies integrating inquiry science and reading instruction, gender disparity was either nonexistent among ELLs on English language (Lara-Alecio et al., 2012), academic achievement in science (O. Lee, Deaktor, Hart, Cuevas, & Enders, 2005), or narrowed among ethnic diverse low-SES students on reading comprehension (Stephens, 2010). Given the range of these findings, second-language acquisition researchers have argued that other than neurobiological differentiation, learner variables such as motivation (Chavez, 2001; Ehrlich, 1997; Polat, 2011) or instructional variables such as language of instruction and quality of instruction (Tong et al., 2010; Tong, Lara-Alecio, Irby, & Mathes, 2011) may be contributing factors to the effect of gender on second-language attainment.

Method

Setting

Our study was conducted in an urban school district in Southeast Texas, United States. According to the latest state report in 2010 (Texas Education Agency, 2010), 45% of the student population in this district spoke Spanish at home, 31% were identified as ELLs, and 85% were classified as low-SES family (qualified for free or reduced lunch). This district has enjoyed a long-standing, positive reputation with lengthy experience working with ELLs. Based on student achievement in the district, national awards, such as the Broad Foundation Prize for urban school achievement, have been garnered.

Sample and Participants

We used archived data that were derived from a larger randomized interdisciplinary science intervention with English language/reading literacy embedded. This intervention was implemented with low-SES fifth-grade ethnic minorities and the data were from an interdisciplinary English language/reading literacy intervention with science-embedded implemented with Hispanic ELLs (K–3). In the current study, there were 56 student participants who were Spanish-speaking ELLs as determined by the district identification criteria upon school entry in Kindergarten. Prior to the initiation of the science intervention at the beginning of Grade 5, six of them were relabeled English proficient after 2 years of monitoring (according to the state policy ELLs are monitored for a maximum of 2 years after being redesignated as fluent in English), four of them were designated as monitored for the second year, and 22 of them monitored for the first year. The remaining 24 students were continued as ELLs, with an average age by the end of Grade 5 of 11.55 years ($SD = 0.52$ years) in the treatment condition, and 11.44 years ($SD = 0.42$ years) in the control condition.

In this study, we included 15 students from the treatment and 13 students from the control condition who also previously participated in a 4-year (K–3) randomized interdisciplinary science-embedded English language/literacy intervention implemented in the same district by the same research team (fourth grade was not an intervening grade level; however, in a fifth year of the study, we monitored the students who had participated in the treatment in K–3 who continued in regular classes). These 28 students were then matched from the current literacy-embedded science intervention with those who did not participate in the K–3 literacy intervention (15 from experimental and 13 from control). The matching criteria included language proficiency status (i.e., ELL, monitored Year 1, monitored Year 2, and English proficient), ethnicity (i.e., Hispanic), SES (i.e., economically disadvantaged), gender, and attending the same elementary or intermediate school in the district. Among these matched students, three of them moved to the district at the beginning of Grade 5, and the remaining students have been enrolled in the same district since kindergarten/first grade. This 2 × 2 balanced design is presented in Table 1. In elementary grades, these 56 students came from eight control classrooms and 11 treatment classrooms. In Grade 5, these students are from four intermediate schools with five control teachers and three treatment teachers. Among the eight teachers, the average number of years of teaching was 5.88 ($SD = 5.23$ years), with two new to teaching profession (one from control school and the other from treatment school).

Design of the Study

In the larger literacy-embedded science intervention, four of 10 intermediate schools with principals' approval from the district site were randomly assigned to conditions, resulting in two treatment (enhanced science practice) and two control (typical science practice) schools. Both ELLs and low-SES non-ELLs in the same school received the same practice to allay contamination between experimental and control classrooms. When a school was assigned, teachers from that campus were then randomly selected to the assigned condition within that campus. Such design makes the overall project quasi-experimental at the student level and

TABLE 1. Breakdown of Students by Condition in K–3 Interdisciplinary Science-Embedded Language Intervention and Grade 5 Literacy-Embedded Science Intervention and Gender

	Language intervention-E		Language intervention-C		
	Male	Female	Male	Female	Total
Science intervention-E	10	5	10	5	30
Science intervention-C	5	8	5	8	26
Total	15	13	15	13	56

Note. E = experimental/treatment; C = control.

experimental design at the school level. A similar design was implemented in the larger science-embedded English language and reading literacy intervention K–3 among 22 schools (for a detailed description of the design, see Tong et al., 2010).

The Grade 5 Interdisciplinary Literacy-Embedded Science Intervention

The 23-week science intervention had two main components. The first component was professional development provided to content area teachers (professional portfolio assessment, biweekly staff development sessions, and monthly staff meetings for paraprofessionals). This component consisted of ongoing training workshops for both teachers (biweekly) and paraprofessionals (monthly) delivered by research coordinators for 3 hr per session and a total of 43 hr in Grade 5 with systematic and structured training, monitoring, mentoring, feedback, and self-assessment through reflection via professional portfolio. Initial teacher training was conducted before the implementation of the project to give experimental teachers an overview, preview the lesson plan format, and distribute instructional materials. Throughout the school year, the sessions, aimed at enhancing science teachers' knowledge about content area literacy, included (a) English science vocabulary building and fluency, (b) oral and written academic science language development, (c) integrated science content reading comprehension, (d) imbedded ESL strategies (e.g., questioning strategies, language scaffolding, visual scaffolding, manipulatives, and realia [real objects or events], advanced organizers, cooperative grouping, content connections, and technology integration) in science, and (e) enhanced instruction for science teaching with 5-E model and questioning strategies. The curriculum was tightly aligned to the state science standards, national science standards (based on the 1996 standards as the New Generation National Science Standards were not developed at the time of the implementation of this study), and English language proficiency standards. Such intensive training was continued to help build teachers' science knowledge and how to integrate English language/reading literacy in science. All teachers in the study held Texas teaching certificates (Grades 4–8) and were not required to have a separate science certification at this grade level.

The second component was the academic science intervention implemented with students 85 min daily with the 5-E model (i.e., Engage, Explore, Explain, Elaborate, and Evaluate) and strategies for leveled questions based on Bloom's taxonomy with cognitive verbs such as identify, describe, explain, analyze, and create. This component infused reading and writing activities into the instruction. First, it supported students' science and reading skills with expository (informative) text extracted from the Scott Foresman science series (Cooney et al., 2006) which included scaffolded text and ScienceSaurus directly aligned to state guidelines of Grade 5 science to assist the explanation of science concepts, vocabulary development and extensions (e.g., prefix, stem, and roots), word-reading instruction, and partner reading. For example, students were provided with direct instruction of vocabulary, including pronunciation and definition of words, and visual scaffolding. To increase students' reading fluency and comprehension, they were taught to partner-read and then ask each other scripted comprehension questions. Second, the science vocabulary were entered into the glossary of their individual weekly notebook, or science journal, which was used to help students process science content through use of written academic science vocabulary. With these interactive science journals as study guides, students had increased opportunities to write daily by recording predictions and observations, designing, predicting, completing notebook foldables as evaluation, creating perspective-based writing/postcards/newspaper articles, and reflecting on science field trips. Teachers were trained to provide both science and writing feedback. Each activity had allotted time with each minute fully utilized.

The Control/Typical Practice of Science Instruction

The control condition in the study was the typical science instruction conducted in the district taught by certified or permitted bilingual/ESL education and science education teachers. All teachers followed a locally developed science curriculum aligned to the state standards. Although the science instruction was also delivered 5 days a week, the 5-E model was only incorporated once per week rather than on a daily basis, and the ESL strategies and teachers' questions strategies were observed to vary without consistency, when observed at all. Further, English language and literacy instruction only involved word walls and students' use of glossaries with very limited use of science journals. Students read textbook and answered questions at the end of reading. Each class varied from 80 to 90 min daily with students' time on task varying.

Fidelity of Implementation

To ensure the implementation of the science intervention, fidelity measures were established through four rounds of classroom observation conducted by trained project staff. The fidelity included a 4-point Likert-type scale ranging from 1 (lowest) to 4 (highest) of the 5-E with areas pertinent to the intervention (e.g., knowledge with lesson content, student involvement, academic language scaffolding). The mean score for treatment teacher was 107.17 ($SD = 16.90$) with a total possible score of 124. The interrater reliability of the fidelity measure was .86.

The K–3 Interdisciplinary Science-Embedded Language and Literacy Intervention

Though the middle school intervention was focused on science with English language/reading literacy embedded, the K–3 intervention with an average length of 28 weeks was focused on English language/reading literacy with science embedded. The K–3 literacy intervention was implemented at both teacher and student levels, with a commitment to promoting ELLs' English oral and reading skills. At the teacher level, biweekly professional development workshops were provided to bilingual and ESL teachers and paraprofessionals for 6 hr per month for an average of 50 hr per school year, with the activities including reviewing and practicing upcoming lessons, and being instructed on the ESL strategies that were incorporated into the predeveloped lessons. Detailed scripted lesson plans were given to these teachers to follow during instruction each week. These plans listed scope and sequence that were aligned with the state standards and the national science standards (based on the 1996 standards as the New Generation National Science Standards were not developed at the time of the implementation of this study). All teachers in the K–3 intervention held Texas teaching certificates at the elementary grade level and in addition either a bilingual or ESL certification endorsement. At the student level, the structured and direct English instruction was delivered during the ESL block with 75 min in kindergarten, 90 min in Grades 1–3 daily. Throughout the 4 years, science contents were integrated into the longitudinal intervention. The research team was able to negotiate the time with the administrators by using the entire ESL block and integrating science content. In kindergarten and first grade, a research-based program that covered content areas including science was used as one intervention strand to engage ELLs in their own learning, which provided effective practice in phonics, vocabulary, and fluency. Another strand from Grades 1 to 3 was a daily oral language and writing activity where a chart with preprinted science-embedded questions and science-related visuals was presented to students to scaffold concept development, encourage oral language, and stimulate written language in order to promote academic language in the area of science. The integration of science became even more intensive in the third grade when the Scott Foresman's science (Cooney et al., 2006) was adopted as the basis of the intervention with reading and ESL strategies written and integrated with the text to help second-language learners develop science academic language and expository reading skills. The class started with prereading strategies through teacher-guided practice on pronunciation and definition of any challenging vocabulary words that appeared in the initial reading. Then a cycle of partner reading, emphasizing visuals, and leveled questions was repeated until students read the entire lesson. Throughout the lessons, students were exposed to vocabulary extension mini-lessons, hands-on science activities, guided inquiry, and multiple opportunities to practice the target expository reading skill. In addition, the students were provided with state standardized science assessment (given the first time in Grade 5) preparation passages (for a detailed description of the longitudinal intervention see Tong et al., 2010).

The Typical Practice of English Language Instruction

As mentioned previously in the research design, the matched student sample in our current analysis attended either the same elementary schools or a nearby school in the same district, and therefore, was exposed to typical/control practice of English language instruction taught by certified ESL or bilingual teachers without any intervention from the research team. In a typical lesson of ESL instruction, the length of time varied between 45 and 60 min. The ESL instruction, also aligned with district benchmarks and state standards, was less intensive, and there was great variation in vocabulary instruction across classrooms. This time block was also interrupted at times by restroom breaks. At times, but not typically, other subjects such as mathematics, science, and social studies were infused into the ESL block.

Fidelity of Implementation

Validity measures were developed to ensure the quality of implementation of this language intervention. Interrater reliability over a 4-year period averaged to .95 through ongoing classroom observation. This quantitative check was based on a 4-point Likert-type rating scale for the following areas (a) knowledge of the content and script, (b) material usage and student involvement, (c) teacher talk versus student talk, (d) leveled questions, and (e) classroom management, with a total possible score of 96 (1 being the lowest and 4 being the highest on each item). The mean scores were over 4 years were 86.6 (for a detailed description of the fidelity measures, see Tong, Lara-Alecio, et al., 2008; Tong et al., 2011).

Measures

The following measures were used to compare students' performance across conditions, including both standardized tests and district developed benchmark tests in science and English language and literacy. The reason to include both types of tests was based on the recommendation by Ruiz-Primo et al. (2002) who promoted the concept of multilevel, multifaceted assessments of science achievement. According to Ruiz-Primo et al., students' science achievement should be measured at proximal level to ensure that teachers are teaching the assigned standards/curriculum (which was observed in the benchmark test in our study), and then transfer to statewide and national assessments (i.e., a distal level assessment based on state standards in a particular domain [in our case, the state standardized tests]).

District benchmark tests in science. The district-wide benchmark tests in science use cutoff scores to determine if a student passes and/or meets commended performance. These tests are developed according to the scope and sequence of Texas Essential Knowledge and Skills (TEKS), the state standards/curriculum in science/reading for each grade level. A student who passes the test (e.g., 15 correct items of 20 in Science Benchmark Test 6) demonstrates satisfactory performance, meeting state standards and a sufficient understanding of TEKS-aligned curriculum. If a student meets commended performance (e.g., 18 correct items of 20 in Science Benchmark Test 6), it suggests high academic achievement that is considerably above state standards and a thorough understanding of the science curriculum. These assessments are developed by a committee comprised of curriculum specialists, teachers, and program directors that use the district curriculum guide to determine which TEKS will be taught for each 6-week period and reference-related questions from previous state standardized test to write test items. Once the items are generated, they are reviewed and proofread by science specialists. After that the tests are sent back to the writing committee for modification when needed before forwarded to district curriculum directors for final grammar and format edits. There are a total of six benchmark assessments given at the end of each 6-week period during the school year, with each covering different topics (e.g., physics for test 1, chemistry for test 2, life science for test 5). In our study, the sixth benchmark test was included for the final analysis, because it addressed all the topics in science taught throughout the academic year, including physics, chemistry, space, and earth and life science, with process skills integrated into these topics, and therefore, could be considered as an overall measure of students' science knowledge and skills. Internal consistency for the Science Benchmark Test 6 is noted as Cronbach's alpha of .68 for the sample of this study. The benchmark tests are curriculum-based and state standards-aligned assessments developed by the district as a reflection of what students are expected to know at various time points. Hence, the benchmark tests can be used as an external measure to evaluate the effect of this science intervention.

State standardized test: TAKS. The TAKS is a state standardized criterion-referenced assessment that measures student mastery of the content areas of state curriculum outlined in the TEKS. Similar to benchmark assessments, student performance is determined based on two levels: passing and mastery. Students who pass TAKS demonstrate satisfactory performance and a sufficient mastery of the TEKS-aligned curriculum. The level of commended performance suggests high academic achievement and a thorough mastery of the state curriculum. The TAKS reading assessments, available in both English and Spanish, are first administered during the spring of Grade 3; and TAKS science assessments are first administered during the spring of Grade 5. Typically, Spanish-speaking ELLs who are not otherwise exempt can take the TAKS in Spanish for up to 3 years in Grades 3–6. Whether to take English or Spanish reading TAKS is a recommendation made by the student's assessment committee (Texas Education Agency, 2009). In the current study, two ELLs from science treatment classrooms were recommended to take reading TAKS in Spanish.

Grade 5 English TAKS tests in reading and science consist of multiple-choice items. Internal consistency in the form of α is reported to range from .87 to .90, and predictive validity from .56 to .79 with SAT and ACT (Texas Education Agency, 2008). Information on construct validity for reading in Grades 3 and 5 is also available (Burk, Johnson, & Whitley, 2005; Davies, O'Malley, & Wu, 2007). For Grade 5 TAKS in 2010, a raw score of 29 of 40 (i.e., total number of correct items) in science and 30 of 42 in reading corresponds to the level of passing (i.e., meeting standards). A raw score of 37 in science and 39 in reading corresponds to the level of mastery (i.e., commended performance; Texas Education Agency, 2010).

Dynamic Indicators of Basic Literacy Skills. The Dynamic Indicators of Basic Literacy Skills (DIBELS; Good & Kaminski, 2002) test was initially developed as a curriculum-based assessment to measure critical skills that underlie early reading success. The test includes a set of procedures and measures for assessing the acquisition of early literacy skills from kindergarten through sixth grade. In this study, the subtest of Oral Reading Fluency in English was administered to students in the beginning and end of Grade 5. Reliability and validity have been reported to be satisfactory with a median alternate form reliability of .95 (Good, Kaminski, Smith, & Bratten, 2001), concurrent validity of .92–96 with the test of Oral Reading Fluency, and predictive validity of .71 with Stanford Achievement Test 10 (Roehrig, Petscher, Nettles, Hudson, & Torgesen, 2008). In this subtest, students are asked to read aloud fictional passages that are grade-level appropriate, with the number of words correctly read counted in 1 min. For each time of administration, three stories were tested, and the middle score was used for analysis.

Woodcock Language Proficiency Battery–Revised. The Woodcock Language Proficiency Battery–Revised (WLPB-R English; Woodcock, 1991) is a battery of standardized instruments assessing a broad range of English language ability and proficiency in oral, reading, and writing. This individually administered battery consists of subtests as well as clusters in receptive and expressive vocabulary, verbal reasoning, decoding skills, comprehension, punctuation, and expression. Construct, content, and concurrent validity and related information can be found in the test manual (Woodcock, 1991). We used WLPB-R to measure students' English language development because all the students in our study were either former or current ELLs. Three subtests were therefore administered. In Verbal Analogies, test takers are asked to complete a logical word association. Although the words in this subtest remain simple, the relationship between words increases in complexity to a higher level that involves the ability to discern implications. In Oral Vocabulary there are two parts: Synonyms and Antonyms, in which test takers either state a word that is similar or opposite in meaning to the word presented. Both parts measure knowledge of word meanings. In Passage Comprehension test-takers are required to point to the picture represented by a phrase. It also measures skills of reading a short passage and identifying a missing key word. Grade-based standard scores were used for analysis as they not only have equal units that are appropriate for statistical calculations but also reflect the relative standing of each student as compared to the norm. The average reliability coefficients (Cronbach's alpha) based on our sample were .78 for Oral Vocabulary, .83 for Verbal Analogies, and .78 for Passage Comprehension.

Data Collection and Analysis

Scores on Science Benchmark Test 6 were collected at the end of Grade 5 in the spring of 2010, and TAKS scores were collected in the spring of 2010. DIBELS and WLPB-R were administered at the beginning and end of Grade 5. As a first step, to establish initial equivalence among students in their respective condition (i.e., those who received the earlier English intervention vs. matched sample in treatment and control condition of the current science intervention), a two-way analysis of variance (ANOVA) was conducted on DIBELS and WLPB-R at the beginning of Grade 5. No difference was identified between the English intervention sample and matched sample in the respective condition in the science intervention on Oral Reading Fluency (*F*s < 3.329, *p*s > .074), Oral Vocabulary (*F*s < 0.319, *p*s > .575), Verbal Analogies (*F*s < 0.576, *p*s > .451), or Passage Comprehension (*F*s < 3.684, *p*s > .060). Therefore, it is evident that initial equivalence was established. Please note that the aggregated *F* values were yielded from a series of ANOVAs, and for the brevity of reporting only the maximum *F* value is presented to indicate statistical nonsignificance. Similar ways of reporting results for multiple ANOVA analyses can be found in Vaughn et al. (2006), and Tong, Irby, Lara-Alecio, and Mathes (2008).

To compare student performance across conditions after 1 year of the science intervention, chi-square tests of independence were conducted for Benchmark Test 6 (Research Question 1) and TAKS (Research Question 2) on the rate of passing and commended performance by conditions in the science intervention and the previous English literacy intervention; additionally, gender was the additional layer in the analysis. Cramer's *V* was reported as one type of effect size for the chi-square tests. Because two students (one from treatment and one from control condition) took the Spanish TAKS reading test and not the English TAKS reading test, we excluded these data because we were comparing the English literacy achievement, not Spanish literacy achievement across conditions. To analyze scores of oral reading fluency in DIBELS and subtests in WLPB-R (Research Question 3), four-way repeated measures ANOVAs were conducted, with three between-subject factors: condition in science intervention (experimental vs. control), condition in previous English intervention (experimental vs. control), and gender (male vs. female); and one within-subject factor: time (pretest and posttest). These analyses allowed us to address oral language and reading growth as a function of condition and gender in English. We also tested for differences between gender and conditions over time by including interaction terms. Partial eta squared (η_p^2) was reported to represent the magnitude of significant difference.

Results

Results are presented for each instrument used.

Benchmark Science Test 6 (Research Question 1)

The 2 × 2 chi-square test of independence yielded significant result on the passing rate, $\chi^2(1, N = 28) = 3.877, p = .049$, Cramer's $V = .372$. Further investigation suggested that the difference existed within the control condition of literacy intervention between the treatment and control groups in the science intervention, with all treatment students passing (100%), as opposed to an average rate of 76.9% passing in typical practice science instruction. Chi-square test of independence also revealed marginally significant result on the rate of commended performance, $\chi^2(1, N = 28) = 3.232, p = .072$, Cramer's $V = .360$, suggesting a moderate association (Rea & Parker, 1992). Similarly, the difference was found within the control condition of literacy intervention, with a higher average rate of commended performance among treatment students (66.7%) as compared to control students (30%) in the science intervention. When gender was added to the analysis, significant results were found within the typical practice science instruction on the rate of commended performance, $\chi^2(1, N = 26) = 5.529, p = .019$, Cramer's $V = .607$, indicating a strong association. Upon further examination, the data suggested that within the control condition of science intervention, female students with the K–3 science-embedded literacy intervention demonstrated a higher rate (75%) than female students (14.3%) who did not receive that intervention. Table 2 shows that female students who were in the control condition of both interventions had the lowest rate of commended performance.

State Standardized Test—TAKS (Research Question 2)

TAKS science test. The 2 × 2 chi-square test did not reveal significant difference regarding the rate of passing or commended performance on the TAKS science test. There is an average of 93.3% passing and 36.7% commended performance rate in the treatment condition, and 92.3% and 38.5% in control condition of the science intervention. However, when student gender was included in the analysis, no significant difference was observed except that male students from science treatment without language intervention demonstrated a statistically higher percentage of commended performance (60%) than their female peers from the same condition (0%), $\chi^2(1, N = 15) = 5.000, p = .025$, Cramer's $V = .577$.

TABLE 2. Rate of Passing and Commended Performance on Science Benchmark Test 6, by Gender and Condition

	Rate of passing				Rate of commended performance			
	Language intervention-E		Language intervention-C		English intervention-E		English intervention-C	
	Male	Female	Male	Female	Male	Female	Male	Female
Science intervention-E	100	100	100	100	70	80	80	40
Science intervention-C	100	87.5	60	85.7	20	75	66.7	14.3

Note. E = experimental/treatment; C = control.

TAKS reading test. The 2 × 2 chi-square test yielded a marginally significant result on the rate of commended performance, $\chi^2(1, N = 28) = 3.062$, $p = .08$, Cramer's $V = .337$, with the difference identified between students in science treatment (35.7%) and control (7.7%) conditions who did not receive the literacy intervention. When gender was added to the analysis, no statistically significant results were found. The alternative analysis of covariance with Grade 4 TAKS reading score as covariate generated similar result with students in science treatment condition outperforming those in science control condition by 50 points in the scaled score, $F(2, 55) = 4.61$, $p = .039$, $\eta_p^2 = .126$.

English Oracy and Literacy (Research Question 3)

DIBELS. The 2 × 2 × 2 × 2 repeated measures ANOVA showed statistically significant main effect of time, $F(1, 47) = 50.62$, $p < .001$, $\eta_p^2 = .518$, suggesting significant improvement across gender and condition from pretest to posttest. Other significant within- and between-participants interaction effects were also identified, for example, between time and condition in both interventions (see Table 3). Similar results were obtained when gender was not part of the analysis. For example, students in the science treatment outperformed their peers in the control group. All of the two- and three-way interaction effects were further evidenced by the four-way interaction effect among time, gender, science, and language condition, and the difference was most salient in the science treatment condition, with male students without literacy intervention and female students with literacy intervention demonstrating higher gain of estimated marginal means (31.1 and 22.6, respectively) from pretest to posttest than their counterparts in the respective condition (see Table 4).

WLPB-R. The 2 × 2 × 2 × 2 repeated measure analysis showed statistically significant main effect of time on all the three subtests, $Fs(1, 48) > 11.237$, $p < .002$, η_p^2 .190, suggesting significant improvement across gender and condition from pretest to posttest. The two-way interaction effect between gender and science condition was also significant on all two subtests, $Fs(1, 48) > 6.113$, $p < .017$, η_p^2 .113. For example, on Verbal Analogies, male students in science treatment group had a higher estimated marginal mean (M = 101.340, $SE = 2.752$) than female students in science control condition ($M = 90.650$, $SE = 3.789$). Same pattern was observed on the other 2 subtests. In addition, the two-way within-participants interaction effects were found to be significant between time and science intervention on Oral Vocabulary, $F(1, 48) = 4.662$, $p = .032$, $\eta_p^2 = .089$, and between time and literacy intervention on all three subtests, $Fs(1, 48) > 4.333$, $p < .043$, η_p^2 .083, with students in the treatment condition (in either intervention) achieving higher gains in estimated marginal means (provided in Table 5) from pretest to posttest. For example, on Oral Vocabulary, the gain for literacy intervention group was 16.94 points, as compared to 13.21 points in the

TABLE 3. Statistically Significant Interaction Effects Generated by Repeated Measures Analysis of Variance in Oral Reading Fluency

Source	*df*	Mean square	*F*	Sig.	η_p^2
Time	1	3497.879	50.620	<.001	.519
Time × Science Intervention	1	1183.161	17.122	<.001	.267
Gender × Science Intervention	1	5890.401	4.521	.039	.088
Time × Language Intervention	1	429.729	6.219	.016	.117
Time × Gender × Science	1	222.175	3.215	.079	.064
Time × Gender × Language	1	528.848	7.653	.008	.140
Time × Gender × Science × Language	1	350.251	5.069	.029	.097
Error (time)	47	69.100			

TABLE 4. Estimated Marginal Means and Standard Errors for Significant Two-Way Interaction Effects, by Gender, Condition, and Test Occasions on Oral Reading Fluency

	Language intervention-E				Language intervention-C			
	Pretest		Posttest		Pretest		Posttest	
Condition	M	SE	M	SE	M	SE	M	SE
Science-E								
Male	127.560	9.319	129.330	8.591	93.800	8.841	124.900	7.684
Female	95.20	12.503	117.800	10.867	100.600	12.503	119.400	10.867
Science-C								
Male	112.400	12.503	118.400	10.867	86.000	12.503	97.400	10.867
Female	122.130	9.884	122.250	8.591	123.500	9.884	125.630	8.591

Note. E = experimental/treatment; C = control.

control group. Such interaction effect was further reflected by the marginally significant three-way within-participants interaction among time, science and language condition on Passage Comprehension, $F(1, 48) = 3.445$, $p = .07$, $\eta_p^2 = .067$, with students in both science and language interventions demonstrating highest gain (17.35 points).

Discussion

The purpose of this study was to investigate the joint impact of two interdisciplinary interventions: an intervention of science with English-reading literacy embedded among fifth-grade former and current native Spanish-speaking ELLs, and a previous intervention of English language/reading literacy with science-embedded from kindergarten to third grade regarding students' science and English literacy achievement, so as to provide a step toward understanding the relationship between learning to read and reading to learn in science. Overall findings suggested that students receiving the current literacy-embedded science instructional intervention in Grade 5 outperformed those who did not in the areas of English oral reading fluency, knowledge of word meanings, and mastery of science concepts comparable to grade level, indicating high academic science and reading achievements that are considerably above the state standards. Further, students who received the K–3 science-embedded English language intervention not only continued to develop faster than those students who did not receive the intervention in their English oral reading fluency (i.e., expressive and receptive vocabulary knowledge, verbal reasoning, and word meanings) and comprehension skills, but also approached or outscored their monolingual native English peers as reflected by the grade-based standard scores (Table 4). We also discovered that students benefited more from the interdisciplinary English language and reading literacy-embedded science intervention during Grade 5 if they received the interdisciplinary science-embedded English language and reading literacy intervention continuously from kindergarten to third grade. This positive effect is evident in students' knowledge of science concepts (including physics, chemistry, and life, space, and earth science), performance on state mandated reading achievement assessment, and reading comprehension skills. Conversely, students with neither of the interventions displayed a disadvantage in oral reading fluency, science learning, and reading achievement. These ELLs demonstrated the lowest performance in meeting state standards in science and reading, and in English language development.

TABLE 5. Estimated Marginal Means and Standard Errors for Significant Two-Way Interaction Effects, by Measure, Condition, and Test Occasions on WLPB-R

		Pretest		Posttest	
Measure	Condition	M	SE	M	SE
OV	Language intervention-E	79.759	3.190	96.694	2.290
	Language intervention-C	83.113	3.248	90.325	2.332
PC	Language intervention-E	85.667	2.882	98.017	1.959
	Language intervention-C	91.300	2.934	94.188	1.995
VA	Language intervention-E	91.906	2.736	102.397	2.611
	Language intervention-C	90.219	2.712	92.688	2.589
OV	Science intervention-E	80.840	3.123	97.844	2.242
	Science intervention-C	82.031	3.313	89.175	2.378

Note. WLPB-R = Woodcock Language Proficiency Battery-Revised; OV = Oral Vocabulary; E = experimental/treatment; C = control; PC = Passage Comprehension; VA = Verbal Analogies.

Interestingly, when gender was included in the analysis, we observed that male students who were placed in science treatment in Grade 5, but who did not participate in the previous science-embedded literacy intervention experienced the greatest gain in oral reading fluency, followed by female students who received both the Grade 5 science intervention and the K–3 literacy intervention. This finding suggested that the literacy-embedded science intervention improved fifth-grade students' fluency skills for both males and females, whereas female students were more dependent on the intensive English language intervention in earlier grades than their male counterparts were in order to achieve at a higher level. Similarly, female students who did not receive either of the intervention were least likely to accomplish at grade level in language and science. The Grade 5 science intervention did not result in any gender difference on science achievement, regardless of students' participation in the previous language intervention. Our finding corroborates the similar finding from two previous studies that identified a small effect size of gender gap on math achievement (Else-Quest, Hyde, & Linn, 2010) and science achievement (Maerten-Rivera et al., 2010), thus supporting a gender similarities hypothesis (Hyde, 2005). More specifically, we found that interdisciplinary literacy-embedded inquiry-based science instruction can enhance academic achievement for both males and females; similar findings were also reported by O. Lee et al. (2005) and Stephens (2010). However, our findings that male ELLs demonstrated higher gains than their female peers in English oral reading in Grade 5 runs counter to several studies of female superiority in L2 acquisition (e.g., Duursma et al., 2007; Ellis, 1994). This finding may be indicative of the genre of instructional materials that may impact the gender difference in English language acquisition (Tong et al., 2011) or of the various constructs being measured as part of the general language proficiency. However, from a pedagogical perspective, what is more important is that such a difference was observed only in the control conditions, which implies that a quality instructional intervention could alleviate any gender disadvantage and could close the gender gap. More specifically, we continue to find a consistent pattern as reported in our previous findings (e.g., Tong et al., 2010, 2011) that indicate—provided with quality instruction in language and science, both gender groups could achieve satisfactorily.

Implications for Science Intervention Among ELLs and Former ELLs

Our findings lead us to the following claims. First, they underscore the importance of early intervention with interdisciplinary science-embedded reading curriculum. Intensive, longitudinal instruction seems to prepare ELLs in learning to read by intentionally and strategically infusing a variety of topics in science into the language instruction in each grade level as early as kindergarten. Such quality instruction is reflected in the teaching of word recognition and spelling, fluency, and comprehension (Gersten et al., 2007), as well as the integration of the academic language of science through content-area instruction during which ELLs acquire academic literacy (O. Lee et al., 2008; Santau et al., 2011; Spycher, 2009). According to the existing literature, structured and direct instruction, together with grade-appropriate ESL strategies, and context-embedded vocabulary learning are effective in teaching native Spanish-speaking ELLs (Tong, Lara-Alecio, et al., 2008; Tong et al., 2010; Carlo et al., 2004). Additionally, a strong and positive effect can be anticipated when the subject area and language learning are integrated and aligned with standards (Amaral et al., 2006; Klentschy, 2005; Lindholm-Leary & Borsato, 2006; Palumbo & Sanacore, 2009; M. A. Snow et al., 1989; Watkins & Lindahl, 2010). Note that all the students in this study were identified as ELLs in their elementary grades, and approximately half of them still remained at the same language status at the beginning of Grade 5. It is also worth noting that the integration of science is particularly essential for the state in which this study was implemented because although the state standardized test in science is administered the first time in Grade 5, the expectation is for students to master science knowledge accumulated in all grades prior to Grade 5, students will be placed at risk of failure if comprehension is not taught early enough for them not only to develop decoding and fluency, but also comprehension skills deemed necessary for content-area learning (Kieffer et al., 2009; National Reading Panel, 2000). Therefore, it is reasonable to state that instruction for ELLs in elementary grades should emphasize learning to read in content areas such as science.

Second, early exposure to reading literacy integrated with content area curriculum simultaneously is not enough. Rather, instead, although it is widely accepted that learning to read takes place in early grades and consists primarily of decoding and memorizing sight words, skillful reading does not automatically translate into higher academic content literacy, because learners need practice with these basic skills with continued emphasis and instruction on interpreting and comprehending what they read as well as practice with the reading skills embedded in science content. In the subject of science, which is "a unique mix of inquiry and argument" (Yore et al., 2004, p. 347), students are required to use scientific methods for observing, investigating, and identifying the natural phenomenon, as well as language discourse to communicate scientific knowledge, procedures and reasoning to others (Fang & Wei, 2010). Consequently, the infusion of reading into science instruction is beneficial, which also supports the statement that "science learning entails and benefits from embedded literacy activities and that literacy learning entails and benefits from being embedded within science inquiry" (Pearson et al., 2010, p. 462). Hence, we assert that instruction for ELLs in middle grades should emphasize reading to learn with continued support in English language and reading literacy to ensure current and former ELLs' success in science.

Limitations

There were limitations to this study. First, the sample size of this study was small ($n = 56$), which did not allow for multilevel/mixed model analysis particularly designed for clustering data (i.e., students clustered in class, and class clustered in campus; Raudenbush & Bryk, 2002) and which resulted in some nonsignificant results. Similarly, the obtained power and robustness levels of some of the findings might have been affected, and thus mandate caution to interpret or overgeneralize some of the findings of the study due to the limited number of participants. For the English language and reading literacy intervention in elementary grades, the teacher–student ratio was relatively small (with an average of 2–3 students per treatment teacher, and 3–4 students per control teacher), and such a teacher effect would not significantly impact the results. Conducting other studies investigating a much larger sample of student participants from sufficient number of classrooms and schools would better inform the science research community. Second, all participants in this study were Hispanic ELLs or former ELLs; generalization cannot be reached beyond this group of students in a district that is similar in demographics. Additionally, for this particular study no writing samples were drawn from the data, due to the focus of the study being on reading literacy as opposed to general language arts. Finally, inherent with a longitudinal design, attrition was identified in both the language and science interventions, with an average rate of 15% at each school year, 5% differential attrition rate between treatment and comparison groups at the student level, and no attrition rate at teacher or school level. Therefore, attrition was more likely related to random causes such as family mobility or school schedule of the intact cohorts at schools during the longitudinal study; hence, the degree of threat to internal validity is acceptable (What Works Clearinghouse, 2011).

Summary

There has been a lack of clear understanding based on published research of how to most effectively assist ELLs and former ELLs in acquiring the second language of English and science knowledge at the same time so as to remove academic disadvantage in science and reading. Learning to perform complex tasks in science relies heavily on academic language skills. Unfortunately, ELLs struggle to understand much of the language that is used in content area classrooms and in the curricular materials, and most learners are not explicitly taught to read, write, or speak scientific and academic language (Cazden, 1986; Lager, 2006). To address this issue, we implemented a rigorous longitudinal experimental design in which the English language and reading literacy was integrated with science content; such a study has been indicated to be desired by other researchers (e.g., O. Lee & Luykx, 2006; Merino & Scarcella, 2005). More importantly, we were able to test the effect of integration between English language and science for Hispanic ELLs and former ELLs longitudinally. We conclude that the integration between the science and English language and reading literacy should be interdisciplinary with a primary focus on learning to read in K–3 considering the importance of English language and reading skills as the foundation for academic learning in science. Supporting the notion of reading to learn, the primary focus at the lower middle grades should be on science when students are developing further their science content knowledge and when they are continuing their English language/reading literacy acquisition.

NOTE

1. "Former ELLs" means that students have met the state reclassification criteria to be exited from the ELL program in which they were initially served.

REFERENCES

Allington, R. L., & McGill-Franzen, A. (1989). School response to reading failure: Chapter 1 and special education students in Grades 2, 4, and 8. *Elementary School Journal*, *89*, 529–542.

Amaral, O., Garrison, L., & Duron-Flores, M. (2006). Taking inventory. *Science and Children*, *43*(4), 30–33.

August, D., & Shanahan, T. (Eds.). (2008). *Developing reading and writing in second-language learners: Lessons from the report of the National Literacy Panel on language-minority children and youth*. New York, NY: Routledge.

Brantmeier, C., Schueller, J., Wilde, J. A., & Kinginger, C. (2007). Gender equity in foreign and second language learning. In S. S. Klein (Ed.), *Handbook for achieving gender equity through education* (2nd ed., pp. 305–334). Mahwah, NJ: Erlbaum.

Burk, J., Johnson, D. M., & Whitley, J. (2005). Validity of the Texas Assessment of Knowledge and Skills (TAKS). *The Journal of Border Education Research*, *4*(2), 29–39.

Bybee, R. W. (1997). *Achieving science literacy: From purposes to practices*. Portsmouth, NH: Heinemann.

California Department of Education. (2001). *STAR state summary report*. Sacramento, CA: Author.

Carlo, M., August, D., McLaughlin, B., Snow, C., Dressler, C., Lippman, D., . . . White, C. E. (2004). Closing the gap: Addressing the vocabulary needs of English language learners in bilingual and mainstream classrooms. *Reading Research Quarterly*, *39*, 188–215. doi:10.1598/RRQ.39.2.3

Carrier, K. (2005). Supporting science learning through science literacy objectives for English language learners. *Science Activities*, *42*(2), 5–11.

Cawthon, S. W. (2010). Assessment accommodations for English language learners: The case of former-LEPs. *Practical Assessment, Research & Evaluation*, *15*(13). Retrieved from http://pareonline.net/getvn.asp?v=15&n=13

Cazden, C. (1986). Classroom discourse. In M.C. Wittrock (Ed.), *Handbook of research on teaching* (pp. 432–463). New York, NY: Macmillan.

Chavez, M. (2001). *Gender in the language classroom*. Boston, MA: McGraw-Hill.

Collier, V. P. (1987). Age and rate of acquisition of second language for academic purposes. *TESOL Quarterly*, 21, 617–640.

Cook, V. (2001). *Second language learning and language teaching*. New York, NY: Oxford University Press.

Connor, C., Kaya, S., Luck, M., Toste, J., Canto, A., Rice, D., . . . Underwood, P. (2010). Content area literacy: Individualizing student instruction in second-grade Science. *The Reading Teacher*, *63*, 474–485.

Cooney, T., Cummins, J., Flood, J., Foots, B. K., Goldston, M. J., Key, S. G., . . . Romance, N. (2006). *Scott Foresman science*. Glenview, IL: Pearson.

Cummins, J. (1979). Linguistic interdependence and the educational development of bilingual children. *Review of Educational Research*, *49*, 222–251.

Cummins, J. (1984). Wanted: A theoretical framework of relating language proficiency to academic achievement among bilingual students. In C. Rivera (Ed.), *Language proficiency and academic achievement* (pp. 2–19). Clevendon, UK: Multilingual Matters.

Davies, S., O'Malley, K., & Wu, B. (2007, April). *Establishing measurement equivalence of transadapted reading and mathematics tests*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

De Jong, E. (2004). After exit: Academic achievement patterns of former English language learners. *Education Policy Analysis Archives*, *12*(50), 1–18.

Ellis, R. (1994). *The study of second language acquisition*. Oxford, UK: Oxford University Press.

Duursma, E., Romero-Contreras, S., Szuber, A., Proctor, P., Snow, C., August, D., & Calderon, M. (2007). The role of home literacy and language environment on bilinguals' English and Spanish vocabulary development. *Applied Psycholinguistics*, *28*, 171–190.

Ehrlich, S. (1997). Gender as a social practice: Implications for second language acquisition. *Studies in Second Language Acquisition*, *19*, 421–46.

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin*, *136*, 103–127. doi:10.1037/a0018053

Fang, Z., & Wei, Y. (2010). Improving middle school students' science literacy through reading infusion. *The Journal of Educational Research*, *103*, 262–273.

Florida Department of Education. (2001). *ESOL 2000/01 Annual status report on the implementation of the 1990 League of United Latin American citizens (LULAC) et al. v. State Board of Education et al. consent decree*. Tallahassee, FL: Office of Multicultural Student Language Education.

Genesee, F., & Riches, C. (2006). Literacy: Instructional issues. In F. Genesee, K. Lindholm-Leary, W. M. Saunders, & D. Christian (Eds.), *Educating English language learners: A synthesis of research evidence* (pp. 14–63). New York, NY: Cambridge University Press.

Gersten, R., Baker, S. K., Shanahan, T., Linan-Thompson, S., Collins, P., & Scarcella, R. (2007). *Effective literacy and English language instruction for English learners in the elementary grades: A practice guide* (NCEE 2007–4011). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

Good, R. H., & Kaminiski, R. A. (Eds.). (2002). *Dynamic Indicators of Basic Early Literacy Skills* (6th ed.). Eugene, OR: Institute for the Development of Educational Achievement.

Good, R. H., Kaminski, R. A., Smith, S., & Bratten, J. (2001). *Technical adequacy of second grade DIBELS oral reading fluency passages* (Technical Report, No. 8). Eugene, OR: University of Oregon.

Greenleaf, C., & Hinchman, K. (2009). Reimagining our inexperienced adolescent readers: From struggling, striving, marginalized, and reluctant to thriving. *Journal of Adolescent and Adult Literacy*, *53*, 4–13.

Greenleaf, C., Litman, C., Hanson, T., Rosen, R., Herman, J., Schneider, S., . . . Jones, B. (2011). Integrating literacy and science in biology: Teaching and learning impacts of reading apprenticeship professional development. *American Educational Research Journal*, *48*, 647–717. doi:10.3102/0002831210384839

Greenleaf, C., Schoenbach, R., Cziko, C., & Mueller, F. (2001). Apprenticing adolescents to academic literacy. *Harvard Educational Review*, *71*, 79–129.

Guthrie, J. T., McRae, A., & Klauda, S. L. (2007). Contributions of Concept-Oriented Reading Instruction to knowledge about interventions for motivations in reading. *Educational Psychologist*, *42*, 237–250.

Guthrie, J. T., Wigfield, A., Barbosa, P., Perencevich, K. C., Taboada, A., Davis, M., . . . Tonks, S. (2004). Increasing reading comprehension and engagement through Concept-Oriented Reading Instruction. *Journal of Educational Psychology*, 96, 403–423.

Hapgood, S., & Palinscar, A. (2007). Where literacy and science intersect. *Educational Leadership*, *64*(4), 56–60.

Haycock, K. (2001). Closing the achievement gap. *Educational Leadership*, *58*(6), 6–11. Retrieved from http://www.ascd.org/readingroom/edlead/0103/haycock.html

Hines, P. J., Wible, B., & McCartney, M. (2010). Science, language, and literacy: Learning to read, reading to learn. *Science*, *328*, 447.

Huntley, M. A. (1998). Design and implementation of a framework for defining integrated mathematics and science education. *School Science and Mathematics*, 98, 320–327.

Hyde, J. S. (2005). The gender similarities hypothesis. *American Psychologist*, *60*, 581–592.

Kamil, M. L. (2004). Vocabulary and comprehension instruction. In P. McCardle & V. Chhabra (Eds.), *The voice of evidence in reading research* (pp. 213–234). Baltimore, MD: Brookes.

Kieffer, M. J., Lesaux, N., Rivera, M., & Francis, D. J. (2009). Accommodations for English language learners taking large-scale assessments: A meta-analysis on effectiveness and validity. *Review of Educational Research*, *29*, 1168–1201.

Klentschy, M. (2005). Science notebook essentials: A guide to effective notebook components. *Science and Children*, *43*(3), 24–27.

Krashen, S. D. (1982). *Principles and practices in second language acquisition*. New York, NY: Prentice-Hall International English Language Teaching.

Lager, C. (2006). Types of mathematics-language reading interactions that unnecessarily hinder algebra learning and assessment. *Reading Psychology*, *27*, 165–204.

Lara-Alecio, R., Tong, F., Irby, B. J., Guerrero, C., Huerta, M., & Fan, Y. (2012). An experimental study of science intervention among middle school English learners: Findings from first year implementation. *Journal of Research in Science Teaching*, *49*, 987–1011. doi: 10.1002/tea.21031

Lee, C. D., & Spratley, A. (2010). *Reading in the disciplines: The challenges of adolescent literacy*. New York, NY: Carnegie Corporation of New York.

Lee, O., Deaktor, R. A., Hart, J. E., Cuevas, P., & Enders, C. (2005). An instructional intervention's impact on the science and literacy achievement of culturally and linguistically diverse elementary students. *Journal of Research in Science Teaching*, *42*, 857–887.

Lee, O., Lewis, S., Adamson, K., Maerten-Rivera, J., & Secada, S. G. (2008). Urban elementary school teachers' knowledge and practices in teaching science to English language learners. *Science Education*, *92*, 73–758. doi:10.1002/sce.20255

Lee, O., & Luykx, A. (2006). *Science education and student diversity*. New York, NY: Cambridge University Press.

Linan-Thompson, S., & Hickman-Davis, P, (2002). Supplemental reading instruction for students at risk for reading disabilities: Improve reading 30 minutes at a time. *Learning Disabilities Research & Practice*, *17*, 242–251.

Lindholm-Leary, K., & Borsato, G. (2006). Academic achievement. In F. Genesee, K. Lindholm- Leary, W. M. Saunders, & D. Christian (Eds.), *Educating English language learners: A synthesis of research evidence* (pp. 177–222). New York, NY: Cambridge University Press.

Maerten-Rivera, J., Myers, N., Lee, O., & Penfield, R. (2010). Student and school predictors of high-stakes assessment in science. *Science Education*, *94*, 937–962.

McComas, W. F., & Wang, H. A. (1998). Blended science: The rewards and challenges of integrating the science disciplines for instruction. *School Science and Mathematics*, *98*, 340–348.

McMurrer, J. (2007). *Choices, changes, and challenges: Curriculum and instruction in the NCLB era*. Washington, DC: Center on Educational Policy.

Merino, B. J., & Scarcella, R. (2005). Teaching science to English learners. *Invited Essay. Language Minority Research Institute Newsletter*, *14*(4), 1–7.

Morrow, L., Pressley, M., Smith, J., & Smith, M. (1997). The Effect of a literature-based program integrated into literacy and science instruction with children from diverse backgrounds. *Reading Research Quarterly*, *32*, 54–76.

Muller, P. A., Stage, F. K., & Kinzie, J. (2001). Science achievement growth trajectories: Understanding factors related to gender and racial-ethnic differences in precollege science achievement. *American Educational Research Journal*, *38*, 981–1012.

National Center for Education Statistics. (2009). *The nation's report card: Reading 2009* (NCES 2010–458). Washington, DC: Institute of Education Sciences, U.S. Department of Education.

National Center for Education Statistics. (2010). *The nation's report card: Grade 12 reading and mathematics 2009 national and pilot state results* (NCES 2011–455). Washington, DC: Institute of Education Sciences, U.S. Department of Education.

National Center for Education Statistics. (2011a). *The condition of education 2011* (NCES 2011-033). Washington, DC: U.S. Department of Education. Retrieved from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid = 2011033

National Center for Education Statistics. (2011b). *The nation's report card: Science 2009* (NCES 2011–451). Washington, DC: Institute of Education Sciences, U.S. Department of Education.

National Reading Panel. (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction*. Washington, DC: National Institute of Child Health and Human Development.

Next Generation Science Standards. (2012). *Diversity and equity in the Next Generation Science Standards (NGSS): "All Standards, All*

Students". Retrieved from http://www.nextgenscience.org/next-generation-science-standards

No Child Left Behind Act of 2001, Pub. L. No. 107–110, § 115, Stat. 1425 (2002).

Palumbo, A., & Sanacore, J. (2009). Helping struggling middle school literacy learners achieve success. *Middle School Literacy Learners*, *82*, 275–279.

Pearson, P., Moje, E., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. *Science*, *328*, 459–463. doi:10.1126/science.1182595

Polat, N. (2011). Gender and age differences in motivation and L2 accent attainment: An investigation of young Kurdish learners of Turkish. *Language Learning Journal*, *39*, 19–41.

Quiros, A. (2008). *Structured story reading and retell related to listening comprehension and vocabulary acquisition among English language learners*. Available from ProQuest Dissertations and Theses database. (UMI No. 3333243)

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods*. Thousand Oaks, CA: Sage.

Rea, L. M., & Parker, R. A. (1992). *Designing and conducting survey research*. San Francisco, CA: Jossey-Boss.

Rentner, D. S., Scott, C., Kober, N., Chudowsky, N., Chudowsky, V., Joftus, S., & Zabala, D. (2006). *From the capital to the classroom: Year 4 of the No Child Left Behind Act*. Washington, DC: Center on Education Policy.

Rivard, L. P. (2004). Are language-based activities in science effective for all students, including low achievers? *Science Education*, *88*, 420–442. doi:10.1002/sce.10114

Roehrig, A. D., Petscher, Y., Nettles, S. M., Hudson, R. F., & Torgesen, J. K. (2008). Accuracy of the DIBELS Oral Reading Fluency measure for predicting third grade reading comprehension outcomes. *Journal of School Psychology*, *46*, 343–366.

Ruiz-Primo, M. A., Shavelson, R. J., Hamilton, L., & Klein, S. (2002). On the evaluation of systemic science education reform: Searching for instructional sensitivity. *Journal of Research in Science Teaching*, *39*, 369–393. doi:10.1002/tea.10027

Santau, A. O., Maerten-Rivera, J., & Huggins, A. C. (2011). Science achievement of English language learners in urban elementary schools: Fourth-grade student achievement results from a professional development intervention. *Science Education*, *95*, 1–23. doi:10.1002/sce.20443

Saunders, W. M., & O'Brien, G. (2006). Oral Language. In F. Genesee, K. Lindholm-Leary, W. M. Saunders, & D. Christian (Eds.), *Educating English language learners: A synthesis of research evidence* (pp. 14–63). New York, NY: Cambridge University Press.

Schoenbach, R., Greenleaf, C., Cziko, C., & Hurwitz, L. (1999). *Reading for understanding: A guide to improving reading in middle and high school classrooms*. San Francisco, CA: Jossey-Bass.

Scott, J. A., Jamieson-Noel, D., & Asselin, M. (2004). Vocabulary instruction throughout the day in twenty-three Canadian upper-elementary classrooms. *The Elementary School Journal*, *103*, 269–286.

Shehadeh, A. (1999). Gender differences and equal opportunities in the ESL classroom. *English Language Teaching Journal*, *53*, 256–261.

Snow, C. (2002). *Reading for understanding: Toward an R & D program in reading comprehension*. Santa Monica, CA: Rand.

Snow, C. (2006). Cross-cutting themes and future research directions. In D. August & T. Shanahan (Eds.), *Developing literacy in second-language learners* (pp. 631–651). Mahwah, NJ: Erlbaum.

Snow, C. (2010). Academic language and the challenge of reading for learning about science. *Science*, *328*, 450–452. doi:10.1126/science.1182597

Snow, M. A., Met, M., & Genesee, F. (1989). A conceptual framework for the integration of language and content in second/foreign language programs. *TESOL Quarterly*, *23*, 201–217.

Spycher, P. (2009). Learning academic language through science in two linguistically diverse kindergarten classes. *The Elementary School Journal*, *109*, 359–379.

Stoddart, T., Pinal, A., Latzke, M., & Canaday, D. (2002). Integrating inquiry science and language development for English language learners. *Journal of Research in Science Teaching*, *39*, 664–687.

Stephens, K. E. (2010). Improving reading achievement of low SES minority students with science-related informational texts and structured responses. *Mentoring Literacy Professionals*, *1*, 317–333.

Texas Education Agency. (2008). *Raw score conversion tables for TAKS 2007–2008*. Austin, TX: Author. Retrieved from http://ritter.tea.state.tx.us/student.assessment/ scoring/convtables/2008/taks/

Texas Education Agency. (2009). *LPAC decision-making process for the Texas assessment program: A procedural manual for the 2009–2010 school year*. Austin, TX: Author. Retrieved from http://ritter.tea.state.tx.us/student.assessment/ELL/lpac/LPAC1-Manual2010.pdf

Texas Education Agency. (2010). *2009–10 Academic excellence indicator system*. Austin, TX: Author. Retrieved from http://ritter.tea.state.tx.us/perfreport/aeis/2010/state.html

Tong, F., Irby, B. J., Lara-Alecio, R., & Mathes, P. (2008). The effectiveness of a three-year longitudinal randomized trial study on Hispanic bilingual students' English and Spanish acquisition. *Hispanic Journal of Behavioral Sciences*, *30*, 500–529.

Tong, F., Irby, B. J., Lara-Alecio, R., Yoon, M., & Mathes, G. P. (2010). Hispanic English learners' response to a longitudinal English instructional intervention and the effect of gender: A multilevel analysis. *The Elementary School Journal*, *110*, 542–566.

Tong, F., Lara-Alecio, R., Irby, B. J., & Mathes, G. P. (2011). The effects of an instructional intervention on dual language development among first grade Hispanic English learning boys and girls: A two-year longitudinal study. *Journal of Educational Research*, *104*, 87–99. doi:10.1080/00220670903567364

Tong, F., Lara-Alecio, R., Irby, B. J., Mathes, P., & Kwok, O. (2008). Accelerating early academic oral English development in transitional bilingual and structured English immersion programs. *American Educational Research Journal*, *45*, 1011–1044. doi:10.3102/000283120832-0790

Uchikoshi, Y. (2006). English vocabulary development in bilingual kindergartners: An individual growth modeling approach. *Bilingualism: Language and Cognition*, *9*, 33–49.

Vaughn, S., Cirino, P., Linan-Thompson, S., Mathes, P., Carlson, C., Hagan, E. C., . . . Francis, D. (2006). Effectiveness of a Spanish intervention and an English intervention for English-language learners at risk for reading problems. *American Educational Research Journal*, *49*, 449–479.

Watkins, N. M., & Lindahl, K. M. (2010). Targeting content area literacy instruction to meet the of needs of adolescent English language learners. *Middle School Journal*, *41*(3), 23–32.

Watts, S. M. (1995). Vocabulary instruction during reading instruction in six classrooms. *Journal of Reading Behavior*, *27*, 399–424.

What Works Clearinghouse. (2011). *Procedures and standards handbook*. Washington, DC: Institute of Education Sciences (IES), U.S. Department of Education.

Woodcock, R. W. (1991). *Woodcock Language Proficiency Battery–Revised, English and Spanish Forms: Examiner's manual*. Itasca, IL: Riverside.

Yore, L., Hand, B., Goldman, S., Hildebrand, G., Osborne, J., Treagust, D., & Wallace, C. (2004). New directions in language and science education research. *Reading Research Quarterly*, *39*, 347–352.

AUTHORS NOTE

Fuhui Tong is an Associate Professor in the Department of Educational Psychology at Texas A&M University. Her research interests include second language and literacy development and assessment for English learners in bilingual and English-as-a-second-language settings, as well as the quality of teachers serving these students.

Beverly J. Irby is a Professor and Associate Department Head, Department of Educational Administration and Human Resource Development at Texas A&M University. She was affiliated with Sam Houston State University at the time this manuscript was submitted for review. Her primary research interests center on issues of social responsibility, including bilingual and English-as- a-second-language education, administrative structures, curriculum, and instructional strategies.

Rafael Lara-Alecio is a Professor and Director of Bilingual Programs in the Department of Educational Psychology at Texas A&M University. His primary areas of research are in assessment, evaluation, and bilingual content area instruction. He coauthored a pedagogical theory and model for transitional English bilingual classrooms.

Janice Koch is Professor Emeritus from the School of Education at Hofstra University, Long Island, New York. Her research interests center on broadening participation in STEM fields and examining best practices for reaching underrepresented populations in science and engineering disciplines.