ORIGINAL ARTICLE

Investigating the Impact of A Literacy-infused Science Intervention On Economically Challenged Students' Science Achievement: A Case Study from A Rural District in Texas

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***Abstract**: In this empirical study we examined the effect of a literacy-infused science intervention on fifth grade economically challenged students' science achievement in the curriculum-based and standardized assessments. A total of 27 treatment students and 20 comparison students from two intermediate schools in a rural district in South Texas in the United States participated in the present study. The intervention consisted of ongoing, structured, bi-weekly virtual professional development (VPD) with virtual mentoring and coaching (VMC) at the teacher level and literacy-infused science lessons with inquiry-based learning delivered at the student level. Results revealed a significant and positive intervention effect in favor of treatment students as reflected in higher normal curve equivalent scores in the standardized science assessment and higher scores in curriculum-based assessment. We conclude that the literacy-infused science intervention, inclusive of evidence-based curriculum, VPD, and VMC, is particularly beneficial for promoting science learning for the students in rural areas with educational and economical challenges due to geographic isolation.*

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Introduction

OVER the past decades, the population of economically challenged (EC) students has been growing steadily in the United States. According to United States Department of Agriculture (USDA), Food and Nutrition Service (2021), the percentage of students who participated in free or reduced lunch programs (FRLP) were 30.3 million children in 2016; 29.9 million in 2017; 29.7 million in 2018; 29.5 million in 2019, and 22.4 million in 2020 (2020 was impacted by COVID-19). Students who participate in FRLP, those in our study are considered to be EC students, are those with participation based on their families' incomes of 130% and 185% of the Federal poverty level; schools are not allows to charge more than 40 cents for a reduced price lunch (USDA, 2017).

EC students have been reported to academically underperform when compared to their monolingual, middle, and upper-class peers (McFarland et al., 2019). According to the Texas Education Agency (2019), there were 60.6% EC students enrolled in public schools in 2018-2019 (2018-2019 data are the latest data for Texas, since 2019-2020 reporting is incomplete due to COVID-19). In fifth-grade in 2019, 39% of EC students passed the state standardized science and 43% in the reading assessment, respectively, at the level of meets grade level or above, compared to 49% of all students in science and 54% in reading. Such gaps in science and reading remained similar in the eighth grade (Texas Education Agency (TEA), 2019).

The EC students face the challenge to acquire the language of science to be able to understand science concepts, phenomena, and inquiries that are offered in the reform‐based science instruction (Stage et al., 2013). To address the challenge, researchers have recommended the infusion of language and literacy into science instruction to support science learning (i.e., Llosa et al., 2016; Maerten-Rivera et al., 2016; Tong et al., 2014a; Tong et al., 2014b). Researchers have determined effective strategies integrating science and literacy to encourage teachers' use of scientific classroom discourse (e.g., Lewis et al., 2015), improve teachers' quality of instruction (e.g., Maeng et al., 2018), and increase teachers' understanding, confidence, and delivery of science-literacy integration instruction (e.g., Maeng et al., 2020; Santau, et al., 2010; Tong et al., 2019). Such integrated instruction has demonstrated positive evidence of enhancing students' learning in science (i.e., Llosa et al., 2016; Maerten-Rivera et al., 2016) or in both science and literacy (Lara-Alecio et al., 2012; Tong et al., 2014a, 2014b).

However, academic language is frequently information-dense, abstract, and technical (Huerta et al., 2016; Lara-Alecio et al., 2018), and teachers may lack the knowledge or capacity integrating robust language-based activities in the science classroom (Lee, 2005; Rubini et al., 2018). Science teachers are required to understand and learn how to construct a learning environment for students to acquire science-specific vocabulary for meaning-making, further to learning science core ideas, concepts and practices (Buxton & Caswell, 2020; Greenleaf et al., 2011; Irby et al., 2018; 2020).

To improve their instructional practices, teachers, particularly those from rural areas (Tang et al., 2021a), need to be provided the following educational resources related to science and literacy infusion (a) research-based curriculum (Arias et al., 2016; Cervetti et al., 2015); (b) structured ongoing virtual professional development ([VPD; Irby et al., 2015]; Costello et al., 2014; Mackey, 2009; Tang, 2018); and (c) virtual mentoring and coaching (VMC; Irby, 2015), as part of VPD, which provides teachers real-time pedagogical support to transfer their understanding of the science and literacy infused curriculum and knowledge gained from VPD and VMC to classroom instruction (Irby et al., 2020). Effective professional development and mentoring and coaching also help teachers better understand critical components of literacy and science infusion and implement the intervention with high fidelity (Tang et al., 2020). Researchers suggested that professional development and mentoring and coaching need to be provided with substantial frequency and length to be effective on teachers' instruction and further transfer on students' outcome (Maerten-Rivera et al., 2016; Tong et al., 2014b). In particular, VPD and VMC, in the virtual format, provide the same quality of support and resources and allow more flexibility for teachers with different time schedules and locations than do traditional face-to-face professional development and mentoring and coaching (Irby et al., 2020; Tong et al., 2015).

Rural school districts, including the current study context, are reported to have limited state and federal funding to address various school needs (Showalter et al., 2017; Wang et al., 2019; Williams, 2010). These districts normally have significantly low instructional expenditure (Tang et al., 2021b), and high percent of EC students (Strange et al., 2012), student mobility (Paik & Phillips, 2002; Reynolds et al., 2009), and teacher turnover (Lowe, 2006). Students in rural districts demonstrate relatively low academic achievement in reading (Cantrell et al., 2018; Tang et al., 2021a) and science (Holland et al., 2011; Wang et al., 2019) as compared to students in districts serving middle- and upper-class population. Due to geographic isolation and limited educational resources, rural teachers have not been provided with adequate professional development opportunities (Vernon-Feagans et al., 2010) to be trained to integrate literacy and science instruction for supporting their students' science learning (Tang et al., 2021a; Wang et al. 2019). Lara-Alecio et al. (2021) confirmed that when provided with the same VPD, rural teachers demonstrated similar gains in content knowledge and pedagogy as their peers in urban and suburban school districts. Given the feasibility and accessibility of virtual delivery, VPD and VMC seem to be possible solutions for rural teachers to access the quality pedagogical support for providing literacy-infused science instruction to their students.

Purpose, Context, and Research Questions

The purpose of the current study was to investigate the impact of a literacy-infused science intervention on fifth-grade students' science achievement in a rural school district in the state of Texas in the United States. The rural district in our case study served more than 60% of students on free and reduced lunch, and 30% of students failed State

of Texas Assessments of Academic Readiness (STAAR, state high-stakes test) in fourth grade reading. Treatment teachers received VPD and VMC support based on a 25-week literacy-infused science (LIS) curriculum intervention delivered daily to their students. We compared students' science achievement between the treatment and control conditions. The following research questions guided our study:

(1) Is there a statistically significant difference in students' science achievement (as measured by state standardized assessment) between treatment and control conditions, controlling for their initial performance at the beginning of 5th grade?
(2) Is there a statistically significant difference in students' science achievement (as measured by curriculum-based assessment) between treatment and control students, controlling for their initial performance at the beginning of 5th grade?

Method

Research Design

This study is derived from a larger randomized, longitudinal literacy-infused science project funded by the U.S. Department of Education (LISTO, #U411B16001). The larger project was designed to increase 5th grade science teachers' instructional capacity and their students' science and English literacy in rural and non-rural schools across Texas for EC students, inclusive of former and current English learners. The current study focused on one rural school district located in the boundaries of South Texas and the Texas Coastal Bend region. We selected this district because of a large student population (68.4%) eligible for free or reduced lunch (TEA, 2018). Further, this district included schools in both conditions whereas other rural districts in the larger project only had one school. In addition, 92.4% of the students in this district were Hispanic (TEA, 2018). Two middle schools (grades 5 and 6) in the districts were randomly assigned to treatment and control conditions in the 2017-2018 school year when the intervention started.

Participants

In this study, we included all consented teachers and students in both treatment and control campuses. There were three control teachers and two treatment teachers with an average of 13.6 years of teaching science. All teachers held a bachelor's degree as well as Texas Certification in Grade 4-8 Generalist or EC-6 Generalist and are certified to teach science subject. Each participating teacher taught one section of science on their respective campus. As was mentioned earlier, two intermediate schools were randomly assigned to treatment and comparison conditions to avoid contamination of the intervention between treatment and control classrooms. At the student level, there were 50 students (30 in treatment; 20 in control) who took pre-test in science before intervention and reported their performance in the state high-stakes reading test in fourth grade. At

the end of the year-long intervention, 47 students (27 in treatment; 20 in control) took post-test, which was the analytical sample in this study. It is worth noting that only 70% of control students and 63% of treatment students passed fourth grade state high-stakes reading test.

Literacy-infused Science Intervention-Teacher Training

Literacy-infused science intervention in the larger research project included three major components: virtual professional development (VPD), virtual mentoring and coaching (VMC), and literacy-infused science (LIS) curriculum. Treatment teachers participated in bi-weekly synchronous VPD sessions throughout the year-long intervention. The sessions were delivered through high-definition video conferencing, in which VPD coaches worked with treatment teachers on previewing upcoming lessons, building capacity for LIS teaching, implementing instructional strategies, and reflecting on student learning. Treatment teachers also viewed modeling videos related to upcoming science inquiry activities. VPD sessions were recorded and shared with treatment teachers to revisit and review as needed. In addition, treatment teachers participated in VMC that was conducted via an online platform for coaches to virtually observe and provide real-time feedback on treatment teachers' delivery of LIS curriculum.

Literacy-infused Science Intervention-Curriculum

The literacy-infused science (LIS) used in the current study was derived from a previous intervention that demonstrated effectiveness in improving EC students' science achievement (Tong et al., 2014b). The LIS curriculum is standards-aligned and follows the 5E hands-on science model (Bybee et al., 2006). It is a 25-week LIS curriculum for approximately 80 minutes daily. Instructional components and strategies were embedded to support students' academic science vocabulary and concepts via listening, speaking, reading, and writing in science. It also includes technology integration for students to access online educational tools and science-related software or applications via tablets. In this section, we present examples of the LIS curriculum. First, each lesson plan unit includes language objectives that specify how literacy (listening, speaking, reading, and writing) will be developed or supported during the teaching of the science concept. The example in **Figure 1** represents daily objectives related to earth's changing surface in one week.

Treatment teachers were also provided resources to support LIS implementation. For example, the images in **Figure 2** display slides from a corresponding PowerPoint presentation to guided students to describe and compare the landform models they created using clay.

The literacy infusion can also be reflected on the vocabulary slide in **Figure 3**, which includes a variety of embedded strategies including (a) breaking down the word into syllables, (b) providing a student friendly definition, (c) providing a real-life image representing the target word, (d) a sentence including the use of the target word, and (e)

Daily Objectives		
	Science Objectives	**Language Objectives**
Day 1	The students will build models of naturally occurring landforms such as mountains, rivers, and canyons.	The students will name and describe landforms based on evidence found in images and 3D models.
Day 2	The students will explore how changes to the Earth's surface caused by wind and water affect humans.	The students will use scientific terms to describe how wind and water change the surface of the Earth.
Day 3	The students will use models to explore the rate water and wind can change the Earth's surface.	The students will read on grade-level text related to natural hazards like landslides, avalanches, and floods.
Day 4	The students will investigate factors that increase or decrease the damage caused by landslides.	The students will write to reflect on the damage cause by water- and wind-based natural hazards.
Day 5	The students will apply their knowledge to reduce the negative effects of earth's changing surface through flooding.	The students will use scientific terminology and evidence to evaluate and critique their peers proposed solutions to the flooding river challenge.

Figure 1. Week 10 Days One to Five Daily Science and Language Objectives.

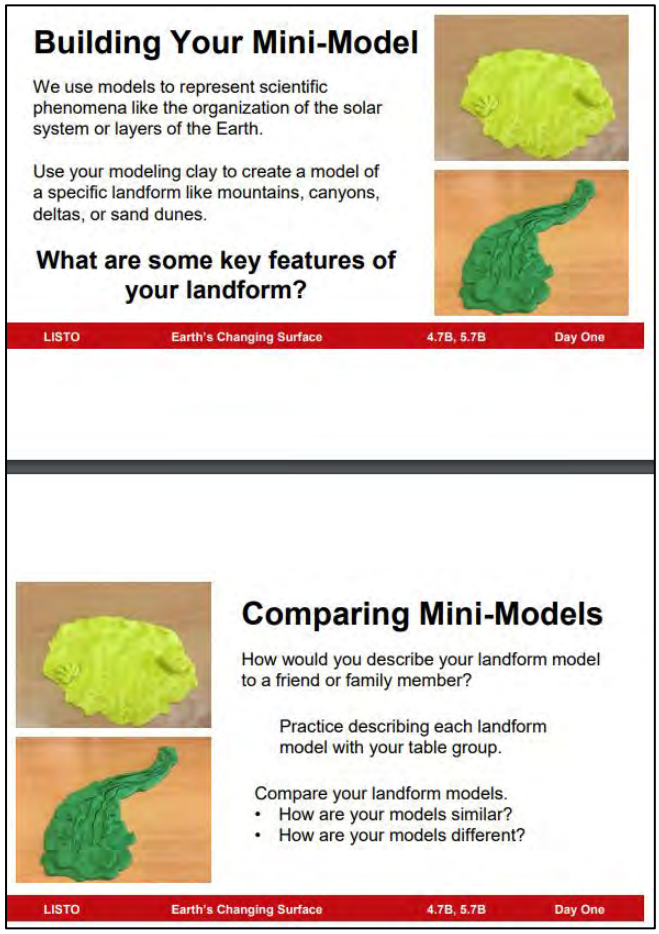

Figure 2. Week 10 Days One Hands-on Activity: Building Your Mini-Model.

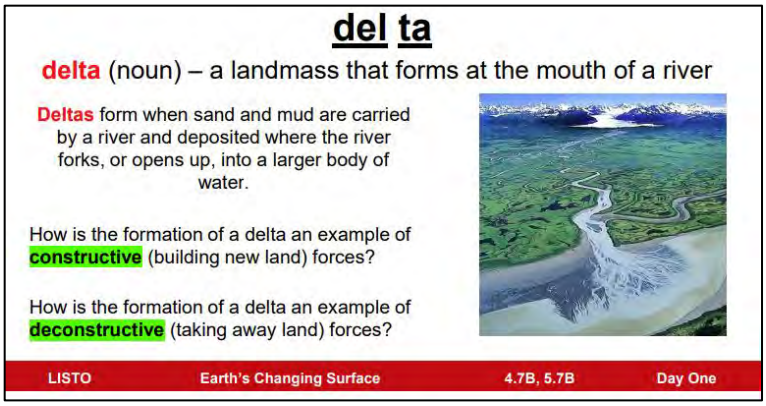

Figure 3. Week 10 Days One Science Vocabulary.

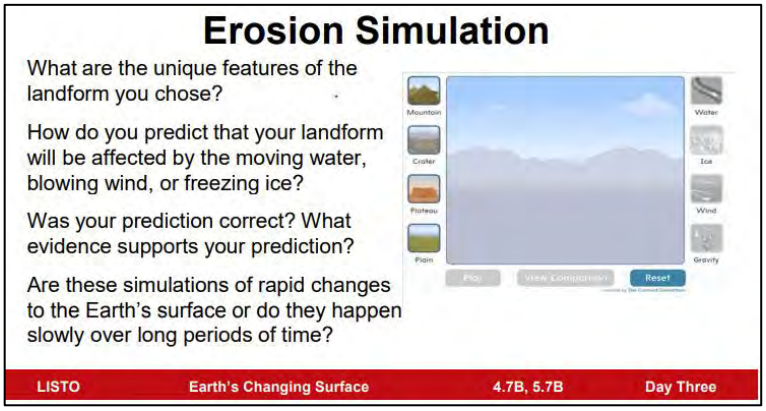

Figure 4. Week 10 Day Three Online Simulation.

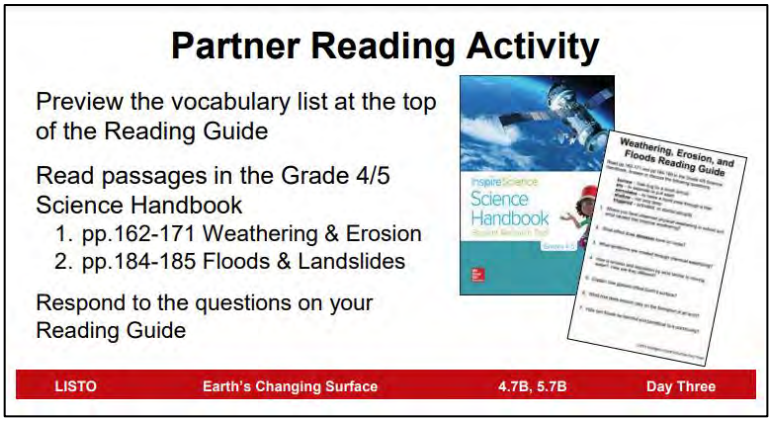

Figure 5. Week 10 Day Three Partner Reading Activity.

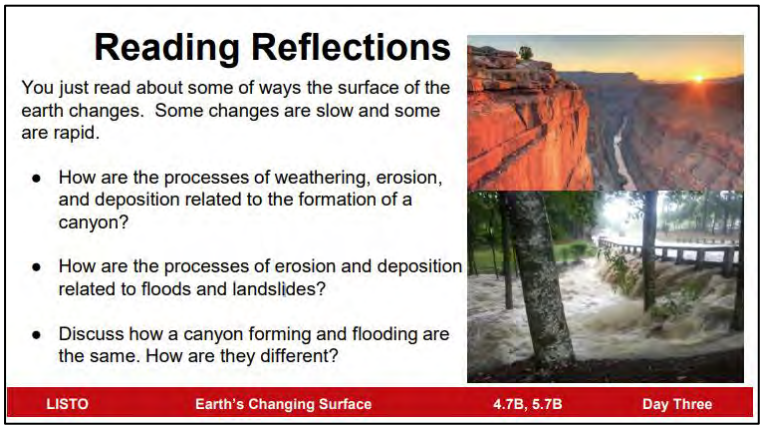

Figure 6. Week 10 Day Three Reading Reflection.

Figure 7. Week 10 Day Three Reading Reflection.

questions for students to discuss and respond to that provide opportunities for students to practice using academic vocabulary.

Figure 4 provides students with focus questions as they work through an online simulation related to erosion.

Figure 5 guides students through a partner reading activity. Students are strategically partnered based on their reading level. After previewing vocabulary that will be encountered in the text, partners take turns reading the assigned text (e.g., partner A reads the first paragraph, partner B reads second paragraph), support each other during reading by helping to decode challenging words, and calling attention to expository text structures (e.g., images, graphics, captions, headings, subheadings, bold words). After

reading, partners read the comprehension questions on the reading guide to discuss and record their responses (see **Figure 6**).

Figure 7 is displayed while small groups of students work through a hands-on, collaborative activity to investigate two landslide slopes. Students refer to the activity guide for instructions and to record their observations.

Instruments

In the fifth grade intervention, students were pre-and post-tested using a standardized assessment and a curriculum-based researcher developed assessment. The Iowa Test of Basic Skills [ITBS] (Dunbar et al., 2015) is a norm-referenced, group-administered test measuring knowledge and skills in academic areas, including reading, math, science, social studies, and etc. For the purpose of the larger project, we administered the science subtest (ITBS Level 11 Form E) to measure students' knowledge of scientific principles and information, and the methods and processes of scientific inquiry. According to the test manual, reliability is reported at 0.848 in form of Kuder-Richardson Formula 20 (K-R 20). There are 37 items in the ITBS Level 11 Form E. The Big Ideas in Science Assessment (BISA) is a researcher-developed standards-aligned science assessment, which is developed following big ideas in science based on standards (see Lara-Alecio et al., 2018 for the details of development and validation of BISA). There are 30 items in the BISA test. To examine the impact of literacy-infused science intervention on students' science achievement, students' fourth grade English reading proficiency measured by the State of Texas Assessments of Academic Readiness (STAAR) reading assessment were collected. Grade 4 STAAR reading examined whether students demonstrate an ability to understand and analyze written, literary, and informational texts across reading genres (TEA, 2017).

Data Collection and Analysis

To address the first research question, we examine the differences in the post-test of ITBS between treatment and control students, controlling for their performance in ITBS pre-test and fourth grade English reading proficiency. Normal curve equivalent (NCE) scores generated from ITBS were used for analysis. To address the second research question, we compared the differences in the post-test of the BISA between treatment and control students, controlling for their performance in the BISA pre-test and four grade STAAR reading scores. Analysis of covariance (ANCOVA) was conducted with the pre-test and fourth grade STAAR reading as covariates and post-test as the outcome variable to monitor students' science learning and compare between treatment and control conditions.

Students took the fourth-grade STAAR reading assessment at the end of fourth grade, and school districts transferred their scale scores to us at the end of fifth grade. The BISA and the ITBS assessments were given at the beginning and end of grade 5. The number of items answered correctly in BISA, ITBS NCE scores, and STAA read-

ing scaled scores were used in data analysis. A total of 47 students (27 in treatment; 20 in control) completed the intervention and had both pre-and post-test scores.

Results

Descriptive statistics of pre- and post-tests from both treatment and control conditions are listed in **Table 1**. There was no statistically significant difference between treatment and control students regarding their pre-intervention science achievement as measured by ITBS (p = 0.465, Cohen's d = -0.218) and BISA (p = 0.074, Cohen's d = 0.074). According to the What Works Clearing House (WWC, 2017), an effect size with an absolute value greater between 0.05 to 0.25 indicated baseline equivalence was achieved, but pre-test scores need to be included as the covariate in the outcome analysis. In the following section, we present our findings by research questions.

RQ1. Is there a statistically significant difference in students' science achievement (as measured by state standardized assessment) between treatment and control conditions, controlling for their initial performance at the beginning of 5th grade?

An ANOVA was performed to determine the effect of the literacy-infused science intervention on students' science achievement measured by nationally normed test, ITBS, after controlling for students' pre-intervention performance. The results (see **Table 2**) indicated that there was a statistically significant difference in post-intervention ITBS NCE scores between intervention and control students after adjustment for pre-intervention performance in science measured by ITBS and in reading measured by Grade 4 STAAR Reading test, $F(1, 43) = 19.24$, $p < 0.001$, partial $\eta^2 = 0.309$, suggesting a statistically large effect size (Cohen, 1969; Richardson, 2011).

RQ 2. Is there a statistically significant difference in students' science achievement (as measured by curriculum-based assessment) between treatment and control students, controlling for their initial performance at the beginning of 5th grade?

An ANOVA was performed to determine the effect of the literacy-infused science intervention on students' science achievement as measured by researcher-developed curriculum-based instrument of BISA, after controlling for students' pre-intervention performance. The results (see **Table 3**) indicated that there was a statistically significant difference in post-intervention BISA scores between treatment and control students after adjustment of students' pre-intervention performance in science as measured by BISA and in reading as measured by Grade 4 STAAR, $F(1, 43) = 6.188$, $p = 0.017$, partial $\eta^2 = 0.126$, suggesting a statistically medium to large impact (Cohen, 1969; Richardson, 2011).

Discussion and Conclusion

In this study, we investigated the impact of a literacy-infused science intervention on fifth-grade students' science achievement in a rural school district in the state of Texas in the United States. Our study included bi-weekly VPD over 25 weeks with mentoring and coaching of the LIS curriculum delivered by science teachers. Our results indicated

Table1. Description of Pre and Post and Baseline Equivalence.

		Pre-test/Baseline Equivalence				Post-test	
Condition		N	Mean	S.D.	Cohen's d	Mean	S.D.
ITBS_NCE	Treatment	27	35.6	18.72	-0.218	43.41	16.77
	Control	20	40.35	20.28		26.70	24.36
BISA	Treatment	27	11.9	5.75	0.074	17.07	4.11
	Control	20	11.85	5.1		15.05	6.07

Table 2. ANCOVA Results of Comparing Treatment and Control Students' Science Improvement Measure by ITBS NCE Scores Controlling for Students' Initial Performance in Reading and Science.

Source	SS	df	MS	F	p-value	Partial Eta Squared
Intercept	2,631.76	1	2,631.76	10.57	0.002	0.197
Condition	4,789.74	1	4,789.74	19.24	< 0.001	0.309
ITBS_Pre_NCE	73.04	1	73.04	0.29	0.591	0.007
G4 STAAR Reading	3,985.35	1	3,985.35	16.01	< 0.001	0.271
Error	10,702.99	43	248.91			
Total	83,724.00	47				

Note: SS, sum of squares; MS, mean squares; df, degree of freedom.

Table 3. ANCOVA Results of Comparing Treatment and Control Students' Science Improvement Measure by BISA Controlling for Students' Performance in Reading and Science before Intervention.

Source	SS	df	MS	F	*p*-value	Partial Eta Squared
Intercept	11.231	1	11.231	0.843	0.364	0.019
Condition	82.416	1	82.416	6.188	0.017	0.126
G4 STAAR Reading	88.620	1	88.620	6.654	0.013	0.134
BISA_Pre	121.511	1	121.511	9.124	0.004	0.175
Error	572.692	43	13.318			
Total	13,540.000	47				

Note: SS, sum of squares; MS, mean squares; df, degree of freedom.

a positive effect of the literacy-infused science intervention on fifth grade students' science achievement on a standardized test as well as a researcher-developed test, with medium to large effect sizes. This is consistent with previous studies that integrating instructional components of literacy and language into a subject area would yield higher

achievement in that subject (Llosa et al., 2016; Lara-Alecio et al., 2018; Maerten-Rivera et al., 2016).

A further examination of students' performance on ITBS indicated that after one year of literacy-infused science intervention, treatment students on average make more than one year's gain (8 points increase in NCE) in contrast with a loss of 13 points in NCE scores among control students. Given the relatively low passing rate of fourth grade STAAR reading test (both conditions having one-third of students who failed the test), treatment students' progress in science learning suggested that extra literacy support, as embedded in LIS curriculum played a critical role in supporting low-achieving students' science learning. Further, by the end of 5th grade, the average performance of these students was still below the national average (50 points on NCE). We argue that one year of LIS intervention was effective for EC students, and anticipate a continued upward trajectory with a longer duration of such intervention or early intervention that spans longitudinally which has been reported to have strong impact on students' science achievement (Tong et al., 2014a).

The findings are consistent with the previous studies with grade 5 EC students (i.e., Tong et al., 2014a; 2014b) and were also supported by theorists (e.g., Halldén, 1999) and researchers (Kieffer et al., 2009; Lee & Stephens, 2020) who advocated and highlighted the benefit of language/literacy support for diverse learners. In rural school districts with a high percent of EC students and students who underperform in reading/literacy (Showalter et al., 2017; Wang et al., 2019), our literacy-infused science intervention is promising and beneficial as we found that it scaffolds students' science learning with extra science-related literacy support, which addressed the needs of these ED students in rural schools. In science classrooms, students are expected to apply literacy skills to conceptualize ideas, make connections, and exchange their scientific thoughts with their peers (Wright et al., 2016). The literacy-infused science instruction (Lara-Alecio, et al, 2016), as was described in our study, provided opportunities for students to practice their language skills and at the same time in a content area, strengthen the foundation for establishing background knowledge and vocabulary, and increase their academic achievement. This finding is also supported by findings from August et al. (2009). Our findings are particularly important for rural school teachers and students.

We also emphasize that the VPD that supported teachers' learning about language-and-literacy infused instruction is helpful for teachers to understand the critical role of literacy in students' science learning, particularly for teachers in rural districts with limited instructional and PD resources (Vernon-Feagans et al., 2010). Furthermore, even experienced science teachers may face challenges in implementing inquiry-based practices. Strategies, such as modeling teaching and peer collaboration, as were included in our VPD, supported teacher learning, shaped teachers' pedagogical practices, and further created more structure opportunities for students' science learning. Arais et al. (2016) also support this conclusion. In our intervention, VPD coaches worked with treatment teachers to preview lessons and reflect on student learning, and provide real-

time feedback on treatment teachers' delivery of LIS instruction, which ensured teachers' fidelity of implementing the LIS curriculum.

Implication for Literacy-infused Science Intervention of EC students in Rural schools

Due to isolated geographic characteristics and relatively small enrollment, rural schools have limited access to educational resources and state and federal funding, which limits rural teachers' professional growth (Showalter et al., 2017; Tang et al., 2021a; Wang et al., 2019). While science teachers hold the most important role in supporting students' science knowledge and literacy learning, they need an environment or a platform that supports their professional development, provides equitable access to instructional resources, and promotes students' science learning as a natural consequence. VPD and VMC seem to be such environments that teachers, especially rural teachers, can receive in an equitable manner, as high a quality of professional development and mentoring and/or coaching as do their peers in more privileged districts.

Beyond VPD and VMC, the literacy-infused science curriculum that incorporates 5E model and integrated with literacy support for developing students' listening, speaking, reading, and writing in science context, is particularly resourceful for science teachers who work with EC students. Access to these resources may contribute to reducing the achievement gap between rural and non-rural students (Tang et al., 2021a). As Lara-Alecio et al. (2021) pointed out, VPD and VMC enhanced teachers' content knowledge and instructional capacity, regardless of teachers' locations. Our study confirmed the benefit of VPD, VMC, and LIS curriculum which enhance science teachers' instructional capacity and professional growth, and promote students' science achievement in rural schools. It also stands to reason that such benefit to teachers and students in the teaching and learning of science may extend to other school settings that serve a large population of EC and under-privileged population.

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