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A Culturally Responsive Literacy Approach to Develop Scientific Conceptual Knowledge Through Creative Narratives

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Abstract

Our study examined the effects of culturally responsive literacy pedagogical approaches in the development of scientific vocabulary and conceptual knowledge among minoritized middle-grade students during a summer program. We describe the design and implementation of a literacy-enriched STEM instructional unit of study built upon the background experiences of Latina/Latino migrant farmworkers' children to expand their STEM literacy skills and knowledge. Our aim with this unit was to increase the students' science knowledge and skills; strengthen their mathematical abilities; enhance their ability to use technology for research; and improve their academic vocabulary, language, and writing skills. This program also had as an objective to explore the students' self-perceptions regarding science learning. Qualitative and quantitative data were collected from the students' pre- and postsurveys, pre- and post-tests, assignments, and group interview. The results demonstrated significant improvements in the students' vocabulary and conceptual understandings. The students developed an awareness of the interrelation of science, math, technology, and literacy with their background experiences, expanded their interest in science, and increased their ability to write effectively about STEM topics. These results also highlighted the significance of connecting STEM instruction with both background knowledge and possible careers via out-of-school efforts like this program to increase minoritized students' interest in pursuing STEM careers.

Keywords: culturally responsive teaching, Latina/Latino students, migrant education, STEM literacy

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Introduction

Although White Americans account for 57.8% of the entire U.S. population, African American, Hispanic/Latino, Asian, Pacific Islander, American Indian, and Alaska Native people comprise more than 42% of the entire population of the U.S., as reported by the United States Census Bureau (Jensen et al., 2021). Despite an increase in these minoritized populations during the past few years, most of these groups continue to be underrepresented in science, technology, engineering, and mathematics (STEM) fields (National Science Foundation, 2017). This underrepresentation is problematic; broadly, research on diversity and performance outcomes has shown that diversity in the workplace can increase performance and productivity, and specially, "it has already been associated with improved patient health outcomes" (Gomez & Bernet, 2019, p. 391). For example, Holley (2013) stated that relationships between patients and medical professionals are more positive if they share language, culture, and/or ethnicity—something that is not available for many people of color because their communities are "less likely to have physicians of color" (p. 2). Holley (2013) suggested that one way to increase diversity among medical providers is to create K–12 healthcare and STEM enrichment initiatives to increase and sustain students' interest. One subpopulation of particular relevance, but often overlooked by educators, are the United States' predominantly Latina/Latino farmworkers. According to the most recent National Agricultural Workers Survey, fewer than 16% of farmworkers identify as "not Hispanic or Latino" (U.S. Dept. of Labor, 2017, p. 36). Our study was based upon the premise that the children of Latina/Latino farmworkers should be included in efforts such as those described by Holley.

To address the national shortages of minoritized scientists, doctors, and engineers in the United States, we must connect children of color with high-quality STEM instruction in P–12 settings. The National Research Council (NRC, 2012) created a new framework for K–12 science education standards to ensure that, by the end of 12th grade, all students have the STEM literacy skills necessary to engage in public conversations about science and apply scientific knowledge and research to real-life situations. The framework emphasized building strong foundational understandings of science and continuous development of cross-disciplinary knowledge and skills at all grade levels. Also, the NRC standards highlighted the social nature of science, stressing the importance of collaborative and cooperative work as well as the use of language as a tool and means toward cognitive development (Vygotsky & Cole, 1978). The standards place special emphasis on equity and diversity because the NRC understood science instruction as a cultural endeavor that values and benefits from multiple modes of investigation and communication (Kress, 2009) and builds on students' experiential backgrounds, personal interests, and funds of knowledge (Gonzalez et al., 2005).

Thus, there is a need to implement literacy-enriched STEM programs using socioculturally responsive pedagogies (Gay, 2018) that place diverse students' cultures, languages, knowledge, experiential backgrounds, and ways of learning at the center of the curriculum. These pedagogical approaches provide students with meaningful and sensible instruction linked to students' experiences while expanding their awareness of new topics that they may not be interested in initially. These types of literacy-enriched STEM programs work well in informal spaces, where pacing and testing are not as consequential as they are in formal educational settings. Opportunities to learn science in informal environments provide students with spaces to expand their knowledge, increasing students' curiosity and inquiry skills. Informal learning environments also give students "a sense that science learning can be personally relevant and rewarding" (NRC, 2009, p. 13). The NRC (2009) consensus on informal science learning concluded that these types of experiences support "science learning for virtually all people that is conducive to learning systematic and reliable knowledge about the natural world" (p. 2). However, minoritized populations tend to underutilize informal science opportunities (Dawson, 2018; DeWitt & Archer, 2017; Falk et al., 2009; Godec et al., 2021).

Our study examined the effects of the implementation of an agriculturally themed literacy-enriched STEM instructional unit built upon the background experiences of Latina/Latino migrant farmworkers' children to expand their scientific vocabulary and concept knowledge through a literacy-enriched STEM unit. The instructional approaches, activities, and tasks used in this instructional literacy-enriched STEM program were grounded on culturally responsive literacy pedagogies, reading and writing to learn, and education in informal settings. Culturally responsive literacy pedagogical approaches need to be integrated into informal science learning environments. Research on such perspectives needs to be conducted to increase understanding of how to engage historically marginalized students' literacy development in STEM. To address this, we focused upon the following question in this study:

How does using purposeful and creative expository writing, socioculturally responsive pedagogy, and multimodal meaning-making to teach a literacy-enriched STEM agricultural unit influence students' conceptual learning, vocabulary acquisition, and perceptions of their ability to participate in science?

Framing the Study

Role of Culturally Responsive Literacy Pedagogy in STEM

Literacy skills are essential for students to succeed across all content areas, including STEM. Thus, a literacy-enriched STEM unit of study should address all modes of language: reading, writing, speaking, listening, viewing, and representing. Guided by a desire to improve educational outcomes among minoritized students, our study's choice of STEM literacy materials and activities was grounded in a culturally responsive literacy pedagogical approach. Culturally responsive pedagogies focus on the histories, experiences, and ways of learning of students who are not part of the dominant culture to make learning more relevant and effective (Ladson-Billings, 1995). These are essential components of culturally responsive pedagogical practices, as these approaches validate the students' cultural frames of reference and, at the same time, challenge students with an engaging, empowering, and comprehensive curriculum (Gay, 2018). Gay (2018) contended that well-implemented culturally responsive teaching promotes students' confidence, empowerment, and desire to seek success. This is especially significant when planning for instruction to serve minoritized students, such as students from migrant farmworker families. Thus, to make the STEM instructional unit culturally relevant, the researchers planned inclusive activities and materials that acknowledged the migrant students' culture and diversity. This was achieved by including materials regarding STEM professionals who mirrored the cultures and diversity of the students (Ladson-Billings, 1995).

Informal Science Learning Environments

Informal science learning has been identified as a venue for students to deepen their affiliation with science (Mulvey et al., 2020). Science affiliation intersects with the sixth learning strand the NRC identified, which discusses how students "think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science" (NRC, 2009, p. 4). In addition, informal science experiences can also increase the time students engage in science and "create opportunities for students and others to develop interest, readiness, and capacities to pursue science, technology, engineering, and math (STEM) learning in school and beyond" (NSTA, 2012, p. 2).

Previous studies of informal science learning environments have provided the field with much research on areas such as situational interest, engagement, scientific literacy, equity, science identity, and sense of place. For instance, Dou and colleagues (2019) conducted a nationwide survey with college students enrolled in a Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) of the National Science Foundation (n = 15,847). The participants were representative of the general population in regard to gender and race/ethnicity, and there was a mix of STEM and non-STEM majors in the survey pool. They found that talking about science with friends and family had the highest influence on students' STEM identity. In addition, reading or watching both fiction and nonfiction science media also positively influenced STEM identity development. Similarly, Dou and Cian (2021) found in their research on Hispanic/Latino college students that talking with family about their experiences with science was the number one factor from the students' childhood informal science learning experiences that positively impacted the students' STEM identity formation.

Chittum and colleagues (2017) discovered that students who participated in an after-school program rated their engagement with science higher than nonparticipants, and their motivation and desire to pursue a college degree was also more persistent over time than nonparticipants. Furthermore, Leblebicioglu and colleagues (2021) examined whether participating in a 1-week summer camp could alter middle school students' perceptions of scientists. Students (78) participated in one of four 1-week summer nature camps that were run by scientists from historically underrepresented groups in science. The participants were instructed to draw a picture of a scientist at the beginning of each camp and then again at the end. The researchers found in the analysis that the number of male scientists drawn decreased significantly from presession to postsession. In addition, nature as the research setting increased significantly from presession to postsession. Thus, even small interventions can impact students' image of scientists.

Reading and Writing

Children's picture storybooks can be an effective and appealing springboard for content learning. Their engaging illustrations and short length have proven to be useful as a model for student writing (Stevenson & Beck, 2017) and encourage and facilitate connections with different content areas (Kane, 2020; Massey, 2015). Well-chosen picture storybooks can be socioculturally relevant and enabling (Tatum, 2006) by connecting with students' personal experiences, building background content knowledge, and serving to initiate literacy and STEM integration.

In addition, using multiple modes of expression (The New London Group, 1996) affords students opportunities to develop their expository writing skills while expressing their learning through a variety of representations that go beyond traditional, formal oral, and written assessments. Writing is essential to learn and to communicate understanding. Through writing, students concretize their thoughts and reflect on their learning and their interpretations of the information they have received from various, sometimes-conflicting sources. Using writing purposefully to learn can positively impact academic achievement and can "create a connection between school and life experiences" (Lee, 2017, p. 35). Purposeful writing can also serve as a scaffold for learning as is with expository-framed paragraphs (Olson & Gee, 1991).

Writing requires different skills and uses of language for each academic discipline (Shanahan & Shanahan, 2014). Although it can be challenging for teachers to avoid using formulaic approaches to writing across the disciplines (Applebee & Langer, 2015), academic writing does not have to be done using only traditional genres and formats. It can be done using more creative formats, such as storytelling using the Role, Audience, Format, Topic (R.A.F.T.) activity—where students are given the opportunity to choose a Role, write for an Audience, and choose the Format for a Topic given by the instructor (Santa et al., 2004). This type of thinking outside the box affords students the possibility to write in different creative genres while incorporating their new conceptual knowledge.

Methods

A mixed-methods approach was used to answer the research question guiding this study. A combination of qualitative and quantitative approaches to collect and analyze data were used to provide a better understanding of the research question and to support the findings (Creswell & Plano Clark, 2011). This combination of data collection was achieved through a group interview, individual journal responses, final written products, and pre- and post-survey as well as pre- and post-test data.

The purpose of our study was to examine the impact of using purposeful and creative expository writing, socioculturally responsive pedagogy, and multimodal meaning-making to teach a literacy-enriched STEM unit on the students' acquisition of scientific vocabulary and concepts. Also, this study sought to look at the effect of these pedagogical approaches on the students' perception of the program and their ability to participate in science.

Context of the Study

The high school dropout rate for children of migrant farmworkers is four times higher than any other group (Humans Rights Watch, 2010). Part of the reason is the difficulty of providing appropriate individual academic instruction for migrant students (Free et al., 2014). In an effort to provide migrant students with academic enrichment and to enhance their motivation, the Georgia Department of Education's Migrant Education Program has been sponsoring, in conjunction with Georgia Southern University, a summer program for students from migrant farmworker families. We were invited by the state Migrant Education Program to create, plan, implement, and instruct a Language Arts, Science, Math, and Literacy curriculum for the Migrant Middle School Summer Program. This was a week-long, residential summer program that ran on the university campus; the STEM instructional unit was one aspect of the overall program. We were motivated to participate in this effort by the critical need for middle school students to develop the necessary disciplinary literacy skills to facilitate the communication of their understandings across the content areas, especially STEM.

Participants

There were a total of 25 student participants in this study: 12 rising 6th grade, 7 rising 7th grade, and 6 rising 8th grade, ages 10–14 years old, all of whom were children of migrant farmworkers of Latina/Latino heritage, living in and attending public schools in Georgia. All students (named here with pseudonyms) were bilingual (Spanish/English), of Mexican descent, and came from households where Spanish was spoken. The students were selected to participate in the Migrant Middle School Summer Program at Georgia Southern University by the Georgia Department of Education's Migrant Education Program. The students were selected according to their priority for service status—students whose education had been interrupted and/or had been retained qualified under this status. Thus, we were not involved in participant selection. All 25 participants and their parents/guardians provided their assent and consent to participate in the research study.

Data Sources: Program Curriculum

The literacy-enriched STEM unit that we created for this opportunity was based on the principle that science and literacy complement and benefit each other by incorporating literacy activities into the science curriculum and science inquiry into literacy (Pearson et al., 2010). The unit also was grounded in a recognition of the importance of teaching the disciplinary literacy practices that combine talking science, multimodal literacy, and science education (Lemke, 2004). Thus, using socioculturally relevant literature (Ladson-Billings, 1995) and multimodal meaning-making (Kress, 2009), we designed and implemented a 1-week unit on Soil Ecosystems, where students received instruction in mathematics, science, writing, and agriculture. This focus on agriculture was justified, in part, by the fact that we knew the students would likely have spent many days in the fields working alongside their families (Stevenson & Beck, 2017).

We met with the students for an average of 4 hours every day for 6 days. The objectives of the instructional STEM in agriculture unit were to increase students' scientific knowledge and skills; strengthen their mathematical skills; provide access to technology; and improve their academic vocabulary, language, and writing skills. We addressed the state's Middle Grade standards for Mathematics, English Language Arts, Science, and Agricultural Education. Throughout the instructional unit, the students participated in science labs, readings, discussions, research using iPads, hands-on activities, and interactive lectures that provided the content knowledge and academic vocabulary necessary to fulfill a series of writing tasks, culminating in a creative academic story. The following is an overview of the different activities, divided by subject, that were included in the instructional routines that provided our study's data.

Literacy

There were several different literacy strategies included during the program. All literacy strategies and activities used in the program were aimed at enhancing the learning of science and mathematics concepts "individually and holistically" (Jackson & Mohr-Schroeder, 2018, p. 43) involved in the unit to advance the students' STEM literacy. For instance, two texts, one fiction and one nonfiction, were selected to be read aloud to the students. *Radio Man* (Dorros, 1997), the fiction text, was chosen as the springboard to create math problems and to support the writing activity. The second text, *A Handful of Dirt* (Bial, 2001), is an expository book about the importance of soil, which provides examples illustrated with photographs.

Students were assigned a partner for the week who matched (as closely as possible) their ages and grade levels. The student pairs worked collaboratively over the course of the week to write a science-content-based fictional story. The story's theme was "finding the perfect place to grow" and was written from the point of view of a seed, with each student pair choosing which vegetable or fruit seed they wanted. Their stories, although fictional, were to be, at the same time, academic and reflective of their content learning. On the first day, we started them toward this goal via a R.A.F.T. writing strategy (Santa et al., 2004). The writing process and a later storyboarding activity were used to scaffold the students toward their final product, a digital, Google Slides version of their story illustrated with images from the internet. We provided the students with iPads to research the appropriate soil conditions for their chosen seed and plant and thereby enrich their story with additional horticultural facts. At the end of each lesson, students were asked to write a reflection using a writing guide as a scaffold. Sometimes, the guide was in the form of open-ended questions and, other times, it was in the form of an expository-framed paragraph (Olson & Gee, 1991).

Science

An overview of ecosystems was provided to activate students' prior knowledge and to set the context for thinking of soil as an ecosystem. Students spent at least half of each day in the lab conducting science investigations. As recommended by Ritchie and Tobin (2001), we used the science laboratory as a place to accomplish the exploratory aspect of the scientific inquiry, instead of using it to do confirmatory exercises derived from lectures.

First, using microscopes and hand lenses, students examined local soil samples looking for examples of biotic and abiotic materials. Students were also encouraged to make observations about how the soil samples felt, looked, and smelled. On the 2nd day, students qualitatively and quantitatively analyzed the soil texture. Opportunities were provided to talk about soil's properties and to apply mathematics skills, such as measurement and finding percentages.

The next day, students performed labs that compared the permeability, porosity, infiltration, and infiltration rate of a variety of local soil samples. They again applied their math skills using their measurement and finding percentage rates. They also used tables to record their findings. On the final day, the students continued with the previous day's experiment and performed chemical tests to determine the pH, nitrogen, phosphorous, and potassium levels of the soil samples.

Mathematics

Math word problems were developed from the book, *Radio Man*. Students calculated mileage traveled, gas consumed, and trip costs for each leg of Diego's journey. Students also developed a word problem based on a trip they had taken with their families. Math was also integrated into the science experiments as students calculated means, percentages, and percent errors. Students used dimensional analysis to convert units and determine rate of reactions. Students were encouraged to work with their lab groups as they engaged in solving the math problems given, and students took advantage of this group support as they helped each other calculate answers and figure out how to answer the questions. Our plan was for students to create a math word problem to go with their digital story; however, due to time constraints, this activity was not accomplished.

Cuturally Responsive Approach

During the planning stage of this project, we set high expectations for the students, offering a comprehensive curriculum where the students' experiences and cultural frames of reference were validated (Gay, 2018). In the same way, the students' sociocultural and linguistic background were considered in the choice of instructional materials. For example, *Radio Man* (Dorros, 1997), a fictional story about a migrant child and his family who travels to several places around the United States to find work, was chosen with two purposes: to present students with a socioculturally relevant, enabling text (Tatum, 2006), and to use the story as foundation for math word problems and a writing activity.

Additionally, the students' bilingual (Spanish and English) linguistic resources were encouraged during instruction and while performing their hands-on activities in the classroom during writing and in the science laboratory. When the students were asked when they used both of their languages during the week, Joaquín responded, "When my peers [in the science lab] help with the answers in Spanish." This example corroborates the importance of students using their primary or home language as a scaffold to assist each other (Cook, 2001).

Data Collection

Our study qualitatively and quantitatively examined participant responses to the summer program and the students' learning outcomes (Creswell & Plano Clark, 2017). Data were collected during the instructional activities in which students participated. Prior to starting the intensive literacy-enriched STEM unit, the day students arrived for the week-long residential program and we met with them to establish a rapport, inform them about the upcoming week and the program's expectations, and to provide an overview of activities.

On the first day, we administered a presurvey regarding students' interest and perceptions about science. Also, we administered a pretest regarding the concepts and/or vocabulary words involved in the subsequent lessons that consisted of 14 words where students needed to write what they knew about each vocabulary word. This pretest provided us with a starting point for effectively increasing the academic vocabulary and language skills among the students. During the week, the students participated in a variety of activities related to STEM literacy. Instruction took place in two rooms within a campus classroom building. One of them was a regular classroom, and the other was a science laboratory used for teacher education.

The data included:

1. The students' assignments, journal responses, and writings to access their conceptual understanding and use of academic vocabulary;
2. Researchers' field notes to record observations of students' participation in the program;
3. An audio-recording (transcribed) of a final, whole group, semistructured interview (Spradley, 1979) to gather students' perceptions of the program and of science;
4. Pre- and post-surveys regarding students' interest in and perceptions of science;
5. Pre- and post-tests to measure individual students' academic vocabulary.

Data Analysis

Each qualitative source (students' writings, journal responses, and group interview) was analyzed, classified, and coded recursively using a naturalistic, interpretive approach (Denzin & Lincoln, 2018). To address the research question, we predetermined three major themes: student science learning, student use of vocabulary, and students' perceptions of the program and/or their ability to use science. Each of us independently conducted the first round coding on the student interviews and student survey questions. Next, we discussed and compared their coding, and when a disagreement arose in regard to item placement, the three major themes were revisited. This allowed crystallization of the qualitative findings (Tracy, 2019).

In relation to the quantitative data analyses, a paired sample *t*-test was performed in Microsoft Excel on pre- and post-test raw scores. This was to determine if there was significant difference in pre- and post-test scores to determine whether students' conceptual knowledge and vocabulary understanding increased. A two-sample *t*-test was performed in Microsoft Excel on the post-test raw scores by gender (male or female), and a single ANOVA was performed in Microsoft Excel on the post-test raw scores by grade (6th, 7th, or 8th). We choose to look at gender to establish if there were significant differences in scientific conceptual learning and vocabulary between genders, given that gender is often used as an indicator in STEM educational research; if no significant difference between gender existed, then the creative expository writing, socioculturally responsive pedagogy, and multimodal meaning we used to teach the literacy-enriched STEM agricultural unit were culturally relevant to both genders. The quantitative results were also used to enrich the student learning themes coded by each of us individually. The pre- and post-survey questions were also coded and placed into the themes of student interest or students' perception of the program.

On the basis of the data analysis, the findings were classified into three major themes that answered the research question: How does using purposeful and creative expository writing, socioculturally responsive pedagogy, and multimodal meaning-making to teach a literacy-enriched STEM agricultural unit influence students' conceptual learning, vocabulary acquisition, and perceptions of their ability to participate in science? The themes discussed in the following section are: (1) vocabulary and conceptual learning; (2) a creative path toward expository writing; and (3) students' perceptions of the program and their own ability to participate in science.

Findings

Vocabulary and Conceptual Learning

At the beginning and during the last day of the program, the students were administered a pretest and post-test consisting of 14 vocabulary words. There was a positive significant improvement among the students on the pre-test (M = 3.96, SD = 1.62) and post-test raw scores (M = 7.68, SD = 3.37); $t(45) = -4.92$, $p = .000$ with regard to their vocabulary and conceptual understanding. There was also a large effect size found (d = 1.44, 95% CI (0.77–2.05) As a group, there was an average increase of 27.6% in these areas (Table 1). There was not a statistically significant difference across gender (M = 7.68, SD = 3.37); $t(16) = -0.63$, $p = .538$ for post-test raw scores, and the effect size found was small to medium (d = 0.45, 95% CI (-0.48–1.33). Grade levels were also found not to be significant $F(2,19) = 0.006$, $p = .994$, and the effect size was quite small ($\eta 2$ = 0.0006). As Alicia explained during the final interview, she felt smart during the STEM Literacy unit because "we used lots of science words" in discussions and writing. Carlos remarked, "If we didn't know the vocabulary words, we wouldn't have been able to find it [the right place for our seed]." He further clarified that students had to think like a scientist because "we had to use the vocabulary words to write our story."

Table 1. *Comparison of Vocabulary Pre- and Post-Test*

Pseudonym	Raw Prescore[a]	Raw Postscore[a]	Points Gained	Percentage Gained
1	3	1	-2	-14
2	4	8	4	29
3	3	9	6	43
4	3	6	3	21
5	3	10	7	50
6	3	4	1	7
7	8	11	3	21
8	2	3	1	7
9	3	6	3	21
10	7	9	2	14
11	3	4	1	7
12	4	12	8	57
13	2	8	6	43
14	4	9	5	36
15	6	8	2	14
16	6	4	-2	-14
17	4	14	10	71
18	2	7	5	36
19	2	4	2	14
20	5	11	6	43
21	3	9	6	43
22	4	12	8	57

Note: [a]Score was out of 14 possible points.

In analyzing the participants' final product (short story about a seed), 11 of the original 14 vocabulary words (Table 2) appeared throughout the students' stories in either word or definition form, which totaled 67 references. All 12 groups identified at least one of the three types of soil that had been studied, and soil type accounted for 17.9% of the 67 vocabulary instances. Also, nine of the groups discussed the particle size(s) of the soil(s) they used in their stories, which accounted for 13.6% of references. Six of the nine groups that discussed particle size also discussed how this contributed to the soil's permeability and porosity. The least mentioned vocabulary word was "abiotic" with only three groups referencing it. One group defined abiotic factors, while the other two groups gave examples of abiotic factors (e.g., temperature, rainfall). These findings corroborate the importance of integrating purposeful writing into the STEM curriculum to scaffold and facilitate the learning process (Fisher & Frey, 2016).

Table 2. *Vocabulary and Conceptual Learning in Short Stories*

Vocabulary/Concept	Percentage of Occurrence[a]	Percentage Used by Groups[b]
Abiotic	4	1
Biotic	6	8
Infiltration Rate	6	9
Nitrogen (N)	9	6
Particle size	13	10
Permeability	9	4
pH	9	11
Phosphorus (P)	9	3
Porosity	9	6
Potassium (K)	8	9
Type of Soil	18	4

Note: [a] There were a total of 67 occurrences. [b] There were 12 groups.

Finding a Creative Path Toward Expository Writing

At the end of this literacy-enriched STEM unit, the students were expected to accomplish learning objectives about soil ecosystems in science and agriculture. They needed to identify the types of soil and its nutrients and use this knowledge to choose the best soil conditions for a specific fruit or vegetable. During this program, students were given myriad opportunities to learn and use the language and scientific vocabulary needed to accomplish the learning objectives. These opportunities involved listening to mini-lessons during English language arts and science, doing hands-on activities in the science laboratory, researching using iPads, and using various writing activities to reflect on their learning, such as reflections using guiding questions and framed paragraphs (Olson & Gee, 1991) after a science lab activity.

Throughout the week, the students were also asked to take notes and write reflections, using guiding questions or a framed paragraph (Olson & Gee, 1991) about their learning during the science laboratory. These writing activities served as a scaffold for their main writing project, the creation of a digital fictional academic story using Google Slides, told from the perspective of a seed. At the same time, these activities allowed students to advance their STEM literacy since students were provided with opportunities to use the vocabulary words and concepts, apply them, and then reflect upon their learning (Zollman, 2012).

In this story, students were asked to use the scientific vocabulary and knowledge acquired during the science laboratory and through their research using the iPads. The students embraced the opportunity to write a fictional story stating, "We had to use our vocabulary words in our story." Fernando was more specific, adding "[writing a fictional story] made it a little easier to learn the [science] vocabulary words." Jaime added, "We had to know about science facts because when we wrote our story about a seed, we had to write facts about like other soil, and you have to know vocabulary words." Rosy remarked, "We had to know a lot of science facts to help us find out what the vocabulary meant." This demonstrates the importance of providing students with opportunities to work collaboratively and utilizing strategies to scaffold their learning of scientific concepts to expand their STEM literacy. These strategies included providing opportunities to discuss the concepts, participating in hands-on activities during science laboratories, using technology to research and expand their concept knowledge, writing reflections using guiding questions and framed paragraphs (Vygotsky & Cole, 1978; Zollman, 2012), as well as integrating writing with a purpose to enhance the students' learning experience (Fisher & Frey, 2016).

Using Scientific Concepts in Fictional Writing

Through their stories, the students made it evident that they learned how to correctly use vocabulary words and concept knowledge involved in the literacy-enriched STEM instructional unit. These stories also included information learned through their experiments and research sessions. For example, Joaquín asserted, "We had to know about science facts because when we wrote our story about a seed we researched, and we had to write facts about… like other soils and the vocabulary words." Juan remarked, "We had to know a lot of science facts to help us find out what the vocabulary meant." Below are three excerpts exemplifying the students' use of information learned through their lectures, science experiments, and research sessions in their stories:

1. "The top soil is organic. There is lots of sun and it rains once in a while. The pH on this farm is about 6.0 to 6.2," wrote Katia and Josefina.

2. "The pH we like is 4.5 to 7.0, neutral to acidic soil that isn't salty," stated Anna and Rosie.

3. "They then thought about a medium light texture of soil with some nematodes," observed Alejandro and Jenny.

As previously stated, a quantitative analysis of the academic vocabulary and related academic language was performed on the students' stories. Academic language involves more complex language and grammatical structures used to explain a concept in textbooks and classroom setting. During the data analysis, a single use of academic vocabulary and/or academic language was counted each time either a content vocabulary word and/or a definition and/or explanation was used correctly within context. It was found that 67 uses of academic language occurred among the 12 groups (Table 2). The group with the highest academic language usage accurately incorporated 10 of the 11 (91.9%) vocabulary words or explanations of those words in their writing. Below there are excerpts from two of the groups' stories demonstrating their uses of academic language (vocabulary and contextual clues are bolded below).

I said, "Let's go to Blue Ridge." 'We will have to find a **place that has well-drained sandy loam soil** [noted in lab journal; type of soil and porosity and permeability considered]," I suggested… 'Ok, now remember what type of soil and also **we have to avoid areas where water stands after it rains'** [from interactive lecture; porosity and permeability considered]," I exclaimed. "So that means that **the particles of sand have to be big because otherwise the water would stay and not go down when it rained** [porosity and permeability explained further] (Carmen and Carlos story).

"We started off with a place that **was orange and red** [color noted in lab journal; type of soil]. It had watermelon seeds like me sinking so I guessed it was good, but Furry Ball [rabbit traveling companion introduced earlier in the story] **said it was not good** [type of soil needed]. I tried it anyways. Furry Ball planted me. It was **squishy and soft** [qualitative description from lab journal], but then it rained and it was **becoming hard**. I got stuck! Furry Ball said that it got hard because **clay has small particles and water couldn't pass through** [porosity and permeability considered; type of soil identified] (Beatriz and Cristóbal story)."

As can be perceived, these examples show the students' vocabulary and concept knowledge regarding the types of soil. The two participants in the last group were not the students who scored the highest on the post-test. One participant's post-test score was low (29%), only scoring 7% higher than his pretest. The other participant's score was average (71%) but scored 50% higher than her pretest. This example emphasizes how providing opportunities for students to engage in fictional writing can demonstrate their use and understanding of scientific vocabulary and concepts in ways that typical assessments (i.e., vocabulary tests or multiple-choice tests) might miss. Thus, multimodal learning and multiple types of assessments can highlight students' strengths (The New London Group, 1996).

Students' Perceptions of the Program and Their Ability to Participate in Science

According to the presurvey, 92% of students thought science was interesting; however, only 67% thought they could be good at science, and only 38% thought they would make a good scientist (Table 3). After the week-long STEM-intensive unit, according to the postsurvey, 86% of students indicated that their interest in science had increased, which was surprising given that most of the students indicated a high interest in science on the presurvey. However, only 33% indicated the program increased their interest in a science-related career (Table 4).

Table 3. *Presurvey Responses Coded for Interest*

Presurvey Question	Average[a]	Percentage rated 4 or 5[b]
I think science is interesting.	4.54	92
Science is important to me.	4.13	75
I am good at science.	3.92	67
I think I could be a good scientist.	3.09	38

Note: [a]The Likert scale items ranged from 1 (not at all) to 5 (very much agree). [b] n = 24.

Table 4. *Postsurvey Responses Coded for Interest*

Postsurvey Questions: To what extent did participating in the STEM program increase your…	Average[a]	Percentage rated 4 or 5[b]
Interest in science	4.24	86
Interest in nature	4.25	86
Interest in participating in other science experiences	4.57	90
Interest in taking care of the environment	4.10	71
Desire to find a science-related job/career	2.90	33
Interest in helping your friends get good grades in science next year	3.86	67

Note: [a]The Likert scale items ranged from 1 (not at all) to 5 (to a great degree). [b] n = 21. Three participants had to go home early, so they were unable to take the postsurvey.

Their level of ability to participate was also confirmed during the post-interview when students were asked to think of three words that would describe them during the project. The students' responses were generally positive, such as "fun," "smart," "interested," and "fascinated." When asked to name one thing about the project that made them feel good about themselves, Marisela said, "The experiments because we got to do the science." Other students agreed with her. Juan elaborated, saying, "It was interesting because we don't get to the hands-on parts in school." There were no significant differences in the pre- and post-survey results across gender or grade levels.

In their daily journals, some students added similar comments that demonstrated their interest and engagement. For example, Josie was really excited about the living creatures found in the soil samples, stating that she found "other types of worms and insects," adding, "it was fun, and we got to do experiments!" Rosie stated, "today we learned that soil has porosity… it was fun because we could play with dirt." Saúl, one of the students who preferred to write his responses in Spanish, said, "hoy en esta clase hicimos experimentos e investigamos… miramos que significan unas palabras… juntando todo lo que sabía y lo que aprendí para tener mejor información. (today in this class we did experiments and investigated… looked at the meaning of some words… putting together all I knew and what I learned to have better information)." Victoria was more descriptive, asserting, "What I learned was a lot about clay, silt, bedrock, and we touched how it felt, how clay was hard and about three types of soil, and lots of fun things!" Elena confirmed, "I learned about soil! It was so much fun!" These results highlight the importance of using culturally responsive pedagogical approaches by incorporating culturally relevant instructional materials into the curriculum that will be challenging enough and appealing to students (Gay, 2018; Ladson-Billings,1995) along with providing students with opportunities to use technology to enhance their researching skills and participate in collaborative activities.

The post-survey showed that 57% of the students believed they could be good at science or would make a good scientist, which was higher than the percentage on the pre-survey. In addition, 62% indicated that, in the literacy-enriched STEM program, they were perceived as smart in science, and 90% felt they were able to be successful in the class (Table 5).

Table 5. *Postsurvey Responses Coded for Perceptions*

Postsurvey Questions: To what extent did participating in the STEM program…	Average[a]	Percentage rated 4 or 5[b]
Increase your confidence in doing science	4.10	86
Increase your ability to use scientific tools	4.33	81
Increase your successfulness	4.43	90
Increase your braveness	4.10	67
Increase your awareness of your strengths and weaknesses	4.10	71
Increase your belief that you have a good future ahead of you	4.45	81
Make you feel that you could be good at science or related field	3.57	57
Make you feel confident to try new things	4.55	86
Make you feel curious about nature	4.38	86
Make you feel that you could teach others about soil and plants	3.52	57

Make you feel that you were seen as smart in science	3.71	62
Make you feel like a science person	3.40	52
Increase your ability to think like a scientist	3.71	62
Increase your ability to talk like a scientist	3.14	43
Increase your ability to understand threats plants and crops face	4.05	76
Increase your ability to understand what people do in science-related jobs or careers	3.90	71
Increase your ability to connect to nature	4.10	76
Increase your ability to connect to my local community	3.86	62

Note: [a]The Likert scale items ranged from 1 (not at all) to 5 (to a great degree). [b]*n* = 21. Three participants had to go home early, so they were unable to take the postsurvey.

Perceptions of the Materials and Activities Used in the Program

Regarding the effect of using socioculturally relevant texts, the students responded positively to *Radio Man*. As Elena shared during the students' final interview, "When we read the *Radio Man,* it kind of like matches us because, you know, we migrate with our parents." She went on saying that she "would like to have the same books read again." Elena's statements evidenced the importance of using texts where characters look like them and live experiences to which they can relate to make learning more meaningful. In relation to the fictional stories, Kris stated that he liked writing their fictional stories because "you have a friend and you got to travel." Though Kris struggled with engagement throughout the class, his interview revealed the cultural significance the writing had for him. Saúl, the student who was still developing his English language, also liked writing the story. He declared, "Fue divertida… crear los personajes [It was fun… to create the characters," when we asked why he liked writing the story.

Alicia explained during the final interview question ("Tell us about a time you felt smart during this program") that she felt smart during the literacy-enriched STEM unit because "we used lots of science words" in discussions and writing. During this program, the students participated in science lab experiments and used technology to enhance their learning of the concepts discussed in the laboratory and the lessons. Several students agreed that they liked the experiments and using technology, stating, "It was fun because we don't really get to use tablets or electronics [in school]." Regarding the experiments, Carlos elaborated, "because when we had to do the experiments we had to think like scientists because we had to measure it out at the exact measure. And then, with our writing, we had to think like a scientist because we had to use the vocabulary words to write our story." Thus, overall, this program provided an environment where students felt validated, challenged, and accomplished.

Summing Up

Our study sought to answer the question: *How does using purposeful and creative expository writing, socioculturally responsive pedagogy, and multimodal meaning-making to teach a literacy-enriched STEM unit influence students' conceptual learning, vocabulary acquisition, and perceptions of their ability to participate in science?* As evidenced in the findings, using purposeful and creative expository writing can help students express their conceptual understanding in ways that standard assessments cannot. In providing multimodal meaning-making opportunities, we were able to increase the students' vocabulary acquisition and capture their conceptual learning through different forms of expression. For example, the students were able to apply the vocabulary words and/or concepts in the fictional stories that they created. In addition, they were offered opportunities to participate in science labs where they investigated and created graphs representing their findings, worked in pairs, used technology to research and investigate the nutrients needed for their chosen vegetable or fruit, and applied their acquired knowledge regarding nutrients and types of soil. These opportunities helped them gain STEM literacy skills related to the cognitive and affective learning domains (Zollman, 2012). Students responded positively to the socioculturally responsive pedagogy as the entire literacy-enriched STEM unit centered on their life experiences as migrant agricultural families. This also enabled us to capitalize on students' funds of knowledge (Gonzalez et al., 2005) as we focused on soil and agricultural science. These pedagogical strategies positioned students as active learners and doers of science who had prior experiences that were valued rather than as passive learners with little to no contribution to offer. Students also recognized this difference and spoke to how they felt valued and capable of learning and doing science.

Our study advances the understanding of the value of socioculturally responsive pedagogical approaches (Gay, 2018), integrating culturally relevant literature, including technology, and using creative expository writing assignments to promote interest and understanding in STEM among socioculturally and linguistically diverse students. We also underscored the importance of partnerships between federally funded programs, such as the Migrant Education Program, and state universities to provide students with opportunities to further their learning while experiencing life on a college campus. The results clearly demonstrated that students can be successful at displaying scientific conceptual understanding and vocabulary acquisition if their experiences, cultures, and languages are placed at the center of the curriculum. Similarly, the results revealed that their interest in STEM careers can be increased if they are provided with opportunities where they can explore and apply STEM concepts in different ways, such as participating in science labs, researching using technology, reading culturally relevant and content-relevant stories, and especially, writing in different genres.

However, the results also confirmed national trends that indicate students from underrepresented populations do not easily envision STEM careers as an option for themselves. In the pre-survey, only 38% of the participants indicated their interest in pursuing a STEM career. Somewhat disappointingly, only 33% indicated in the post-survey that their interest had increased because of their participation in this program. This result suggested that longer, recurring experiences might be needed to substantially increase student interest in STEM careers. Connecting STEM instruction with both background knowledge and possible careers via out-of-school efforts like this program can increase minoritized students' interest in pursuing STEM careers, but sustained efforts are likely needed across the K–12 years.

Final Thoughts

Our study described a summer literacy-enriched STEM instructional project that sought to build scientific vocabulary and concept knowledge and to advance the students STEM literacy skills in a manner that is transferrable to a wide range of both school classroom and informal learning environments for Latina/Latino rising middle grade students from migrant farmworking families. Moreover, as noted earlier, most farmworkers in the southeastern states are Latina/Latino and, therefore, a population underrepresented among STEM and medical professions. Initiatives like this, where students are afforded the opportunity to experience life on a college campus have the potential to help mitigate the problems caused by such underrepresentation at both the local and national levels (Holley, 2013).

Our program provides models for such efforts because the students were constantly asked to apply their agricultural knowledge to research, lab findings, self-scaffolding, and assessments. The students developed an awareness of the interrelation of science, math, technology, and literacy with their background experiences, expanded their interest in and understanding of science, and increased their ability to write effectively about STEM topics.

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