# OPPORTUNITIES TO LEARN SCIENCE: MULTILINGUAL LEARNERS IN A FIRST GRADE MAINSTREAM CLASSROOM

By

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## ABSTRACT

Opportunity for an equal education is one of the cornerstones of the United States educational system, and it means access for all to all that is available. Today, the vast majority of Latino multilingual learners are not on a trajectory to participate in 21st century science, technology, engineering, and math (STEM) careers. The Latino share of the workforce has increased significantly—from three percent in 1970 to 15 percent in 2011—yet Latinos represented only seven percent of the STEM workforce in 2011, a very small portion, compared to White participation (71%) in the STEM workforce (U. S. Census Bureau, 2013). For that reason, it is critical that Latinos gain equal access to the requisite knowledge and skills to participate in the fastest growing job sector, STEM.

In a case study, the experiences of Latino multilingual students' opportunities to learn (OTL) science in first-grade mainstream elementary classrooms in central New Jersey were explored. In a sociocultural perspective of opportunities to learn (OTL), Gee (2008) made the point of the right of each student to have OTL, which includes not only access to content, but also participation, experience, resources, tools, a community of practice, and language. The study examined the students' access to the resources, materials, experience, and language of the science curriculum.

Over the last few years, the United States has opted to update 20-year-old science standards in preparation for 21st century STEM careers, and to make science learning accessible for all learners. The Next Generation Science Standards (NGSS) require students to engage in inquiry based science the way engineers and scientists do-- asking questions, creating models, investigating, hypothesizing, analyzing outcomes, and communicating findings. Utilizing the NGSS Framework, the study examined the opportunities of students to experience inquiry based

science. The curriculum quality, teaching quality, and individual student characteristics either supported or posed barriers to science instruction for these learners.  In the end, multilingual learners were disenfranchised when teachers lacked training, appropriate curriculum and materials, and the administration lacked an enduring commitment to teacher professional development for this large segment of the student population.

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## Chapter 1: Introduction to the Study

**Teacher1:** Good. A safe place. There's other ways, but that's the easiest way to think about it. A safe place is a shelter. We actually have a drill that's called a shelter in place because it's being safe in our classroom. So, it's the same idea. So, so we have a shelter here. (As teacher points to text). And it says, "What does this wolf pup use for shelter?" Because again, a wolf pup is not going to go and build himself a house. Right? What might a wolf pup use? Arav, what's he using here?
**Arav:** A wood.
**Teacher1:** He's using an old tree trunk, that has been kind of hollowed out here, that he can use for a safe place for shelter. Now let's say, maybe a tree wasn't available. What other shelter do you think a wolf pup might be able to use? Amber what do you think?
**Amber:** A log.
**Teacher1:** That's the same thing as what's there. Something different, Jay?
**Student Jay:** Maybe a cave.

The vignette above is from a first-grade mainstream classroom during science instruction in central New Jersey. During this segment of class instruction, students are previewing a science text to acquire knowledge about animal necessities, specifically shelter. They are viewing an image of a wolf pup as it peeks out of the edge of a hollowed-out tree trunk. The teacher's exchange with two of the three students addressed during the segment reveals some confusion about the specific shelter. It seems the students' word choices do not adequately describe a hollowed-out tree trunk. Those two students are multilingual learners, and their knowledge of English vocabulary may not include the words "hollowed-out" or "tree trunk." In essence, while the students demonstrated some English language abilities, there appeared to be some confusion over their vocabulary choices. There was no further clarification, and the confusion persisted.

Every day in schools across the United States, multilingual learners experience confusion and misunderstand instructional content in classrooms where the language of instruction is English. Multilingual learners are those students who are English language learners (ELLs), or bilingual students, and those who "…have varying degrees of competency in several languages, combination of languages, and/or varieties of languages, and [*sic*] to draw from their multilingual repertoires in the course of their daily lives" (Bailey & Orellana, 2015, p. 54). Furthermore, learning content involves more than just the language we use for social purposes; it also requires technical or domain-specific vocabulary or academic English. This can make learning content difficult for some students, and potentially renders it incomprehensible, inaccessible, and not meaningful for multilingual learners. For learners to be engaged and understand content, instruction must be comprehensible.

To teach multilingual learners, educators must have content knowledge as well as the ability to instruct in a linguistically and culturally responsive manner. While the literature on second language learning is considerable, to educate multilingual learners, researchers agree teachers have to be linguistically responsive (Bunch, 2013; Fillmore & Snow, 2000; Lucas, Villegas, & Freedson-Gonzalez, 2008). In other words, they must deliberately include second language learning principles to: 1) make sure instruction is comprehensible (Krashen, 1981); 2) guide students to develop both social and academic language proficiency (Cummins, 1981); 3) ensure there are opportunities for communicative exchanges and participation (Fillmore & Snow, 2000; Vygotsky, 1978); and 4) reduce "the affective filter" (Krashen, 1981, p. 56) and create "a safe, welcoming classroom environment with minimal anxiety..." (Lucas, Villegas, & Freedson-Gonzalez, 2008, p. 364). This final principle coincides with making connections to the child's background knowledge and experiences in a culturally responsive manner (Ladson-Billings, 1995; Moll, Amanti, Neff, & Gonzalez, 1992; Villegas & Lucas, 2002). When teachers incorporate their students' cultural lives into their teaching, affirm their diversity, and demonstrate these perspectives at their schools, they are exercising culturally responsive teaching (Villegas & Lucas, 2002). Furthermore, linguistically and culturally responsive educators make modifications to instructional content and methods, or scaffold instruction (Coady, Harper, & de Jong, 2016; Walqui, Scaffolding instruction for English language learners: A conceptual framework, 2006). In short, linguistically and culturally responsive educators scaffold content instruction in their mainstream classrooms for multilingual learners by applying second language learning principles.

Teachers who scaffold language and learning begin to create opportunities to learn (OTL) for their students. In a sociocultural perspective of OTL, (Gee, 2008) made the point of the right of each student to opportunities to learn, which includes not only access to content, but also participation, experience, resources, tools, a community of practice, and language. In particular, for students to learn new content, their pre-existing, or prior knowledge must be activated in order for them to engage with the content and participate in the class. Students come to school with their own ideas, beliefs, and conceptions of the world, and how they understand the world depends on their pre-existing knowledge (Bransford, Brown, & Cocking, 2000). Teachers who scaffold learning by connecting what the student knows to what will be taught create OTL. "If students' initial ideas and beliefs are ignored, the understanding that they develop can be very different from what the teacher intends" (Bransford, Brown, & Cocking, 2000, p. 10). When teachers activate prior knowledge and provide background information, they initiate student participation, creating a learning experience that is accessible and comprehensible to all learners. This is especially true for multilingual learners who may still face the conundrum of acquiring a new language and academic content simultaneously in a mainstream classroom (Abedi & Herman, 2010; Estrada, 2014; Lee, 2005). Thus, scaffolding their instruction is essential. Otherwise, when these students do not comprehend the content, then "…curricula create [sic] negative OTL by guaranteeing that a significant number of students *won't* learn; that is, they will fail (Varenne and McDermott 1998)" (Greeno & Gresalfi, 2008). In essence, when teachers scaffold instruction for multilingual learners, the process of creating a comprehensible and accessible learning environment commences.

Opportunity for an equal education is one of the cornerstones of the United States educational system, and it means access for all to all that is available. One of the ways we measure equality in education is through assessment of learning. The most recent average reading scores, from the 2015 National Assessment of Educational Progress (NAEP), reveal a persistent gap of almost 40 points for fourth grade multilingual learners, and a gap of more than 40 points for eighth grade multilingual learners, compared to White students. This gap has not changed appreciably since 2002 (National Center for Education Statistics, 2015). NAEP does not subdivide multilingual learners by race and ethnicity. Hence, using their categories, currently an achievement gap exists between White students and multilingual learners, which is a "significant difference in assessment scores between two groups" (National Center for Education Statistics, 2015). Amongst these multilingual learners, Latinos constitute 76.6% of the population (National Center for Educational Statistics, 2016). Thus, it is not surprising to see that Latino students make up the majority of the lowest performing students, and it appears that they do not currently have access to all that is available in the American educational system.

**Multilingual Learners' Access to Science**

Given this achievement gap, the vast majority of Latino multilingual learners are not currently on a trajectory to participate in science, technology, engineering, and math (STEM) careers. "Employment in occupations related to STEM…is projected to grow to more than 9 million between 2012 and 2022" (United States Department of Labor, 2014, p. 3). Science instruction requires time and materials for students to actively engage in science inquiry.

"Opportunities to learn do not exist for learners who cannot take advantage of them" (Haertel, Moss, Pullin, & Gee, 2008, p. 6). Since 2002, the time allocated to science has been curtailed (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012), especially by states that do not include science in accountability measures. At the present time, there are 38 states that do not include science in their accountability measures, and New Jersey is among them. Most states allocate only two to fewer than four hours per week to science education, and this has been consistent between 2005 and 2009 (Judson, 2013).

The Latino share of the workforce has increased significantly—from three percent in 1970 to 15 percent in 2011—yet Latinos represented only seven percent of the STEM workforce in 2011 (U.S. Census Bureau, 2013), a very small portion, compared to White participation (71%) in the STEM workforce (U.S. Census Bureau, 2013). In fact, despite having increased educational levels over the past decade and being the fastest growing segment of the U.S. population, Latino youth "…do not have the skills required by the information/technology economy" (Anyon, 2005, p. 41). For that reason, it is critical that Latinos gain equal access to the requisite knowledge and skills to participate in the fastest growing job sector, STEM.

Over the last few years, the United States has opted to update 20-year-old science standards in preparation for 21st century STEM careers, and to make science learning accessible for all learners. "Science instruction in the early years can provide the necessary opportunities for young children to develop basic understandings of natural phenomena and fundamental process skills, such as observing, inferring, and exploring (Saçkes, Trundle, Bell, & O'Connell, 2011, p. 217). The new standards require students to engage in science by actually "doing" science the way engineers and scientists do—asking questions, investigating, hypothesizing, creating models, experimenting, analyzing outcomes, and communicating findings. Currently, schools across the nation are in the process of adopting the Next Generation Science Standards (NGSS) released in April of 2013; in New Jersey the deadline for adoption was September of 2017 (Department of Education, 2014; NGSS Lead States, 2013). These standards will require students to act like scientists by applying science and engineering practices, and they include concepts from multiple disciplines to integrate science knowledge across the curriculum (Lee, Miller, & Januszyk, 2014).

Since the inception of the NGSS, the imperatives of inclusivity and accessibility have coexisted to make science learning available to diverse students. Thus, the standards by design require educators to modify instruction to accommodate students who have previously been underserved in science learning. NGSS is “for all students, the emphasis should be on making meaning, on hearing the contributions of others, and on communicating their own ideas in a common effort to build understanding of the phenomenon or to design solutions of the system being investigated and discussed” (Lee, Quinn, & Valdes, 2013, p. 225). In other words, all students will need to have the necessary resources, materials, and language to experience the new ways of doing science, because the Next Generation Science Standards require discourse as students collaborate while “making meaning,” communicating ideas, and executing those ideas in classrooms across the USA. Hence, with the advent of the NGSS, we would expect an opportunity for multilingual learners in New Jersey to acquire the necessary knowledge and skills for 21$^{st}$ century STEM careers.

**Problem of Practice and Research Questions**

The context of this study will be two elementary schools in a regional school district comprised of urban and suburban neighborhoods in a central New Jersey community. Approximately 29% percent of the students in the district receive free lunch. In the 2015-2016 academic year, the enrollment of Latino students in the Oak Street School (pseudonym) was approximately 47%. Meanwhile, at the Herald School (pseudonym), the enrollment of Latino students was 32%. In both schools the remaining enrollment consisted of Asian, Black, and White students. Furthermore, in the 2015-2016 school year, White students were a minority at 31% at the Oak Street School and a majority at the Herald School at 40% compared to all the other groups combined (New Jersey Department of Education, 2016). The majority of the staff at both schools is White at 71% and 90% respectively.

Currently, Latino students at the study sites who require English language development (ELD) support attend a transitional bilingual education (TBE) program and are designated English language learners (ELLs). The focus of the program is English proficiency, not bilingualism, with a goal to transition into a mainstream classroom as soon as possible. Given the fact that the focus is on English development in a TBE program, it is not unusual to have students in a TBE program for kindergarten, who are reclassified English proficient (RFEP) for first grade and placed into a mainstream classroom. The RFEP designation does not equate to on-grade-level proficiency, but rather English language proficiency. Thus, for bilingual kindergarten children who pass an English language proficiency (ELP) exam in the spring, the following apply:

1) They can enter a first-grade mainstream class the following fall.

2) They are deemed sufficiently proficient in English to acquire academic content.

3) They do not receive any additional ELD support.

These students are my study's population, the just-exited Kindergarteners. As well as, those students whose parents declined bilingual kindergarten services. These parent declination students never received ELD support in Kindergarten. The focus of my study is Latino multilingual learners in a mainstream classroom during science instruction. In the 2017-2018 academic year, the study site will begin introducing NGSS in kindergarten through fifth grade. The first-grade RFEP multilingual learners will be in mainstream classrooms without ELD support. It is worth noting that the mainstream teachers in the schools receive no professional development or specific support to work with these multilingual learners. The first-grade teachers in my study will rely on experience or pre-service training to work with the multilingual learners in their classrooms. However, as stated earlier, making connections to students and their requisite prior knowledge begins the process of creating access to the opportunities for learning (Bransford, Brown, & Cocking, 2000). Teachers unfamiliar with the best practices with multilingual learners may not utilize appropriate scaffolding to tap into these students' prior knowledge or schema to create meaning in learning new science content (Walqui, Scaffolding instruction for English language learners: A conceptual framework, 2006). Therefore, examining how the multilingual learners access the resources, tools, learning, and language in first-grade science could provide valuable information to administrators and educators on how best to support these students in the future.

Until now, there has been no research done on Latino multilingual learners' opportunities to learn science in the early grades. Thus, this case study will explore the OTL for Latino multilingual students to learn science in first-grade mainstream elementary classrooms in central New Jersey. In my research, I will define OTL as access to the resources, materials, experience, and language of the science curriculum. The research questions I am interested in pursuing are:

1. Are Latino first-grade multilingual learners in mainstream classrooms able to gain access to the resources, tools, learning, and language of the science curriculum? If so, how?

2. What barriers and supports for accessing the science curriculum exist for Latino multilingual learners?
3. Do the first-grade mainstream classroom teachers scaffold science content to make it accessible to Latino multilingual learners? If so, how?

I hope my research will extend and support current research findings on multilingual learners' opportunities to learn, and perhaps provide evidence to policymakers of the need to evaluate the support systems in place for multilingual learners, in particular Latino multilingual learners, during their trajectory toward college or a STEM career in the 21st century.

# Chapter 2: Literature Review

This literature review will focus on current studies on opportunities to learn (OTL), and then transition into the recommendations for maximizing OTL, that is, the need for best practices in teaching to address the missed opportunities of multilingual learners in schools across the U.S. The review begins with a brief history of the heightened interest in OTL in the 21$^{st}$ century. Next, qualitative and quantitative studies of OTL are presented, followed by current recommendations for researching OTL. Because STEM education has become critically important for college and career readiness, the review will then switch its focus to the various approaches to teaching science to multilingual learners. The research on best practices commences with science content-based literacy instruction and then scientific inquiry-based instruction. Subsequent sections hone in on other approaches, namely, enhanced science curriculum, web-based instruction, and multilingual educational models. The literature review concludes with studies focused exclusively on CRT, culturally responsive teaching.

## No Child Left Behind and Opportunities to Learn

The advent of the No Child Left Behind Act (NCLB) of 2001increased efforts nationwide to address the issues of inequality and lack of accountability in U.S. education; it focused on closing achievement gaps and reporting on student outcomes (Ravitch, 2010). The enactment of NCLB required states to be accountable for ensuring that growth objectives were met in mathematics and reading by all students. The accountability process tied public school funding to student outcomes, creating a high-stakes testing environment. Hence, all schools needed to demonstrate and report progress for all students, across all strata, including multilingual learners. The focus on accountability resulted in the development of state standards, curriculum tied to standards, and extensive test preparation efforts as schools worked to maintain funding levels.

With the NCLB mandates, came the concern regarding how the curriculum content would be adequately covered to meet the needs of all students, across all strata to ensure accurate accountability results. Prior to NCLB, researchers had focused on the opportunities that schools create for learning as part of a system with: 1) inputs – fiscal and other resources, teacher quality, student background, and parent/community norms; 2) processes – related to organizational and instructional characteristics; and 3) outputs – achievement, participation, and attitudes/aspirations (Porter, 1991). While NCLB focused on outputs, researchers' attention was drawn to the internal processes of schooling, where their interest in best practices and OTL led them to question whether students were being given the opportunity to learn the content for which they were being held accountable (Boscardin, et al., 2005; Herman, Klein, & Abedi, 2005). Hence, the instructional process and curriculum became the focus, and not the various input factors.

The early efforts at exploring OTL examined four domains in the classroom: content coverage, content exposure, content emphasis, and teaching quality (Stevens, 1993 ). Thus, a teacher of high quality would present content, thereby providing coverage; spend time on tasks covering the content, thereby providing content exposure; and then instruct students on specific concepts and skills in the content area, thereby providing content emphasis. In essence, NCLB created increased scrutiny among researchers on the activities of the classroom to create opportunities for all learners.

The reality for multilingual learners in the era of high-stakes testing was not access to the full curriculum. Instead, what occurred for multilingual learners with NCLB was a narrowing of the curriculum (Darling-Hammond, 2010 ; Ravitch, 2010). Frequently, as the proximity of the annual achievement test drew nearer, test preparation became the focus; thus, instead of accessing the full curriculum, students were limited to mathematics and ELA in elementary classrooms (Ravitch, 2010). Often, elementary school multilingual learners experienced "skill and drill" activities devoid of breadth or depth of knowledge in preparation for high-stakes tests (Olson, 2007). Additionally, researchers found that when multilingual learners were not involved in test preparation, their curriculum focused on English acquisition more than on the content areas of science and social studies (Escamillia, 2015; Estrada, 2014; Heafner & Plaisance, 2016). Many of these students were also pulled out of their classrooms for ELD support, or remediation, thereby excluding them from accessing the full curriculum until they were English proficient; as a result, they missed opportunities to learn science or social studies content. Moreover, often multilingual learners experienced tracking, where they were placed with other multilingual learners, instead of accessing advance placement classes that lead to college preparation courses (Callahan, 2005; Kanno & Kangas, 2014). Thus, these multilingual learners had limited coverage, exposure, or emphasis in the content areas. In fact, the achievement gap persisted as schools created policies to address the needs of multilingual learners with a focus on English over access to the full curriculum.

**Opportunity to Learn Measured**

The disjointed policies towards multilingual learners have placed them on a trajectory where they miss OTL along various junctures in their academic path. Access to content is an important measure of OTL. After the implementation of NCLB, researchers utilized surveys to assess quantitatively the content coverage dimension of OTL for multilingual learners (Abedi & Herman, 2010; Aguirre-Muñoz & Boscardin, 2008). For example, an OTL study of sixth graders' performance on a language-arts writing assessment required teachers to self-report responses to content coverage, instructional processes, and resources. The results of the writing assessment of students (n=1,038) were: females performed better than males, multilingual learners scored lower than English proficient students, and the better a teacher covered literacy analysis the better students performed (Aguirre-Muñoz & Boscardin, 2008). Additionally, while the results revealed the value of content coverage, for multilingual learners the greater exposure to literary analysis did not produce better scores. The results showed that these students required greater knowledge of complex language to perform as well as English-only students. Indeed, the complex language was not a skill the teachers were prepared to teach in a comprehensible manner to the multilingual learners.

Academic vocabulary in content areas requires a depth of vocabulary knowledge that multilingual learners may not have and that teachers need to develop. In one study, Abedi & Herman (2010) found eighth grade students (n=602) and teachers generally agreed on the number of topics covered in algebra, however, the multilingual learners did not benefit from the coverage due to linguistic difficulties with the topics. Although multilingual learners may be in the same classroom as English proficient students, exposure to content does not necessarily equate to student comprehension or appropriate linguistic scaffolding for ELLs.

The aforementioned studies revealed the need for more in-class and across-classroom observations of OTL to determine the impact of instructional delivery on content coverage and comprehension. Notably, the studies emphasized linguistic scaffolding without mention of culturally responsive teaching, an important part of best practices in teaching multilingual learners. In summary, the studies quantified OTL content but also recognized the importance of scaffolding for multilingual learners and the role of linguistically responsive teaching.

As researchers have now noted, "… OTL refers to equitable conditions or circumstances within the school or classroom that promote learning for all students. It includes the provision of curricula, learning materials, facilities, teachers, and instructional experiences that enable students to achieve high standards" (Aguirre-Munoz & Amabisca, 2010, p. 260). Teaching multilingual learners of various linguistic backgrounds in a mainstream classroom requires knowledge and skills to administer content successfully. While the federal government mandated an appropriate education for students acquiring English, per the *Lau v Nichols Decision* of 1974 (Lau v. Nichols, 1974), how that translates into best practices in classrooms with multilingual learners continues to be a significant issue. To educate multilingual learners, mainstream teachers must engage in linguistically and culturally responsive teaching, scaffold instruction, and incorporate second language learning best practices in order to create learning opportunities for multilingual learners (Bunch, 2013; Coady, Harper, & de Jong, 2016; Fillmore & Snow, 2000; Lucas, Villegas, & Freedson-Gonzalez, 2008).

Over the course of almost two decades, educational researchers have analyzed methods for improving the outcomes of multilingual learners' acquisition of the academic language and content knowledge of science (Buxton, et al., 2015; Fradd, Lee, Sutman, & Saxton, 2001; Lee & Maerten-Rivera, 2012; Tong, Lara-Alecio, Irby, & Koch, 2014; Weinburgh, Silva, Smith, Grouix, & Nettles, 2014; Zwiep & Straits, 2013). The acquisition of both is essential for multilingual learners to succeed in schools. The emphasis has changed from the early focus on the acquisition of the academic language of science and its "…structure (phonology, morphology, vocabulary, and syntax) to an emphasis on language for communication and learning" (Lee, Quinn, & Valdes, 2013, p. 223). Science has its own unique register and manner of communicating knowledge, as well as the component of inquiry as a basis for learning to do science. Today, students are required to ask questions, explain solutions, and argue from evidence to communicate information regarding a model or phenomenon (DiCerbo, Antrom, Baker, & Rivera, 2014; Lee, Quinn, & Valdes, 2013). Accordingly, this literature review analyzes current research on the various approaches to teaching science to multilingual learners.

## Strategies for Teaching Science to Multilingual Learners

**Science content-based literacy instruction.** The use of science content to improve reading comprehension enables multilingual learners to acquire content knowledge and develop English language proficiency simultaneously. “At its broadest level, academic vocabulary consists of words students must comprehend in order to access the concepts associated with a particular discipline and also use in order to display their acquisition of these concepts” (DiCerbo, Antrom, Baker, & Rivera, 2014, p. 452). Therefore, academic vocabulary instruction is one strategy to improve literacy outcomes. An interventional study of science academic vocabulary instruction, Taboada & Rutherford (2011) found fourth grade multilingual learners (n=20) demonstrated improvement in assessments of academic vocabulary, reading comprehension, and expository writing after only eight weeks. The study did not specifically engage in culturally or linguistically responsive teaching, however one Spanish speaker with low level English skills was provided with an opportunity to use L1 for meaning making. Additionally, Spanish cognates or Spanish trade books were provided for low-level readers based on the treatment they received. Interestingly, science content knowledge assessment did not occur in the study.

Another reading comprehension strategy is text-based questioning, where students engage with texts and develop questions. Taboada, Bianco & Bowerman (2012) found that fourth grade multilingual learners (n=10) demonstrated improvement in assessments of questioning, academic vocabulary, and reading comprehension after only six weeks. The students read science texts and worked collaboratively in small groups to create questions. Once again, the study did not specifically cite culturally or linguistically responsive teaching as a component of the study; however, the collaboration and communicative exchanges were an important demonstration of the teacher engaging in linguistic scaffolding. While science texts were the basis of the questioning instruction, the study did not include an assessment of science content knowledge.

**Literacy first and then science content-based instruction.** While the integration of science and literacy has been the focus of some studies with multilingual learners, others have held to the literacy first concept, and then content knowledge. In a two-part longitudinal, interventional study, the first part was K-3 literacy instruction with embedded science (Lara-Alecio, et al., 2012). Thus, acquiring English literacy was the primary focus with science content included during the reading and writing activities. Later, in third grade, science content instruction included hands-on science activities. The second part, fifth-grade science instruction, included English literacy. In that case, teachers engaged students in learning science content while incorporating reading comprehension strategies (Tong, Lara-Alecio, Irby, & Koch, 2014). In fact, the study included comprehensive attention to vocabulary and reading instruction by teachers.

The students benefited from the four-year focus in reading instruction during grades K-3, but comprehensive science instruction was delayed until the fifth grade, the first year of state accountability. All students who received the interventions demonstrated greater mastery on the state reading standardized assessments, and passed the district’s benchmark science test in fifth grade (Lara-Alecio, et al., 2012; Tong, Lara-Alecio, Irby, & Koch, 2014). As a matter of fact, greater than 90% of all study participants passed the state standardized tests of science.

The study did not demonstrate any attention to CRT, an important SLA best practice. Indeed, all study teachers were trained in using ESL strategies and all K-3 study teachers were certified to work with multilingual learners. Furthermore, the use of  SLA best practices may have occurred intrinsically by the highly trained staff, and could also account for the positive results in all student achievement.  In summary, this study of academic language and science content-based instruction revealed multilinguals achieved greater reading mastery, and a high passing rate in the standardized science assessments in fifth grade.

The literacy and science content-based studies focused on reading first. The attention to literacy subsumed science knowledge, and assessments of science content knowledge occurred in later years or not at all. When science content knowledge was not assessed, left unanswered was whether struggling readers in the early years of the study increased their knowledge of science concepts.  When literacy is the first focus, then science content knowledge is backgrounded. In essence, studies of multilingual learners acquiring science content and literacy, emphasized reading, comprehension, acquiring academic vocabulary, and then science content knowledge.

**Scientific discourse and academic writing.** While learning science vocabulary is important, today, inquiry-based science requires students to demonstrate their understanding. This includes engaging in oral and written communication. Acquiring the academic language of science is necessary for students to comprehend science; however, learning the vocabulary does not necessarily entail using the language for communicative purposes. This is true for all learners, but especially significant for ELLs, where instruction on scientific terms may be provided (input), but the processing of that instruction by students may be too limited /may not be successful enough to result in internalized and active understanding (intake). With the advent of NGSS it is not enough for students to passively learn science. “Through scientific inquiry, students plan an investigation, collect data from a variety of sources, develop explanations from the data, and communicate and defend their conclusions (NRC, 2000)" (Lee & Maerten-Rivera, 2012, p. 5). In essence, inquiry-based science requires collaboration, scientific discourse, and academic writing, all expressive activities.

Inquiry-based lessons, then, are an effective method to engage students in learning science while incorporating good SLA principles of communication for a purpose. Lee & Maerten-Rivera (2012) developed a curriculum for teaching ELLs hands-on and inquiry-based science for a five-year intervention study where teachers' knowledge and implementation of the Grades 3-5 curriculum were assessed. The study included extensive PD. Teachers engaged in providing L1 support to students whom learned how to "…use multiple modes of communication and representation (gestural, pictorial, graphic, textual) to enhance students' understanding of science" (Lee & Maerten-Rivera, 2012, pp. 10-11). The purpose of the study was to focus on teacher implementation of the customized curriculum. The teachers demonstrated increased knowledge of science content, better practices to promote scientific understanding, promote scientific inquiry. In summary, the study effectively improved teacher outcomes, and multilingual learners benefited from the enhanced curriculum instruction.

The Lee & Maerten-Rivera (2012) study did not include any assessment of student knowledge in science. For this reason, utilizing fourth-grade multilingual learners (n=81) from the Lee & Maerten-Rivera (2012) study, Buxton, et al., (2015) assessed those students to determine their ability to provide reasoning and explain content related to a scientific concept via oral interviews. In other words, the Lee & Maerten-Rivera (2012) study did not assess students, and the Buxton, et al., (2015) did assess the students on science content knowledge. The students were not assessed via a pencil and paper process. Findings revealed all respondents elaborated or provided details using English scientific discourse, but could not explain the concept using scientific concept knowledge.

Despite a customized curriculum and CRT, the results of the Buxton, et al., (2015) study revealed perhaps too few opportunities to use English scientific discourse during the study or insufficient time on scientific tasks. Since the oral interviews were conducted in English, it is unclear if the results would have been different if students could have demonstrated science conceptual knowledge in their native language. In short, an assessment of students' scientific discourse after instruction with a highly scaffolded and customized curriculum revealed students gained science knowledge but could not adequately explain the concepts presented during science instruction using academic vocabulary to demonstrate mastery in English.

The NGSS requires students to engage in scientific inquiry, design experiments, argue based on evidence, and recount their practices and results orally and in writing. The scientific discipline contains its own structure, complexity of terms, and specific written form to construct meaning. In investigating ways to assist multilingual learners acquiring scientific writing skills, de Oliveira & Lan (2014) observed a fourth-grade classroom in Indiana, where the classroom teacher utilized systemic-functional linguistic (SFL) strategies to teach multilingual learners how to write a procedural recount of a scientific experiment on density. Although the research occurred within a fourth-grade class, only one student, a ten-year-old Korean boy, was the focus of the study. The research revealed the focus student did acquire the appropriate scientific language and organizational writing structure.

In the study, the presence of academic language was limited to the use of temporal connectors, the correct terms for the materials used in an experiment, and one vocabulary word, the purpose of the experiment. The study was grounded in research questions about how the teacher taught science writing and the focus student's ability to demonstrate growth in writing. The study quoted the teacher interacting with the class, in a choral response to teacher prompts about the use of connectors in writing. Missing was the discourse of the focus multilingual learner in the case study discussing temporal connectors or any assessment of the student's science content knowledge on the topic. Whether the case study student could engage in scientific discourse, a critical component of communication and collaboration for success in the 21st century, was left unaddressed. Thus, while writing is an important component of SLA and inquiry-based science education, the student's oracy in the scientific discipline and conceptual knowledge of science were not addressed in the study.

The aforementioned studies of multilingual learners acquiring scientific academic vocabulary revealed the participants' abilities to demonstrate written or verbal skills, but not always a mastery of scientific knowledge. Once again, the demands of NGSS require that all students not only "do" science, but also understand and communicate effectively in scientific language.

**Doing Scientific Inquiry While Learning Academic Vocabulary**

Currently, there is a paucity of research on teaching multilingual learners how to do scientific inquiry and learn academic language simultaneously. One approach to inquiry-based science teaching is to introduce language and science concepts simultaneously. The 5-R (repeating, revealing, repositioning, replacing, and reloading) Instructional Model was utilized during a three-week summer school program, and teachers did not front-load (pre-teach) or explicitly teach vocabulary as a strategy (Weinburgh, Silva, Smith, Grouix, & Nettles, 2014). Inquiry-based science is an approach where "… students are engaged in an investigation in which the purpose is to find the answer to a scientifically oriented question, they do not need to be told the specific objective in advance of the investigation" (Weinburgh, Silva, Smith, Grouix, & Nettles, 2014, p. 521). In this study, the teachers did not present vocabulary or objectives first. This is in complete opposition to Sheltered Instruction Observational Protocol (SIOP) practice, a common instructional model to teach multilingual learners in mainstream classrooms. Instead, "…the language emerge [sic] during an inquiry-based lesson with reloading of language occurring the next day/lesson" (Weinburgh, Silva, Smith, Grouix, & Nettles, 2014, p. 523). In fact, utilizing the 5-R technique, fifth-graders (n=110) improved their word knowledge and demonstrated increased understanding of integrated science and academic language concepts (Weinburgh, Silva, Smith, Grouix, & Nettles, 2014).

When teachers engage students in making connections to prior knowledge, and then students communicate about their learning, they are experiencing culturally responsive teaching. Students in the study had extensive opportunities to discuss the events of the inquiry, which could explain the positive outcomes after fifteen days. While the study did not specifically cite CRT, the method of instructional delivery provided students with opportunities to discuss observations in science and make connections to the events in class and to prior knowledge and experiences. In essence, a three-week, inquiry-based science intervention revealed improvements in multilingual learners' academic knowledge, based on demonstrated improvements from the pre/post-test responses.

Another approach to inquiry-based science teaching is to merge scientific inquiry and ELD (English Language Development). Zwiep & Straits (2013) sought to discern the growth of students in both English and science, after participation in an intervention. In the quasi-experimental study, vocabulary was either front-loaded (pre-taught) or embedded (rolled-out) during grades K-5 instruction. Over the course of four years (2007-2011), teachers (n= 60) in three urban schools in California received two weeks of training via a PD institute, participated in lesson study, worked collaboratively to evaluate the “blended lessons” (Zwiep & Straits, 2013, p. 1318), and utilized 5-E (Engage, Explore, Explain, Elaborate, Evaluate) strategies to instruct. Students who received treatment improved moderately, with small, but significant gains in standardized state assessments of ELD, in all four years, and in three of the four years in ELA (English language arts). Notably, ELD gains were greatest in listening and speaking. Additionally, in the standardized state assessments of science, students in third and fourth grade made significantly higher gains than the comparison schools that did not participate in the study. After one year of the blended curriculum, other schools, including the comparison schools, began utilizing the new approach.

Furthermore, in a researcher-developed test of performance, first and second graders had statistically significant performance improvement, although, it was “…very small, representing a 9% and 5.5% increase based on the total score (100%)” (Zwiep & Straits, 2013, p. 1327). Indeed, the small increase may be a result of more students across the district receiving the blended curriculum, a possible threat to the internal validity caused by “...a diffusion of treatment” (Creswell, 2014, p. 175), where the comparison schools also received the new curriculum. While the diffusion might not have fared well for the internal validity of the study, the blended lessons did include a high fidelity of linguistically and culturally responsive teaching methods. In fact, this study was the only one that demonstrated significant improvements for students, included lesson study, and presented no issues with teacher fidelity in implementing the approach.

Recent studies integrating science with academic language instruction or ELD for multilingual learners appear to hold promise for improving the outcomes of these learners in mainstream classrooms. The blended curriculum yielded the best long-term results. The study was longer in duration and created an educational environment where teaching science content began in kindergarten. However, there are several precautionary notes: studies do not always include CRT; some positive outcomes in science knowledge or academic language were based on researcher assessments rather than standardized assessments; and some studies were done with upper-elementary school children. Frequently, researchers appear to wait until students can read before introducing inquiry-based science. Further research is essential to determine if these successful approaches could be applicable for all younger aged children.

Additionally, only the research on blended curriculum by Zwiep & Straits (2013) included lesson study. Thus, multiple studies where inquiry-based science and academic language or ELD were merged identified the importance of training and the ongoing support required to maintain growth over time. In fact, the most successful study still achieved very small gains, perhaps due to issues between the treatment and comparison group.

**Augmenting the Curriculum**

Efforts to improve the outcomes of multilingual learners include the development, annotation, or revision of curriculum to support teachers in mainstream classrooms. Curricula may be purchased from publishers, developed by researchers, or revised by researchers. The following studies demonstrate different approaches to provide teachers with an enhanced curriculum and associated strategies to teach science to multilingual learners.

**Modifying the science curriculum.** The advent of NGSS highlighted the importance of integrating academic language and scientific-inquiry instruction to teach multilingual learners. “An important role of the science teacher is to encourage and support language use and development in the service of making sense of science” (Lee, Quinn, & Valdes, 2013, p. 231). One such approach, the Quality English and Science Teaching 2 (QuEST2) curriculum, integrates inquiry-based science instruction with academic vocabulary instruction (August, et al., 2014). The curriculum, developed by researchers, incorporates the 5-E approach to science instruction, PD on academic vocabulary instruction, and appropriate scaffolding for multilingual learners. The curriculum also features linguistically and culturally responsive teaching methods. In fact, in a 15-week experimental study, all participants (n=1309) demonstrated improved scores in vocabulary and science based on the pre/post-test assessments (August, et al., 2014) . However, there was no significant difference between the control and treatment groups, and teacher fidelity of implementation was limited to 66% in the quality of instruction amongst treatment teachers (August, et al., 2014) . Furthermore, a demanding scientific and linguistic curriculum may have required a greater depth of knowledge than presented in the QuEST2 teacher materials and more time to teach.

While promising, the study may have suffered from limited PD—only one day prior to the project—with some additional mentoring and PD provided throughout. Moreover, no accommodations were implemented for multilingual learners during assessments, which could have impacted their performance. In summary, a study of an academic language and inquiry-based curriculum revealed limited fidelity of implementation amongst participant teachers and non-significant findings in the science knowledge of participants.

Given the demands of NGSS and SLA best practices, modifying curriculum to specifically support multilingual learners creates a comprehensive approach to science instruction. In an experimental study, Cervetti, Kulikowich, & Bravo (2015) enhanced an inquiry-based science curriculum following best practices in second language acquisition to create supportive features and scaffolds. There were multilingual learners in both control (n=9) and experimental classrooms (n=6). The study assessed the teachers’ use of the recommended strategies within the enhanced curriculum and their students' science learning. All groups of students, control and treatment, demonstrated significant growth in science and vocabulary between pre-test and post-test assessments of the study. Notably, the classrooms with more multilingual learners had lower post-test scores. In fact, even without enhancements, the inquiry-based curriculum enabled the control group classrooms to achieve greater growth in science knowledge.

Achieving positive results for all participants may have been attributable to the use of an inquiry-based curriculum, the uneven distribution of multilingual learners across treatment and control classrooms. The method of instruction, inquiry-based science, is consistent with collaboration and communication, strategies conducive to English language development. As a result, the inherent instructional methods of the curriculum may have proven beneficial and effective for all students.  Furthermore, the majority of the classrooms, nine out of 15, consisted of more monolingual students than multilingual students, and 30% of the classrooms contained 80% or more monolinguals. Under those circumstances, the treatment and control classrooms populations were more similar than dissimilar. Therefore, it seems all teachers needed to differentiate instruction. The study identified more strategies used by treatment teachers, but did not specify where the control teachers gained access to strategies. While treatment teachers did enact more strategies after receiving the PD, not all of them utilized the specific strategies recommended in the curriculum. In addition, teachers in the study were not mentored during the study and relied on the curriculum materials as the sole source of professional development for the study. Given these points, a well-designed experimental study identified: the inquiry-based curriculum was effective for all students, the ratios of multilingual learners to monolingual learners in an experimental study could affect learning outcomes, and greater teacher support could increase the utilization of strategies.

As shown above, multiple studies where curriculum materials were adjusted or created for multilingual learners revealed mixed results. Both studies were experimental with sound methodologies and the incorporation of SLA best practices, yet they experienced low fidelity. The limited teacher implementation of strategies could have contributed to the limited or non-significant growth of science knowledge among multilingual learners in mainstream classrooms. In addition, it is plausible that insufficient time was given to multilingual learners to acquire science content knowledge in these studies, that is 15 weeks for the August, et al. (2014) study, and 11 weeks for the (Cervetti, Kulikowich, & Bravo, 2015). Thus, multiple studies where curriculum materials were adjusted or created for multilingual learners disclosed that more than just curriculum modification is necessary to teach science content, but frequently the level of training and requisite ongoing support make it challenging to maintain over time.

## Web-Based Science Instruction

**Using technology to educate multilingual learners in science.** Utilizing technology to teach multilingual learners across the curriculum is consistent with the goals for 21st century learning. “To be effective in the 21st century, citizens and workers must be able to create, evaluate, and effectively utilize information, media, and technology” (P21 partnership for 21st century learning, 2017). The following two studies represent the most current research on educator efforts to use technology to teach science content to multilingual learners.

For more than 15 years, computer-based science learning environments have existed to provide various scaffolds to students. One of these tools, the Web-based Inquiry Science Environment (WISE) was used in a southwestern state with eighth grade students (n =50) (Clark, Touchman, Martinez-Garza, Ramirez-Marin, & Drews, 2012). The experimental study's purpose was to determine how providing L1 supports via an online inquiry tool to Spanish multilingual learners in a mainstream classroom impacts students' science learning. Students participated in a five- to six-hour study over the course of a week, in conjunction with pre-study and post-study assessments of science content knowledge and an essay writing assignment (Clark, Touchman, Martinez-Garza, Ramirez-Marin, & Drews, 2012). The results of the science knowledge and essay assessments disclosed that the multilingual learners did take advantage of the WISE L1 affordances and demonstrated significant gains in both English and Spanish assessments of knowledge, retaining that knowledge even after nine weeks (Clark, Touchman, Martinez-Garza, Ramirez-Marin, & Drews, 2012) "Without the language supports, they simply cannot make sense of the material in a grounded, consistent way. Without sufficient reference to their everyday experience, which may or may not be encoded in English, the curriculum remains abstract and their command of it remains tenuous" (Clark, Touchman, Martinez-Garza, Ramirez-Marin, & Drews, 2012, p. 1219). Thus, a brief experimental study of multilingual learners acquiring science content and literacy instruction with L1 support demonstrated gains in their science knowledge.  This study focused on students working independently; opportunities for students to engage in oral discourse or scientific practices of collaboration, key components of SLA communicative exchanges and inquiry-based science, were not present.

Likewise, a web-based technology study focused on scientific inquiry prior to academic language. The study took an oppositional stance to the academic language front-loading in SIOP. In a three-day study, (Ryoo, 2015) found fifth graders (n=220) demonstrated improvements in their knowledge of both science content and academic language knowledge.  While exposed to web-based technology, students in the treatment group participated in science instruction that utilized common everyday language to introduce scientific concepts. As the lessons progressed, academic language and more rigorous curriculum were incorporated, and students were required to conduct virtual experiments, make predictions, and draw conclusions afterwards in an essay response. Students in the control group did not begin lessons with everyday language, but rather with science-related academic language; all other aspects of the web-based lessons were the same. Results of the researcher-created assessments, conducted a day after the study's completion, revealed all groups benefited from the web-based instruction; however, the treatment group had greater gains in their essay responses. The study did not explicitly utilize students' native language; however, the language of computers could perhaps be considered native to these young learners. And while the study did not include CRT with connections to students' culture or oracy, the ability to replay and receive visual and auditory input could have been factors in the success of this brief study. In summary, a web-based science lesson of three days demonstrated improvements in the pre/post-test responses when students were engaged using everyday language.

Two studies utilizing web-based technologies to teach English and science to multilingual learners demonstrates that they assist these students in retaining science content knowledge. What remains unanswered are the duration of the knowledge and whether these technologies foster collaboration and oracy. Once again, in the NGSS, communication, collaboration and the use of technology are seen as key components for success in the 21st century. Furthermore, the two studies were very brief, each lasting fewer than seven days, and comprised of upper elementary and middle school students. Not only are these children older, but also their adeptness at utilizing keyboarding and technology skills could affect the student outcomes. Also noteworthy is the fact that both studies appear to have removed teachers from instructional responsibilities; it remains unknown how humans versus computers could affect the successful implementation of various educational models with low fidelity. Another fact that resonates with both studies is the independent nature of student work and the absence of collaboration or oracy. In brief, the two studies show that web-based instruction may be a viable option for helping to teach science to multilingual learners and may provide them with opportunities to learn academic content, albeit absent collaboration or oracy, important best practices in NGSS and SLA.

As shown above, teaching multilingual learners science outside of an educational model requires educators to incorporate academic vocabulary instruction, linguistic scaffolding for support of content learning, and culturally responsive teaching in a holistic instructional approach. Accommodating all of these strategies without a framework, a complex endeavor, requires expertise and professional development for successful implementation in mainstream classrooms with multilingual learners. In essence, sustaining such efforts without a framework requires an enduring commitment from administrators and teachers to achieve the desired outcomes.

## Using Educational Models to Teach Science

**Instructional models for teaching content in mainstream classrooms.** Instructional models designed to teach multilingual learners vary by the grade levels for which they are intended and by their implementation methodology. At this point in time, some models are more than twenty years old. Most of the research on these models was completed by their originators, and there remains a dearth of research on all of them.

***Sheltered instruction observational protocol (SIOP).*** SIOP is the most common instructional model of best practices for teaching multilingual learners (Allison & Harklau, 2010). The model focuses on explicit instruction, making content comprehensible, lesson planning, lesson delivery, grouping strategies, content review, content assessment, and the inclusion of culturally responsive teaching in the delivery of content. The SIOP model is a complex model with thirty features imbedded in eight components for teaching students from kindergarten through secondary school (Echevarria, Short, & Powers, 2006; Echevarria, Vogt, & Short, 2014).

The implementation of the SIOP model requires teacher commitment, along with administrator and coaching support. Initial studies of SIOP (from 1997 to 1998) identified significant improvements in multilingual learners' writing after two years of teacher instruction and implementation in SIOP, compared to non-SIOP instruction of middle school (Echevarria, Short, & Powers, 2006). Subsequent comparative studies by one of the same researchers sought to determine if significant improvements in student performance were possible in other content areas, such as math, science, and history, for middle school and high school students. These studies, conducted in New Jersey between 2004-2006, included implementation timelines as short as nine weeks and up to two years. The studies revealed that students in SIOP classes made growth, and greater gains were made in the second year of the SIOP program compared to non-SIOP classes (Short, 2011). Notably, all of the aforementioned SIOP studies were done by the developers of the protocol, utilizing sound research methodologies, validity, and reliability. The fact that the developers of the protocol are either lead researchers or co-authors of the studies could lead to bias in favor of the protocol.

One of the key components of the SIOP model is a multi-purpose rubric utilized by administrators and researchers to determine an instructor's fidelity in implementing SIOP, and then referenced to provide feedback (Echevarria, Short, & Powers, 2006; Echevarria, Vogt, &

Short, 2014; Short, 2011). In an 18-month SIOP comparative study of kindergarten through fifth grade multilingual learners, researchers recorded improved teacher performance based on the SIOP rubric, that is, on a scale from zero to five, but only seven out of 23 teachers were high implementers who scored a three or greater (McIntyre, Kyle, Chen, Munoz, & Beldon, 2010). Furthermore, while teachers in the program improved, in those classrooms where there was a high level of SIOP instructor fidelity, students performed better in reading assessments (McIntyre, Kyle, Chen, Munoz, & Beldon, 2010). Once again, the level of commitment required was unattainable by as many as seventy percent of the teachers in the study. Although the study indicated it was a sociocultural study of SIOP, there was no inclusion of student or teacher interaction, and the greatest emphasis was placed on the SIOP teacher rubric and its relation to student performance.

Several SIOP studies reveal improved student outcomes, especially after two years of implementation. The authors of the model have attempted to show student growth in as little as nine weeks, but even when a study was 18-months long, it suffered from low fidelity of implementation and non-significant outcomes. Incorporating the SIOP model requires teacher training, and coaching support is critical to achieving the level of complexity required to ensure model fidelity and student improvement (Echevarria, Short, & Powers, 2006; Short, 2011; Kareva & Echevarria, 2013). Although SIOP may be a viable model to introduce into mainstream classrooms, its complexity and the time required for full implementation may deter schools seeking a “quick fix” to attain student improvement.

***SIOP, science, and student voice.*** As noted above, many SIOP studies focus on the teachers’ delivery of instruction and student improvements, without examining the student’s perspective or voice. In two recent ethnographic studies of SIOP in middle schools, researchers analyzed student and teacher discourse to assess the students' experience in the acquisition of science content knowledge (Braden, Wassell, Scantlebury, & Alex, 2016; Zhang, 2016). In both studies, researchers observed science classrooms, recorded lessons on video, and conducted interviews with students. A two-year study of a sixth-grade student-centered classroom in an urban school explored the perspectives of four multilingual learners and included teacher interviews (Braden, Wassell, Scantlebury, & Alex, 2016). The students in the study were at the center of the learning process, completing many projects, and teacher talk was kept to a minimum. Meanwhile, an eight-month study of a teacher-centered classroom in the Midwest looked at the multimodal communication of the teachers and students (Zhang, 2016). In the second study, the teacher was the center of attention and did most of the talking in the class. The studies similarly included the voices of students and how they were making sense of science content learning during sheltered instruction. Notably, "in science classrooms, it is a consensus that teachers and students construct the meaning of science through the "multimodal ensemble" (Kress, Jewitt, Ogborn, & Tsatsarelis, 2001, p. 1) comprised of verbal, visual, mathematical, and actional languages" (Zhang, 2016, p. 7). Thus, both studies exposed how the voices of students are essential for creating an environment focused on student learning, and not just on teacher execution of techniques and strategies. The teachers in both studies did not know their students individually, nor the language and culture they brought to science learning. In both schools, regardless of the methodology for the delivery of instruction, students were not engaged in making sense of content or making connections between prior experience and scientific concepts presented in class, key CRT concepts. In essence, these studies recommend ongoing research to analyze students and teachers engaged in discussion where multilingual learners are assisted in making connections to science content and knowledge for ultimate mastery.

***Language-based approach to content instruction.*** Another instructional model, specifically identified as a teacher preparation model, is the Language-Based Approach to Content Instruction (LACI). Similar to the aforementioned models, LACI is designed to provide teachers with tools to work with multilingual learners.

The author and researcher of LACI, de Oliveira (2016) defines it as an instructional approach, where teachers instruct elementary multilingual learners on how language functions in texts to improve their language and content knowledge of. The methodologies of LACI include principles of SLA, such as communication to improve social and academic language, and CRT to create connectedness between the students' home culture and school. Unlike SIOP, it does not instruct teachers to simplify academic texts. The approach focuses on the function of language in content. Specifically, how language functions to provide meaning. For example, how parts of speech in sentence clauses, in conjunction with various visual scaffolds can function to create meaning for the audience.

While the approach is multi-faceted and includes many SLA principles, it lacks a focus on academic content. In a study of a fourth grade teacher, de Oliveira (2016) demonstrated how the teacher engaged students in activities where the function of language in a science text was analyzed to create meaning during content instruction. The absence of an inquiry-based model of science instruction left the fourth grade teacher interacting with students in an initiation, response, feedback (IRF) format. Students engaged in IRF, but the use of scientific language was missing from the students' communication. Instead, the exchange focused on a verb and its consistent use to provide meaning. Inquiry-based science expects that "through scientific inquiry, students plan an investigation, collect data from a variety of sources, develop explanations from the data, and communicate and defend their conclusions (NRC, 2000)" (Lee &

Maerten-Rivera, 2012, p. 5). Hence, the IRF format appeared to be a contradiction of the LACI principle of a community of collaborative learners. The IRF format limited interactions to individual students and the teacher, without opportunities for students to collaborate in scientific inquiry and with limited opportunities for students to engage in scientific discourse with peers.

While this model has been researched for ten years by de Oliveira (2016), the study itself did not have a research question, and appeared to be focused on demonstrating the viability of the model. LACI appears to limit academic language acquisition, instead “foregrounding” how language functions. Furthermore, the model relies on teachers to locate texts to teach content, analyze the optimal text to teach content, and then design lessons and activities to teach content. Notably, in most public schools today, the focus is on standards-based instruction (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2017) and curriculum that is determined centrally. The centralization of curriculum design limits the responsibilities of teachers to performing the duties of teaching and assessment. All things considered, while the LACI model contains several SLA teaching features, the additional demands it places on teachers, and its focus on language function, rather than on academic language and content simultaneously, may cause multilingual learners to miss opportunities to learn.

***Transformative professional development.*** The ability to engage in systemic reform in an urban environment requires extensive modifications to instructional practices. The Transformative Professional Development (TPD), a comprehensive science instructional model, is an instructional program for educating teachers on how to engage students in learning science concepts, develop professional learning communities (PLCs) within the school and in partnership with a university, and create a school community of diverse science learners among under-represented student populations (Johnson, Bolshakova, & Waldron, 2014).

In a five-year, quasi-experimental, TPD intervention study funded by the Institute of Education Sciences (IES) of the U.S. Department of Education, participant teachers engaged in 24 days of PD over the course of the intervention. In addition, teachers engaged in conversational Spanish courses, accelerated college science courses for elementary teachers, and the implementation of a very structured science inquiry and literacy curriculum (Johnson, Bolshakova, & Waldron, 2014). The two-phased study of primarily Latino students from grades four to eight, in a school district in the southwestern part of the USA, included middle school teachers (n=8) in two schools in the Phase I intervention (2005-2008), and elementary school teachers (n=43) in six elementary schools engaged in Phase II (2009-2012). TPD's highly stuctured science lessons included the use of Spanish to teach vocabulary, frontloaded and embedded vocabulary instruction, discussion, writing, conceptual understanding instruction, and guided inquiry, all best practices in SLA and science instruction (Johnson, Bolshakova, & Waldron, 2014).

Additionally, this mixed method study included state assessments of science knowledge, formal teacher observation protocol, interviews, and focus groups. Results of data analysis revealed that the teachers' capability to teach science in the middle school increased significantly over three years, and over two years in the elementary schools, with declines occurring in the control group (Johnson, Bolshakova, & Waldron, 2014). The state science assessments of the middle school students found no significant growth between the control and intervention groups in science. However, when the multilingual learners' data were extracted from the overall dataset and further analyzed, the data revealed their science knowledge grew in years two and three respectively in the elementary and middle schools, compared to the control schools. Furthermore, the investment in a school culture of science learners improved the general attitude of the teachers and students toward the school and toward science. The data on the improved school climate were anecdotal, as no survey or reports of reduced suspensions or bullying incidents were recorded. Although the overall results of the study were very promising, a number of policy and political changes in the district reduced the efficacy of the TPD program. As the years of the study progressed, schools were forced to reduce time for science inquiry, accountability pressures required teachers to focus on assessment before learning, and impending school closures created increased teacher and student mobility. Thus, a highly structured and well implemented program guided by SLA principles ultimately fell prey to the forces of politics and local policies, and this turmoil may have resulted in a failure to yield significant growth.

***Instructional models comparison.*** The aforementioned instructional models—SIOP, LACI, and TPD—fulfill the tenets of SLA principles by incorporating best practices that assist students in acquiring a second language. Again, these best practices include linguistic and culturally responsive teaching. The TPD model appears to have the most integrated approaches to CRT throughout its implementation of instructional strategies and techniques. For example, in TPD the use of Spanish to teach science vocabulary was a key component of instruction and building a sense of community. While CRT is part of the SIOP model, it was not a featured component in any of the above-referenced SIOP studies. Notably, in the multi-featured model, CRT is a factor to consider in lesson presentation in conjunction with tapping into student's previous experiences and background knowledge before introducing new content. In contrast, social language instruction is not specifically addressed in SIOP, but is accommodated in the grouping of students for specific purposes. Similarly, LACI specifies community and collaboration as key principles, although this was not specifically depicted in the research provided above. In essence, some of the models do not incorporate best practices effectively.

On the other hand, SIOP, the most structured model of the three, focuses on the technical aspects of lesson planning and delivery, and that appears to make it a preferred method for teachers and administrators. The technical aspects of lesson delivery do not necessarily incorporate student voice, perhaps a critical component in the meaning-making that enables multilingual learners to acquire new concepts, especially in science (Braden, Wassell, Scantlebury, & Alex, 2016; Zhang, 2016). Nevertheless, of the three models, TPD appears the most cohesive, implementing all the SLA principles consistently. Indeed, instructional models are more comprehensive in their capacity to address the needs of multilingual learners. That is, unlike, approaches engineered by individuals or schools. Hence, without a framework incorporating sound SLA pedagogy, it appears difficult for administrators and teachers to adhere to the principles of SLA in mainstream classrooms. Overall, the models make allowances for the adjustment of content or its presentation to make it comprehensible, which is also a key principle of SLA.

## What It Means to Exercise Culturally Responsive Teaching

**Using L1 as a strategy in the mainstream classroom.** While there are many strategies to address the needs of multilingual learners in a mainstream classroom, permitting students to use their first language is one meaning-making tool that enables students to achieve comprehension of academic content. "…Home language is a resource. It is a resource for thinking, for feeling and for reflecting on the ways in which the students make meaning of their worlds. It signs affiliation, membership and a sense of belonging to communities beyond the classroom" (Potts & Moran, 2013). While the use of the native language is an important resource and best practice, the ways in which educators can accommodate its use for meaning-making among multilingual learners remains unclear and in need of further analysis. In order for educators to integrate L1 as a strategy most effectively, they need to understand the experiences of their multilingual learners, specifically how these students utilize their first language to mediate content learning in a mainstream classroom.

***Culturally responsive classroom examples.*** Educators who implement robust curriculum content, use the students' first language, and provide explicit academic language instruction demonstrate great adherence to SLA pedagogy. In a dual proficiency (DP) program, the kindergarten through fourth grade educators utilized the students' first language and culture during all instruction, including in the curricular content areas of math, science, geography, and history. Instruction was also tied to the students' life experiences (Hayes, Rueda, & Chilton, 2009). Similarly, in a junior high school, the ESL teachers taught multilingual learners using history and English literacy texts in a sheltered environment, always making connections to students' cultures (Peercy, 2011). Both studies were qualitative analyses of the teachers' performance and did not include assessments of student growth.

Although there were no pre-tests or post-tests of students' performances, the researchers noted students in the DP program demonstrated increased proficiency each year beginning in second grade on California's standardized assessments of English language arts and mathematics. There was, however, no evidence of this data cited in the study. Both studies were incorporated in this review because they were the only examples of teachers utilizing SLA pedagogy and CRT simultaneously, while instructing multilingual learners outside of an instructional model or customized curriculum. As shown above, the researchers presented complete portraits of instruction fulfilling the requirements of best practices in SLA, including linguistically responsive teaching and CRT.

In summary, this review examined the opportunities of multilingual learners to learn science. Notably, at the start of the 21st century, national accountability policies narrowed the curriculum available to these students, and often omitted science content instruction. Then, the review examined best practices studies designed to provide multilingual learners with the access and opportunity to learn science. Indeed, best practices include scaffolded content instruction, in conjunction with linguistically and culturally responsive teaching. Often, the research focused on literate, upper elementary students gaining access to science academic vocabulary and content. Notably, studies of best practices to teach multilingual learners science in the early elementary years remain limited. Lastly, the review examined studies including comprehensive content and culturally responsive teaching. Frequently, culturally responsive teaching is not a component of best practices in classrooms attempting to improve the outcomes of multilingual learners. Thus, without attention to CRT, there exist limited or no communicative exchanges, a critically important component of second language acquisition and NGSS. Researchers need to examine what happens in the classroom and learn about the experiences of the multilingual child in the classroom. The current study seeks to explore young multilingual learners' opportunities to learn science content. Therefore, the expectation is for this study to provide some insight into the mainstream classroom experiences of these multilingual learners commencing their journeys into science, technology, engineering, and math in American schools.

# Chapter 3: Methodology

## Research Study Design

The intent of the research was to observe first-grade Latino multilingual learners during science instruction to determine whether they gained access to the resources, tools, content, and language of the science curriculum during instruction. For my research, I planned to conduct a qualitative case study of up to four first-grade mainstream classrooms in two schools. The choice of a case study is consistent with a strategy to study individuals in real-life situations where control over individual behavior is not desired, and where observation, interview, and the collection of various artifacts provide a holistic view of the case (Yin, 2003). Since the case setting was planned for up to four classrooms in two schools, or sites, I chose a comparative case study design (Creswell, 2013; Merriam, 2009; Yin, 2003), where the cases will be different physical classrooms with different instructors during science content instruction. At these sites, I explored the experiences of my selected population during science instruction, comparing students within each site and subsequently comparing students across the two school sites. In summary, my research design was a comparative case study design that allowed for exploration and comparison within sites and across cases.

## Research Site

The context of this study was two elementary schools (pre-kindergarten to fifth grade) in a regional school district, comprised of urban and suburban neighborhoods in a central New Jersey community. Historically, the school district was comprised of a primarily White population. Currently, in three of the four elementary schools, over 60% of the population consists of Latino, Asian, and other minority groups, with the remainder being White. The Spanish-speaking population in the school district nearly doubled from 2005 to 2015. In addition, the Spanish bilingual program has increased from a primarily K-1 program in 2004 in two elementary schools to a K-5 Spanish bilingual program that functions across all four elementary schools. However, there are not enough Spanish bilingual teachers in the elementary schools to establish Spanish bilingual classes for all grades in each school. As a result, district administrators chose to equalize student enrollment across the four elementary schools, i.e. load balance them. For this reason, students are enrolled in different schools based on their grade level and not proximity to the school. While the district has a large Latino population, it has attempted to distribute these students equally across all elementary schools for the purposes of providing bilingual classes across the district.

My study sites were elementary schools where Spanish bilingual classrooms resided only for kindergarten, first, and fifth grade during the 2016-2017 academic year. There are English-only, or mainstream classrooms available for all K-5 grades. Consistent with the equalizing enrollment policy in my site's school district, when students exit a bilingual program, they might not remain at the school where they attended bilingual classes but instead return to their local school. This had the potential of limiting the number of participants available for my chosen study population—first-grade Latino multilingual learners—because the equalizing policy could limit the number of students who return to my study site the year after they exit bilingual kindergarten and enter a first-grade mainstream classroom.

## Study Participants

**Students.** The focus of my study was the experience of Latino first-grade multilingual learners during science instruction. Participants were selected based on fulfilling the criteria as former students in a bilingual kindergarten program, who were exited for first grade into a mainstream classroom. The other possible participants are students whose parents declined bilingual services. The viable participants were distinguished by a state and school maintained Limited English Proficient (LEP) identifier in the schools' Genesis database. The LEP code is maintained up until two years after a student is deemed English proficient. The participants could have been students in up to four different mainstream classrooms with different teachers. I used convenience sampling (Creswell, 2014), since the students and teachers were available in the district where I teach. I selected two students from each site, observed each child, and then compared the experiences of each child within the site. Subsequently, I compared the experiences of the students in one case site to the students in the other case site, an across-case comparison.

Due to the dispersal of students to their home schools, I had a limited population from which to select participants at my study sites. Coady & Harper (2016) used the terminology "low incidence" when there are only a few identified multilingual learners in a classroom. The participants included both males and females. Research has found gender differences in the performance of multilingual students (Suarez-Orozco, Suarez-Orozco, & Todorova, 2008). Based on my selection criteria, and accounting for gender differences, I wanted to select one boy and one girl from each class. If one child of each gender was not available in any class that fulfilled my criteria, then I selected two children of the same gender across two classes. The selection was also based on the consent of the parents and children to participate. I did not have more students available than necessary. Hence, I did not need to select participants based on regular attendance and parental consultation. In summary, the focus students were multilingual learners in first-grade mainstream classrooms during science instruction in two elementary schools in my district.

**Teachers.** In addition to students, I wanted to include up to four teachers as participants, due to their vital role as the key educational leaders in their classrooms. The interaction of the teachers with the study participants was relevant to answer questions regarding the children's access to the science curriculum, the teachers' abilities to scaffold science instruction, and any barriers to OTL that existed in the classroom. There were four first-grade classes in each school, but only one first-grade teacher was bilingual; as a result, the students received science instruction from English-only speaking instructors. Thus, at the outset, it was possible that the teachers were not aware of the specific scaffolding these students needed.

**Parents.** Latino parents' involvement in education affects their children's academic life. "The association between parental involvement and the academic achievement of Latinos is quite consistent and reasonably strong" (Jeynes, 2017, p. 23). When parents are engaged, the student outcomes are better. Parental involvement can occur in the home, school, or community. For this reason, I interviewed the parents or guardians of each child to obtain demographic information, as well as to acquire information regarding the parents' connection with the school. Parents fill an important gap between the child and school. For example, "Homework completion is a recurrent educational activity during which family members both acquire and impart a set of normative expectations about what it means to be a successful student" (Mangual Figueroa, 2011, p. 265). Interviewing parents allowed me to explore how parents supported their child's education at home, including homework practices and language use. Homework is just one practice in which parents engage, connect, and communicate with their child's school each day (Lanuza, 2017; Mangual Figueroa, 2011; McConnochie & Mangual Figueroa, 2017; Quiroz & Dixon, 2011; Thelamour & Jacobs, 2013; Walker, Ice, Hoover-Dempsey, & Sandler, 2011). In addition, parental support includes attending parent-teacher conferences, meetings, and workshops. Meanwhile, participation in the community includes visits to the library, museums, or other cultural venues. Thus, I used the interview as an opportunity to gain insight into language use at home, communication with the school, and outreach in the community for additional academic support. Interviewing the participant's parents completed a holistic view of the academic support the child received outside of the school.

**Data Collection**

Prior to commencing this study, the Rutgers Institutional Review Board (IRB) reviewed all my research plans. Although I have been in my school district for 13 years, and I am very familiar with district policies with regard to the multilingual population, IRB worked with me to ensure the confidentiality and protection of my participants (Creswell, 2014). Notably, I sought the permission of school administrators, teachers, parents, and students for all observations and interviews.

After I received IRB approval, I began the process of requesting consent. First, I requested the teacher's consent to conduct a study in their classrooms. Next, I contacted parents whose children met the criteria to participate in the study. Then, I delivered parent consent forms in both English and Spanish to the classrooms where the focus students resided. Permissions were requested from all parents for videotaping children, that is, focus student and non-focus students. Most non-participant parents also afforded me consent to record their child's voice and image during observations. When permission was not afforded, the child's data was not included in the study. Thus, went the procurement of consents.

Once all the consents were procured, then interviews and observations began. The first interviews were with teachers. These interviews were followed by classroom observations, focus student interviews, and then parent interviews. The interviews were recorded using a

Smartphone. Additionally, only classroom observations were videotaped. After the observations, the focus students were interviewed, they commenced in English, but code switching and speaking in Spanish was permissible. After the focus child's interview, I interviewed their teacher again, and then proceeded to interview their parents. Interviews with parents were conducted in Spanish, the parents' preference. The semi-structured interviews (Patton, 2002) were audiotaped and transcribed. The data for my study was collected over a period of five months: December, January, February, March, and April. Note, all audiotapes and videotapes of students were destroyed once the data analysis was completed. In summary, I observed four multilingual learners from three mainstream first-grade classrooms, and interviewed their teachers and parents to explore their knowledge of the child's experiences during science instruction.

**Observation protocols.** I observed what types of affordances, if any, the multilingual students acted on during the science instruction. "The affordances of an individual's environment are what the individual can perceive as feasible to, in, on, with, or about the objects or features in that environment" (Gee, 2008, p. 80). Namely, I examined if and how students respond and acted because they had access to affordances such as tools, resources, peers, or materials. In this district, the time allotted for science in the elementary school is three hours per week, or three days per week. Accordingly, I observed students during the science block, arriving 5 minutes early and leaving five minutes after science instruction, in order to capture the start-up and wrap-up activities of the lesson. Thus, I planned to observe each study participant for three consecutive days in a week, or on average 210 minutes.

During observations, I looked for the communicative exchanges between the multilingual learners and their teacher or peers, and the use of tools, technology, or other materials during the science lesson. Research has noted, “In science classrooms, it is a consensus that teachers and students construct the meaning of science through the ‘multimodal ensemble’ (Kress, Jewitt, Ogborn, & Tsatsarelis, 2001, p. 1), comprised of verbal, visual, mathematical, and actional languages” (Zhang, 2016, p. 7). Therefore, I also searched for non-verbal communication, such as visual and gestural communication, by the multilingual learners in the classroom. To that end, these observations were videotaped with two Microsoft Surface devices. The devices were in two separate locations in the classroom. One device was focused on the teacher during instruction and the other device was focused on the students during instruction. When the focus student worked in a small group, the student was audiotaped with a Smartphone to capture the student’s participation in the discussion. All observations were recorded according to an observational protocol adopted from Zhang (2016) (Appendix D) to capture verbal, non-verbal, and researcher field notes. Specifically, during each observation, I focused on one child and his or her science instruction experience.

**Teachers as participants.** The study commenced with semi-structured, 30-minute teacher interviews (Patton, 2002) occurring before classroom observations begin. The purpose of the interview was to acquire information regarding the teacher’s pre-service or in-service training to work with diverse populations (Appendix B). Equally important, the teacher’s perspectives about teaching the multilingual population science were also discussed. After the final observation in each teacher’s class, I debriefed the teacher and asked her to reflect on the lessons, including any scaffolding of the lessons (Appendix C). The discussion focused on the teacher’s perceptions of the multilingual learners’ classroom experience and any perceived barriers the students may have had accessing the science curriculum. In summary, the teacher interviews provided further details to complete a portrait of the child's experience during science instruction.

**Student interviews.** After the final observation of each child, I interviewed the child for approximately 20 minutes. The interviews occurred outside the child's classroom. The locations varied from the hallway to the cafeteria. All locations were near the classroom in quiet spaces. The interviews centered on the activities and the resources the student used during science instruction.

In the course of science instruction, students utilized notebooks called interactive science journals to record their responses to science instruction. I asked each student to bring their science journal to the interview area. The interview protocol (Appendix E) consisted of five questions aimed at understanding the student's view of the classroom science experience and included questions about peers and the teacher as resources. The protocol was developed based on The Young Children's View of Science (YCVOS) questionnaire, which seeks to determine children's knowledge and understanding of science and scientists (Lederman J. S., 2009). Thus, the science journal in conjunction with the interview protocol steered the course of the interview.

While I had an interview protocol to begin the discourse, the student could lead the conversation based on the science lesson under discussion. I asked the student participants to share their science journal during the interview to create "structured activities [sic]" (Ey, 2016, p. 38), whereby the students will be "using concrete materials" (Haghish & Teymoori, 2013), that is, the use of science artifacts and/or their science journals to support the discussion. Thus, the focus student participated in a discussion using the materials or resources from the science lessons to make the discussion more concrete and relevant to them. Research has demonstrated that when students are invited to initiate the discussion and are given ownership and control, a more communicative exchange results (Gibbons, 1998). For the most part, I monitored the conversation for time, but the students controlled the discussion of the science experience.

Individual science interviews with student participants provided insight to their recall of a science experience. Indeed, the students engaged in a brief discussion, where they were invited to explain an activity that had occurred during one of the three days of observation. The discussions were an informal assessment of the child's meaning making of the science content that was taught during the lesson. There was not an attempt on the part of the researcher to supplement or make the lesson more engaging or constructivist. The children utilized the drawings or writings from their science journals, with which they participated in meaning making and formulating ideas (Brooks, 2005). For that reason, I included the students' interactive science journals to help them recall their response to the activity or lesson under discussion. As a result, the discussions provided insight to their learning of the content presented in class.

**Parent interviews.** The study ended with parent interviews, which were conducted in Spanish. These interviews occurred at the participants' home and lasted on average up to one hour. Exploring the parents' perceptions of the school and their interactions with the school was essential to understanding the child's experience of school. Research has demonstrated that immigrant families experience difficulties in negotiating school policies, practices, and expectations (Brabeck & Sibley, 2016; Hamilton, Marshall, Rummens, Fenta, & Simich, 2011; Roosa, et al., 2012; Suarez-Orozco, Suarez-Orozco, & Todorova, 2008). This is especially true when the potential for linguistic and cultural barriers limits communication (Auerbach & Collier, 2012; Good & Masewicz, 2010; Han & Bridglall, 2009). The relationships and support multilingual students and their families develop within their schools, communities, and homes are pertinent to their academic achievement in school (Brabeck & Sibley, 2016; Hamilton, Marshall, Rummens, Fenta, & Simich, 2011; Suarez-Orozco, Suarez-Orozco, & Todorova, 2008; Roosa, et al., 2012). I devised a parental interview protocol with inquiries relevant to language use, school-home partnerships, homework, and perceived student performance (Appendix A). In my interview with the parents, we discussed the science curriculum and examined science artifacts from the school such as study guides. These artifacts guided the discussion and enabled parents to talk about their understanding of the science knowledge their child was acquiring during science instruction. Consequently, this information was used to build a portrait of the child socially, culturally, and academically. Thus, by interviewing the parents or guardians of these children, I gained insight into the child's association with the school, the community, and the family (Vasta, 1979). Moreover, these interviews also provided information about how the parents or guardians interact with their child's school, and about their perception of their child's school experience during science.

In summary, I observed four multilingual learners from three mainstream first-grade classrooms, and interviewed their teachers and parents to explore the students' experiences in a first-grade mainstream class during science instruction.

**Artifacts and documents.** Documents and artifacts contribute to the contextualization and rich description of the research site, its participants, and activities (Merriam, 2009). The use of multiple data sources substantiated the reality of the classroom. Therefore, data from observations, artifacts, and various media were utilized to create a clear description of the students' classroom experience during science instruction. The collection of artifacts also provided data for an analysis of the classroom experience and substantiation of findings. Thus, it is expected that documents will "…contains [sic] information or insights relevant to the research questions…" (Merriam, 1988, p. 105). Therefore, I compiled observational audiotapes and videotapes, field notes, students' written work (i.e., worksheets, assessments, interactive science journals, etc.), teachers' detailed lesson plans, study guides, and textbook pages. I also took photos of environmental images—posters, anchor charts, and other teacher-created visuals in the classroom. Note: Photos obtained during this study did not include children's images. In essence, the acquisition of multiple data sources provided clarity and cohesion to the descriptions of the experiences of the multilingual learners during science.

**Researcher Role**

I became interested in the experiences of multilingual learners in science and social studies several years ago. At the time, I was teaching in middle school and observed the limited academic background knowledge in social studies or science for many of these students. When these students were asked to provide evidence in writing to substantiate their remarks, they would only reformulate the information provided. They exhibited limited experiential or content knowledge in either science or social studies. Thus, they could not provide cohesion to statements about historical figures or even health/environmental-related events. For example, many of these students lacked knowledge of U.S. geography, history, Earth science, or life science facts. Watching many multilingual learners struggle to synthesize evidence in their writing sparked my interest in exploring the experiences of these students in elementary school, when they are first exposed to science.

As a matter of fact, I chose to be a participant observer in my study because I have been a teacher in my district for thirteen years and am well known by students and staff. In addition, I believe it would be impossible to be solely an observer in the classroom. I could foresee my presence as strictly an observer to be disconcerting or perhaps disruptive to the class. However, my intent was not to instruct, but rather assist, if called upon, and primarily observe. I recognize that this dual role, however limited, could create a conflict with my data collection, but I suspected that the purely non-participant role could make the staff and students more uncomfortable. These teachers and I have been colleagues for several years. However, I am the only ESL teacher in the school, and I sense that my presence could feel threatening to them because my expertise in working with diverse children from grades PK-5 is well established. I have collaborated with teachers on best practices for working with multilingual learners, and therefore the staff pursues my methodologies, strategies, and techniques for working with these populations. By merely observing and not engaging at all, I might seem judgmental. Additionally, I feel a connection to the bilingual students and their parents because of the numerous workshops I have conducted to engage and educate parents on the academic processes of the district where I teach. I reminded parents of my commitment to protect their privacy and maintain confidentiality regarding our discussions. Consequently, I recognize my potential bias as a Latina, as a child of immigrant parents, as an educator of many of the multilingual learners in the district, and as an advocate for the rights of these students. As a Latina, I also need to recognize that I might feel compelled to assist sometimes, and I must acknowledge my affinity as a factor that could inform my observations. In essence, as the lead researcher in this study, my role was to observe, participate when asked, and record without bias, inasmuch as this was possible.

I addressed my potential researcher bias by utilizing member checks of observation and interview transcripts. Member checks are the use of participants to review transcripts and initial findings. All interview transcripts were reviewed by teacher and parent participants. In addition, I have had the cooperation of a researcher colleague to review my analysis and interpretation of findings in the field. Furthermore, I am aware that children are considered part of a vulnerable population and, as such, I planned and prepared prior to my interviews to create rapport with the children and "…create a relaxed interactional space" (Danby, Ewing, & Thorpe, 2011, p. 76) in their classrooms.

In summary, my experience as a bilingual/ESL teacher working with multilingual learners from ages 4 to 11 proved invaluable in working with this same population during my research, and my expertise was also tempered with the knowledge of their vulnerability as young individuals.

**Data Analysis**

The data analysis process consisted of rigorous procedures to capture the experiences of the key participants. The scope of data analysis included the organization, management, and categorization of data for the purposes of reflection and interpretation. During data analysis, I began with a large collection of data and utilized an inductive process to go from exploring specific responses or observations to creating more general codes across the data in a deductive mode (Merriam, 2009). The research study included four forms of data collection: interviews, classroom observations, audio/videotapes, and documents. Outlined below are the procedures completed for the six phases of analysis incorporating the various data sources to arrive at holistic findings.

**Phase 1.** Analysis of the data began when it was collected. Hence, after each teacher interview and classroom observation, the field notes were reviewed. The reviews resulted in further insights and information that were recorded in memos and served as input to inform subsequent interviews and observations. For example, if during an observation, the student was engaged in a specific topic in science, this information would be utilized to guide the discussion of the child's subsequent interview on the topic studied. In addition, the information gathered in the notes provided data to share during teacher observation debriefs and parent interviews. After data collection was completed, then the field notes, observation videotapes and audiotapes, and interviews were transcribed into Microsoft Word. The transcriptions were then loaded into a password protected Cloud-based study database by school, teacher, focal student number, study date, and type of data recording. These transcriptions created the basis for deeper analysis for the next phase.

**Phase 2.** During the second phase of data analysis, the videotapes provided input to the multimodal communication data of teacher and student interactions. Following the procedures outlined by (Zhang, 2016), each classroom observation videotape was viewed again. During this iteration of analysis, the transcript was loaded into a two-column table to create a new file for the purpose of documenting multimodal forms of communication (Bruna, Vann, & Escudero, 2007; Jaber & Hammer, 2016; Roth, et al., 2011). Thus, the left column contained the teacher's oral communication, and the right column contained her -non-verbal communication. While viewing the video this time, the focus was on how the teacher communicated via gesture or demonstration. The two pieces of data, teacher oral communication (transcribed in Phase 1), and teacher multimodal communication, were then synced to create a version of the observation that included the original transcription amended with the multimodal interactions of the teacher. In this way, when the teacher was instructing the class about a topic, and then made gestures in conjunction with her speech, those gestures were captured in the transcript in a separate multimodal analysis column associated with her speech. Throughout this process, I wrote memos with my thoughts and questions regarding the classroom interactions. These new multimodal files became input for subsequent analysis of the focal student during science instruction.

**Phase 3.** During this phase of analysis, the response of the child was captured to create a more complete picture of their classroom interactions during science instruction. Once again, the video was viewed, but this time the purpose was to capture the response of the child in connection to the instruction and to amend the multimodal column with the new data. Thus, as the teacher spoke, what the child did simultaneously via language or gesture was captured. In addition, if the child interacted with a peer, the audiotape was also reviewed, and that interaction too, was also documented in the multimodal column. In this phase, the language of instruction was also scrutinized for academic language. Notably, if academic language was used it was highlighted. The data on language was added to a third column in the file. Once again, throughout this process, I wrote memos with my thoughts and questions regarding the classroom interactions, and the use, development, and support of academic language. As a result, at the end of this phase of the analysis, the multimodal transcript contained the language of instruction, the teacher's multimodal communication, and the focal student's multimodal responses.

**Phase 4.** While the transcripts now captured the language of instruction and the multimodal interaction of the teacher and students, it did not explicitly capture the visuals utilized to support instruction. The next step included viewing the video again, but this time the purpose was to capture visuals, materials, or other resources related to instruction. For example, if an image was displayed on the board, a description of the image was included. If videos were viewed during instruction, then those images in the video were described. Likewise, if the teacher demonstrated a worksheet or additional resource for instruction, it too was captured in the multimodal transcript file. The instructional content is comprised of the actual curriculum and what the teacher chose to deliver from the curriculum, that is, the difference between intended and the enacted (Aguirre-Munoz & Amabisca, 2010). Throughout this process, I continued to write memos with my thoughts and questions regarding the classroom interactions, the content of visuals utilized to support instruction, and language use. As a result, at this point in the analysis, the multimodal transcript files were a comprehensive collection of data comprising the visuals and artifacts used for instruction, as well as the language and multimodal responses to the instruction during science for the focal student.

**Phase 5.** The next step included annotating the focal students' interviews with their responses from their interactive science journal. This step included reviewing the e-book and any student worksheets, as well as viewing the video where the child worked on their journal. Thus, this transcript too, included the language of instruction, the student's multimodal response, and how visuals were interlaced in the delivery of instruction. Again, during this process, I continued to write memos with my thoughts and questions regarding the student's classroom interactions. This analysis of the student's interview captured the student's writing in their journal and efforts at meaning making or understanding science. As shown above, the various components of the study were transcribed into MSWord documents, then uploaded to a Cloud database, and finally, all the files were uploaded into Dedoose, a web-based data analysis tool.

**Phase 6.** The next phase of qualitative analysis moved from reading and memoing to description, classification, and interpretation of the data (Creswell, 2014). Dedoose enables researchers to explore data, identify and describe patterns, and create/write memos during data analysis (Hays & Singh, 2012). The use of the Dedoose tool facilitated the analysis and coding of data from "tentative codes" to aggregation into categories (Creswell, 2013, p. 185). These initial codes were based on the research questions and a review of the literature constructed prior to the commencement of the research (See Table 1). In essence, the initial coding included a review of each focal student's data, coding excerpts that supported the tentative codes, and adding new codes or sub-codes as guided by the data.

**Table 1**

Research Questions and Methodology

| Research Question | Data Collection Methods | Data Analysis Methods/ Codes |
|---|---|---|
| 1. Are Latino first-grade multilingual learners in a mainstream classroom able to gain access to the resources, tools, learning, and language of the science curriculum? If so, how? | 1. Classroom observations<br>2. Teacher interviews<br>3. Parent interviews<br>4. Student interviews<br>5. Artifacts:<br>a. Lesson plans<br>b. Pacing guide<br>c. Science curriculum<br>d. Science text<br>e. Student interactive science journal<br>f. Student products: worksheets, projects, inquiry, hands-on activities<br>6. Resources used: e.g., materials, teachers, peers, charts, etc.<br>7. Tools used: science tools, interactive science journal, etc. | Dedoose<br>MSWord<br>MSExcel<br><br>Creating memos, coding, identifying themes and patterns, and making meaning across categories<br><br>Potential initial codes:<br>1. Student engagement<br>2. Peer relationships<br>3. Agency<br>4. Comprehensible input<br>5. Tool use<br>6. Resource use |
| 2. What barriers and supports for accessing the science curriculum exist for Latino multilingual learners? | 1. Classroom observations<br>2. Teacher interviews<br>3. Parent interviews<br>4. Student interviews<br>5. Artifacts:<br>a. Lesson plans<br>b. Pacing guide<br>c. Science curriculum<br>d. Science text<br>e. Student interactive science journal<br>f. Student products: worksheets, projects, inquiry responses, hands-on activity responses, homework | Dedoose<br>MSWord<br>MSExcel<br><br>Creating memos, coding, identifying themes and patterns, and making meaning across categories<br><br>Potential initial codes:<br>1. Student engagement<br>2. Peer relationships<br>3. Incomprehensible |

| | | |
|---|---|---|
| | Resources used: e.g., materials, teachers, peers, charts, etc.<br>Tools used: science tools, interactive science journal, etc. | input<br>4. Scaffolding<br>5. Agency<br>6. Lacks prior knowledge<br>7. Lacks background<br>8. Tool use<br>9. Resource use |
| 3. Does the first-grade mainstream classroom teacher scaffold science content to make it accessible to Latino multilingual learners? If so, how? | 1. Classroom observations<br>2. Teacher interviews<br>3. Parent interviews<br>4. Student interviews<br>5. Artifacts:<br>a. Lesson plans<br>b. Pacing guide<br>c. Science curriculum<br>d. Science text<br>e. Student interactive science journal<br>f. Student products: worksheets, projects, inquiry, hands-on, homework<br>6. Resources used: e.g., materials, teachers, peers, charts, etc.<br>7. Tools used: science tools, interactive science journal, etc. | Dedoose<br>MSWord<br>MSExcel<br><br>Creating memos, coding, identifying themes and patterns, and making meaning across categories<br><br>Potential initial codes:<br>1. Comprehensible input<br>2. Grouping by L1<br>3. Materials reflect diversity<br>4. Background knowledge<br>5. Connections to text<br>6. Connect to prior learning<br>7. Use of visuals<br>8. Check-in with multilingual learners |

As analysis continued, and multiple reviews of the data occurred, the codes grew from an initial list of 17 to 54. As I expected, such categories as agency, peer relationships, scaffolding, and student engagement were found in the data. Reviewing the data again in Dedoose revealed the need to include codes generated from the data itself, or “in vivo codes” (Creswell, 2013). This “in vivo” coding was gathered from all data: the parent interviews created codes on parent communication and awareness. Meanwhile, the teacher interviews generated codes on the curriculum and professional development. Likewise, the observations revealed the need for more granularity, or in “situ codes” (Creswell, 2013, p. 184) for the type of scaffolding occurring in the context of the mainstream classroom. In brief, after data analysis occurred across all students and teachers, the coding was completed and the emphasis on common themes began.

Excerpts were downloaded from Dedoose by student and code to identify themes that occurred across the data. In an iterative process, the excerpts and memos were reviewed to explain possible patterns, themes, or questions (Hays & Singh, 2012). Subsequently, this iterative process concluded when the data revealed “themes [that] can be grouped into even larger dimensions or perspectives, related or compared” (Hays & Singh, 2012, p. 132). Through the Dedoose codes and excerpts, and the OTL literature I developed themes. I sought data that supported the focal students’ access or barriers to the resources, tools, learning, and language of science. As well as data that revealed the scaffolding of science instruction by the teacher in a mainstream classroom. With this in mind, my analysis included paying attention to the unexpected and contrary, that is, reflexivity on my part (Creswell, 2013).

In the last analysis, themes emerged consistent with exploring the content, context, and experiences of multilingual learners OTL science. The themes revealed were compatible with an OTL framework for multilingual learners, inclusive of linguistic and socio-cultural factors, within the instructional processes of curriculum quality and teaching quality (Aguirre-Munoz & Amabisca, 2010). The codes “academic expectations,” “curriculum meets needs,” and “student engagement” combined to describe the curriculum quality. The most prominent among these, “student engagement,” provided insight into how the curriculum met students’ needs and curriculum expectations. Next, “scaffolding,” “teacher knowledge of students,” and “teacher Professional Development (PD)” were the most prominent codes in teaching quality. Reviewing these codes created an image of lesson delivery and the teachers' support of the multilingual learners in the classroom. Finally, the codes that most highlighted linguistic and cultural barriers to access were "incomprehensible input," "student prior knowledge," and "student English language proficiency." The curriculum quality, teaching quality, and individual student characteristics either supported or posed barriers to science instruction for these learners. In conclusion, the data analysis revealed themes consistent with opportunities for multilingual learners to acquire science content knowledge in the context of a mainstream classroom.

**Cross-case analysis**. Following the analysis of each student's experience and the development of themes, a comparative analysis occurred. Once again, utilizing Dedoose and the existing codebook and categories, an iterative process commenced. The comparisons occurred as follows: 1) students within a school, 2) students across schools, 3) teachers within a school, and 4) teachers across schools. This data analysis affirmed findings and differences, within and across schools. At this point, the data had been sufficiently reduced, and the possibility of further categories exhausted. In summary, the data analysis process comprised rigorous procedures to address the research questions, concluded when categories were exhausted, and proceeded to interpretation and reporting.

## Findings from the Analysis

The data were assembled into quotes from the transcript to create descriptions of the findings. In conclusion, I reviewed transcripts, documents, and student products to develop generalizations regarding the experiences of first-grade multilingual learners in a mainstream classroom with the expectation of gaining insights into their opportunities to learn science.

**Validity**

For the purposes of this study, I employed “triangulation by using three methods of data collection—interviews, observations, and documents” (Merriam, 2009, p. 216). In brief, I utilized multiple sources of data to substantiate the reality in the classroom—interviews, observations, and documents. In addition, member check-ins served to validate or refute my analysis. Prior to finalizing findings, transcripts were shared with teacher participants to establish an accurate depiction of the interviews and observations. This helped ensure internal validity or “…how research findings match reality” (Merriam, 2009, p. 213). Furthermore, patterns and findings were also loaded into MSEXCEL tables to facilitate the analysis of a reduced dataset and allow for a “peer review/examination: discussions with colleagues regarding the process of study, the congruency of emerging findings with the raw data, and tentative interpretations” (Merriam, 2009, p. 229). Thus, member participants and external researchers analyzed the findings for validity. In summary, the research process included triangulation, member checks, and peer reviews to ensure validity and credibility of my case study analysis.

# Chapter 4: Description of Findings

The findings revealed how the content and context for learning, created both opportunities and barriers for multilingual learners to learn science in a mainstream classroom. The content of instruction centered around a new curriculum that comprised the Next Generation Science Standards (NGSS). The focus of NGSS is to promote scientific thinking while engaging in inquiry based science rather than simply learning scientific facts (Lee, Quinn, Valdes, 2013). The context, a mainstream classroom, consisted of lessons where both scaffolding and linguistic barriers impacted the accessibility of the science curriculum. The findings were consistent with an OTL framework for multilingual learners, inclusive of linguistic and socio-cultural factors, within the instructional processes of curriculum quality and teaching quality (Aguirre-Munoz & Amabisca, 2010). In lieu of examining the results as isolated examples of instructional processes where curriculum quality and teaching quality can be dissected, I opted instead for narratives of one science lesson in each classroom. Although I chose to portray only one lesson in each classroom as an example, the findings were consistent across all lessons in the observed classrooms. I chose narratives to better capture and convey the experiences of the study's participants.  The narratives made visible: the students' access to content, teacher's support of students, scaffolded instruction, and linguistic barriers through a more holistic view of the lessons I observed. Interwoven in the narratives are the stories of teacher perseverance with a new curriculum and the presence of linguistic barriers when the language of the lesson became complex. Thus, each narrative will contain a lens through which one can examine how student engagement, teacher support, and teacher scaffolding, all combined to create access or barriers to learning.

**Student Engagement During Science**

Inherent in inquiry-based science is the requirement that students engage in classroom activities centered around acquiring science knowledge. The NGSS define what students need to do in an inquiry-based science classroom, including the acquisition of engineering practices. The expectations are that students will be:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

(National Research Council, 2012, p. 42)

During inquiry-based science, students participate in classroom activities where meaning making, understanding, and communication occur (Lee, Quinn, & Valdes (2013), (Samarapungavan, Patrick, & Mantzicopoulos, 2011). Accordingly, when students participate in classroom activities they are engaged behaviorally, and when they spend time on task, they are engaged academically (Reschly & Christenson, 2012). For the purposes of my study, I sought examples of both behavioral and academic engagement. That is, observable manifestations of engagement. First, I examined each focal student's behavior for an indication that they were participating in classroom science lessons. Secondly, I analyzed the student's interactions for evidence of time on task. Therefore, engagement analysis relied on answering two questions: 1) did the focal student participate in the classroom activity, and 2) was the focal student on task for the duration of the event? In essence, one aspect of the classroom observations was the focal student's engagement during classroom science activities.

**Meaning making in science.** The NGSS framework consists of eight science and engineering practices that require discourse as students engage in meaning making. In the lower grades, student science journals are a common tool utilized in the depiction of models and science sense-making. That is, the students are asked to understand and then communicate that understanding. Upon completing an activity, students will record their observations, label their diagrams, and make sense of the science learning they have just experienced. “Students are encouraged to use their journals to record observations, develop explicit representations of their models, and analyze their experiences and understandings of what they are learning in science” (Quinn, Helen; Lee, Okhee; Valdes, Guadalupe, 2012, p. 8). The journals are a basis for these young learners: 1) to communicate an explanation based on the evidence they have gathered, 2) to use for argumentation to express their understanding, and 3) to ultimately depict their refined arguments based on agreed upon conclusions with peers. Thus, as part of my observations, at the conclusion of a science lesson in a first grade classroom, I would expect to see discourse focusing on the explanation of models, argumentation based in evidence, and a final evaluation of the explanation of the phenomenon or system under study.

## Multilingual Learners Gain Access to Science Content

In this first section, I discuss the findings of how multilingual learners in my study gained access to the curriculum. Subsumed in this section are: data on the curriculum content, student engagement, barriers to access, and students’ meaning making during science instruction. The study included observations and interviews of four students, their teachers, and their parents, across two schools (the Herald School and the Oak School). As a result, I will discuss each student individually in the context of their respective school. Subsequently, I will compare the two students within their schools. This will be followed by an analysis of students across schools. To summarize, students will be analyzed individually, within schools, and finally across schools to assess their opportunity to learn science.

**Science instruction within the Herald School**

**The science schedule.** The weekly science schedule at the Herald School was guided by the first grade teachers' decision to rotate science with social studies. What this meant was, one week they would do science for five days, and the next week they would do social studies. In the Herald School, Miss Negro, adhered strictly to the district's curriculum pacing guide, and the curriculum's e-book was the basis of the lessons. Therefore, she followed the published sequence and pace of lessons for science. Thus, while her lessons followed the pacing guide, the timing of science prolonged units across a longer period of time.

**In the classroom.** The observations at the Herald School were conducted in one classroom and were preceded by a teacher interview. The observations began in January and culminated in February. There were two students observed in the classroom, but not concurrently. The first student observed at the Herald School was Victor. The teacher, Miss Negro, was a novice first grade teacher entering her second year of teaching. Her class was comprised of 17 students, four of which she identified as multilingual learners during a pre-observation interview. Upon examining the school's database for the class, I discovered that four of her students' home language was Spanish, and two others home language was Telugu. Therefore, 35 % of the students in her class spoke or heard a language other than English at home. Miss Negro did not have any specific training for working with multilingual learners. However, she acknowledged taking a methodology class in second language acquisition, but she did not feel it was quite the same as working with the multilingual learners in her class.

In Miss Negro's class, science lessons were conducted in the afternoon. Usually, the students had a brain break prior to science, where they did breathing exercises or danced. Science usually began between 1:40 and 1:45, and it ended at 2:20, at which time students packed up for the day and prepared to go to fine arts. Thus, science instruction was approximately 35 – 40 minutes long each day occurring on a bi-weekly basis.

**Focal Student 1: Victor's Background**

Victor, a six-year old, born in the United States, was one of the study's participants. He came from a Spanish-speaking home. In kindergarten, Victor's parents declined bilingual services, and he received no English language development (ELD) support that year. After six months in kindergarten, his English proficiency was assessed using the World-Class Instructional Design and Assessment (WIDA) ACCESS test, an assessment tool used by 39 member-states in the United States (WIDA, 2018)[1]. Victor scored 1.6 on the WIDA Assessment, a level one, with six being the highest level (WIDA, 2009). Thus, according to WIDA, he had the English proficiency level of a student at the beginning stages of acquiring a second language. As a result, according to WIDA standards, his instruction should be guided by "pictorial or graphic representation of the language of the content areas; words, phrases, or chunks of language when presented with one-step commands, directions, WH-questions, or statements with visual and graphic support" (WIDA, 2009, p. iii). While he was still not English proficient when he began first grade, he was provided with Basic Skills Services. His Basic Skills lessons focused on phonemic awareness and learning how to decode words. As a result of his parents' decision to decline services, in first grade, again, Victor received no ELD support.

[1] An assessment tool used by 41 member-states and territories of the United States, and 400 International Schools.

## Victor's Engagement in Science

**The introduction to the lesson.** Over the course of three days, Victor participated in three lessons on the topic of *light*. Victor, like all students in the class, always sat on the rug in an assigned seat. When I entered his class for the first observation, Miss Negro was reviewing, "Lesson 2: How Do Materials Block Light?" (DiSpezio, Frank, Heithaus, & Sneider, 2018). This lesson was part of "Unit 3: Light" (DiSpezio, Frank, Heithaus, & Sneider, 2018, p. 79). The topic had been introduced two weeks earlier (recall, the science lessons were interspersed with social studies and occurred bi-weekly). Miss Negro began by discussing the students' observations of over a week ago, where they discussed how light traveled through objects.

Miss Negro: It's time for science. Let me make sure my magic pen works. All right, friends. It's been a little while since we've talked about science. 'Cause last week we were talking all about…We were doing social studies, and we talked a lot about Martin Luther King, Jr. And it's been a little while since we talked about science. So, we are going to jump right in. Who remembers what we were talking about? What were we learning about in science? Some fun science experiments. We did some fun science experiments. Um, I hear too much noise. Lisa.

Lisa: How light goes through stuff?

Miss Negro: Oh, how light goes through certain things. So, we were talking about light, and Lisa mentioned how light goes through stuff. What does it go through? What did we? What was that experiment that we did, Lisa?

Lisa: We had many tools, the book, and we take turns by our numbers to flash the flashlight on some stuff we pick

In this moment, no objects or images were visible during the start-up to guide the conversation. In the previous lesson, the class used flashlights to look at objects and see how light traveled. At the beginning of the lesson (see line 1, where Miss Negro says, “It’s time for science”), Victor is behaviorally engaged; he is looking at her. But by the time she starts explaining what they will discuss (line 2), “All right friends…”), he is no longer looking at her. Meanwhile, his peer Lisa is discussing (line 8), “How light goes through stuff?” At this point in the lesson, Miss Negro is attempting to tap into prior knowledge and asking students to recall the previous lesson.

**Issues That May Help or Hinder Meaning-Making During Science**

**Vague language in the lesson.** On line 8, a peer responds to Miss Negro with, “How light goes through stuff?” Then, Miss Negro comments (line 10), “…Lisa mentioned how light goes through stuff. What does it go through? What did we? What was that experiment that we did?” The language is about light and how it *goes through certain things and goes through stuff*. The discussion relies entirely on the students’ recall, as there are no images visible to guide the children’s thinking and no exact or specific language/vocabulary being re-introduced.

During most of the introduction, Victor just looked around the class and at Miss Negro. She continued to try to engage the class. Once again, Lisa responded (line 12) as follows: “We had many tools, the book and we take turns by our numbers to flash the flashlight on some stuff we pick.” In that moment, Victor did not attend to Lisa’s response or to Miss Negro. The lesson continued as follows:

Miss Negro: And what did we learn about the light when we flashed it on certain objects? What did we learn about the light?

Lisa: That at some stuff, it won’t go through, and some stuff it goes in. Some light goes through, and the other more. And the other objects, the light goes in it for light goes in it.

Miss Negro: Exactly! So, we talked about as Lisa said, how sometimes the light goes through all the way, all of the light shines. And then in some objects, only some of it shines through, and then sometimes none of it shines through. It blocks all of it. Who remembers an object where all the light passed through? What object did all the light passed through? Anyone remember? Let's think. Luke.

Luke: A plastic bag.

Now, Victor attended to Lisa when she said (lines 3–5), "That at some stuff, it won't go through, and some stuff it goes in. Some light goes through, and the other more. And the other objects, the light goes in it for light goes in it." So, by this point in time, Victor has heard: "it won't go through," "it goes in," "some light goes through," and "it goes in it." The language is not clarified or unpacked. There is no explanation about how light goes: "through," "in," or "in it." For Victor, a student who is in the early stages of second language acquisition, the discussion language is not supported with visuals or broken into smaller chunks. Yet (line 5), Miss Negro says, "Exactly!" However, her exclamation begs the question: *Exactly what?* The discussion language continued to be vague. Miss Negro gestured (lines 5 and 6) and said, "…sometimes the light goes through all the way." Here, she was scaffolding with a gesture to demonstrate how the light can go all the way through. Unfortunately, Victor did not look at Miss Negro or her gestures. He did not attend to the explanation or gestures for the word *through*. Victor originally attended to the start-up of the lesson, but did not maintain attention for the rest of the introduction, perhaps because the language—"light goes through stuff"—did not assist Victor in comprehending or making connections to the prior lesson almost two weeks ago. Again, there were no images to help elicit his recall of the prior lesson. In brief, Victor just looked around the room; without linguistic scaffolding the language of the lesson had, perhaps, become incomprehensible.

During the next segment, once again, Victor appeared to be behaviorally engaged, as he looked at his peer. He may have connected to some of the objects mentioned early in the conversation—a plastic bag, a dollar bill. Then the familiar was followed by more complex yet vague language again. The segment began as follows:

Miss Negro: Ah, the plastic bag. All of the light went through the plastic bag. What about something where only some of the light went through? Oh, raise your hands. Harjeet?

Harjeet: The dollar bill.

Miss Negro: Oh, the dollar bill.  Only some of the light went through. What about none of the light went through?  None of the light. It completely, all of it, none of it could go through? Mary?

Mary: The black paper.

Miss Negro: The black paper, some of it did go through the black paper. Remember, we were a little bit surprised by that. I'm looking for somebody who's in whole body listening position. Kate.

Kate: The book.

Miss Negro: Oh, the book. None of the light went through the book.

During this sequence, Victor looked behaviorally engaged. He may have connected to the comment (line 1), "All of the light went through the plastic bag." Then (line 4), he looks again when his classmate comments, "The dollar bill." He appeared to be attending to the lesson. Then, the word *through* came into the conversation (lines, 5, 6, and 7), and Victor appeared to disengage from the discussion. The lesson had gone on now for about six minutes, and Victor had heard: “light goes through,” “light goes through certain things,” “what does it go through,” “some stuff it won’t go through,” “some stuff it goes in,” and “light went through.” The word *through* appeared in this segment of the lesson 18 times with only a single supporting gesture for *through*. There was no discussion of the word. The assumption was that he understood. The discussion concluded without a single demonstration of the materials from the lesson two weeks prior. In brief, the introduction to the lesson contained extensive oral explanations of events and much incomprehensible language in explaining those events.

The lesson introduction was not over; it would segue into a new idea about light. It transitioned from light sometimes going “through stuff,” to how light travels. Miss Negro was moreover continuing by trying to connect a prior science lesson from two weeks earlier, to the day’s language arts lesson. She introduced the topic and began asking questions, “What does it mean when something travels?” She repeated the question again, but with a slight variation, “When something travels, what does it mean when something travels?” One student responded with, “It moves.” Miss Negro scaffolded this segment by mentioning the previous class experiment and the text read earlier in the day, *Let’s Go to the Moon*. The book was not displayed. However, she was attempting to tap into the students’ prior knowledge about travel to the moon. She went on to say:

> It moves, yeah. How things get from here to there. How it gets from one place to another. So, friends, today we are going to talk about how the light travels. How the light gets from here to another place. And I have some flashlights, and we’re going to talk about that a little bit.

Victor appeared to behaviorally engage with the new discussion. He was attending to the discussion. He was watching as Miss Negro gestured toward the board, and commented on how, “It moves…” Once again, the language was vague with comments such as, “how things get from here to there." *What things* get from here to there was never clarified. Miss Negro also mentioned the students were going to see flashlights. Victor looked at Miss Negro during the exchange. However, the flashlights were not presented in that moment. In brief, he was behaviorally engaged and waiting to see or hear what was coming next despite vague and unscaffolded language.

**Images and queries that do not match.** The lesson pivoted again to a new topic, and Miss Negro used the science curriculum's e-book's visuals and audio. She utilized the e-book clip to introduce the topic of the day's lesson. The image on the screen was a large sculpture in Chicago surrounded by skyscrapers. The title on the page was, "Light in Your Eyes" (DiSpezio, Frank, Heithaus, & Sneider, 2018, p. 112). The accompanying audio commentary stated, "Light travels in a straight line. Sometimes, light can bounce off something, and go in a different direction. As you explore this lesson, you'll find out how materials reflect light. And how people communicate with light" (DiSpezio, Frank, Heithaus, & Sneider, 2018, p. 112). During this e-book audio, Victor was attending to the board and listening. However, there were no animated objects, no bouncing to see, and no accompanying explanations. It was just an e-book audio comment to introduce the lesson. As soon as the audio completed the second sentence, "Light travels in a straight line." Victor could be seen looking away from the board, looking around the room, rocking back and forth on the rug, looking straight at the Surface Tablet recording the class, and finally stretching. He was behaviorally disengaged; he no longer attended to the board.

Next, Miss Negro sought to engage the students in a discussion about the images on the screen with a prompt. She began the discussion with several questions. "What do we see in this picture? What do you see in this picture? Do you see anything?" The topic of the day was:

"How does light travel?" Here, once again Lisa responded with, "The very tall building." Then Briana said, "The circle." Miss Negro went on to explain that the image displayed from the e-book was "The Bean" sculpture in Chicago, surrounded by skyscrapers. The shiny sculpture resembled a bean, and it reflected the objects surrounding it. At no point in this discussion was there a connection made to students' prior knowledge of the word *reflect*, nor realia presented to display reflection, and neither was any background information provided regarding reflection. Absent was any connection to the students' prior knowledge of skyscrapers. By the time Miss Negro asked, "What do you see, Lisa?" Victor was swaying back and forth. While several students looked at the image and attempted to parse through the data presented, Victor did not. He did not appear to engage behaviorally and instead moved around. The dense academic language and images were unscaffolded. Thus, while he had the use of visuals to assist him with the content, without adequate linguistic support he appeared unable to engage academically with this segment of the science lesson.

Non-existent, almost 11 minutes into the lesson, was an explanation of the images, words, or phrases from the e-book. When Miss Negro further asked, "You see what's around it. Is it really boring or is it shi-i-i-n?" For a brief moment, Victor looked at "The Bean." He had just heard the audio's five phrases of academic language: "Light travels in a straight line. Sometimes, light can bounce off something, and go in a different direction. As you explore this lesson, you'll find out how materials reflect light. And how people communicate with light" The audio used the phrases: *bounce off, straight line, different direction, materials reflect light*, and *people communicate with light*. Now, Miss Negro added *shiny*. Victor had to parse even more data to get an understanding of the topic presented. Miss Negro did not explain the word *shiny* further, nor bring in an object that was shiny, nor reference a shiny object in the room. The language of the audio was not further elaborated nor explained. In short, in addition to understanding what happened to light *going through*, and then light *traveling*, Victor had even more language to process.

During this first e-book audio segment, there was an immense amount of academic language for a student at the beginning stages of English acquisition to comprehend. Again, the audio contained the phrases: *bounce off, straight line, different direction, materials reflect light*, and *people communicate with light*. These phrases alone can be complex, but given in quick succession, they can create a linguistic barrier for the novice. Notably, there was no further definition of *bounce, straight, direction, materials, reflect,* or *communicate*. In fact, there was no explanation of the reflecting skyscrapers on the sculpture.

**Perhaps, a relatable moment.** Once again, Miss Negro utilized the e-book to present another discussion on how light travels, the lesson's topic. She chose to share a short e-book clip with the students, to which she was sure they could relate. The e-book audio and its associated image focused on light moving into a classroom window, with a title, "Light in Your Eyes" " (DiSpezio, Frank, Heithaus, & Sneider, 2018). The audio commented, "Think of a time when light shined in your eyes. Play the video to see the problem in action. As you watch the video, think about ways to solve the problem." Miss Negro introduced the discussion that ensued and commented, "Let's watch the video. We've had this problem in class, right?" Immediately Lisa replied, "Miss Negro, when I'm sitting like this in class light came in my eyes." This back and forth between Miss Negro and Lisa mimicked the E-book audio. The audio then stated, "Oh, no, the sun has moved and is shining right in Jayden's eyes. Has this happened to you before?" During this exchange, Miss Negro shared an image of a student at a desk, near a window as the light shone in his eyes. She presumed that the idea of light shining in one's eyes was relatable to the students in her class. However, only one student, Lisa acknowledged the experience.

Next, Miss Negro wanted the class to respond to the E-book's question, "How could you point light away from your eyes." She further elaborated on the video's question. She asked:

> How could you point light away from your eyes? So, friends, you might not know the answer to this question yet. You might not know the answer to this question yet, but that's ok. I just want to get your ideas. If the light is shining in your eyes, how can you point it so its getting away from your eye? So, it's not in your eyes anymore.

She asked the class to "Turn and Talk." Victor immediately turned toward his partner to listen. During this time, Miss Negro walked around and listened to responses, while also engaging the students in thinking more deeply about the question. She asked again:

> How would you make it so the light is not in your eyes anymore?" Point it away from your eye. You don't want the light in your eyes. How are you going to point it away from my eyes? Is that going to change the light? The light is still going to be in the same spot.

When Miss Negro stopped at Victor and his partner she asked, "Is that going to change the light?" Victor nodded "no," and then he said nothing in the exchange with his peer. He sat and listened. Miss Negro went around listening, she found that the students' responses appeared to focus on stopping the light from disturbing them, that is, blocking the light. They did not identify how to make the light move. Thus, their responses coincided with their previous lesson on how materials block light.

During the "Light in Your Eyes" segment, the idea of light traveling was not mentioned. Miss Negro did not mention light traveling through the window either. Next, she wanted to focus on the clip and have the students elaborate on the visual. She lauded them on their ideas during the Turn and Talk. The students had focused their attention on blocking the light, and now when she asked them to look again, one student mentioned moving her seat to get out of the path of the sunlight. She prodded the students further by saying, "But listen to the question though. You moved your seat. Is it, the light, still in the spot though?" The response was, "Yeah." Miss Negro continued to remind the students that their responses meant, "The light is still in the same spot." She repeated the question commenting, "The question is asking how could you point the light so it's not in the same spot anymore? So, it's away from your eyes." She quickly received another response. This time the student mentioned closing the blinds. Miss Negro asked, "And what is closing the blinds going to do?" Immediately, the child said, "It's going to block the sun." Finally, Miss Negro acknowledged, "We don't have the answers just yet, but we're going to do some experiments in this lesson that are going to help us answer that question." The idea of a relatable moment created an opportunity for students to discuss the visuals from the e-book. It was also a question to a real life problem, light in your eyes. In that moment, Miss Negro sensed that everyone in the class did not understand how light travels.

While the science curriculum presented the concept of light in your eyes, the students did not make a connection to light traveling, but rather to ways they could get out of the way of the light. Their responses were about changing seats or blocking light from their eyes with the blinds, but did not engage the topic of changing how light travels. The class had been sitting for nearly 17 minutes, and the students were getting visibly restless. Victor had repositioned himself further back, in an almost reclining position during this exchange. Miss Negro had just mentioned doing some experiments. The idea of an experiment was meant to solicit excitement for the next part of the lesson. The students were ready for an experiment, but there was one more e-book audio clip to share. The e-book audio commented, "By the end of this lesson, I will be able to explain how smooth surfaces reflect light and how to communicate with light." The class and Victor appeared more restless. The image and language accompanying the audio had not been deconstructed. Instead, Victor and his classmates were confronted with an image of a lighthouse overlooking a beach cliff. How did this image correspond to light in your eyes? What was the lighthouse doing overlooking the cliff? There was no discussion of the images on the board or the role of lighthouses in communicating via light. There were no smooth surfaces in this picture to demonstrate light reflecting onto a smooth surface. In addition, the words—*smooth, surface, reflect,* and *communicate*—were not clarified. The concepts and images associated with communicating with light were not scaffolded. The question, “How could you point light away from your eyes?” remained unanswered. Thus, what was meant to be relatable, might have become another linguistic barrier for Victor, who might not understand smooth surfaces, communicating with light, or the role of a lighthouse.

**A demonstration to clarify the discussion.** As a follow up to the previous e-book clip, Miss Negro conducted a three-minute demonstration of a flashlight shining on objects in the room. The demonstration was meant to help students understand how light travels. It went on as follows:

Miss Negro: Friends. Miss Negro turns the flashlight on. And I point it up at the ceiling. Where did the light go?

Students: Up. Up there.

Miss Negro: It went where? Where does it ... what is it touching?

Students: The ceiling.

Miss Negro: Ceil- Okay.

Child 1: Everything above us.

Miss Negro: It’s pointing wherever I move the flashlight. Okay. Now what if I take the flashlight ... did it move back? I’ll take my flashlight and I’m pointing it up at the ceiling, it goes straight up to the ...

Students: Ceiling.

Miss Negro: Okay. Now what if I take the flashlight and I point it ... let's see how far it goes. Over there.

Melissa: I see it.

Students: Right over there.

Miss Negro: It goes straight to where?

Miss Negro: Straight to the floor. Where is it not pointing anymore? Where is it not pointing anymore?

Briana: On the ceiling. Can I tell you something?

Miss Negro: Yes, Briana, what do you need to tell me?

Briana: The light has a shadow.

Miss Negro: It has a shadow? What do you mean it has a shadow? You see the light? You see the light on the floor. It's moving. Remember it's traveling from here to there.

Briana: There.

Miss Negro: To there. Here to there. Is it going like there and there and then there and then there and then there and then there and then there and there?

Child 2: No.

Miss Negro: How is it moving? What direction is it moving friends? What direction is it moving? It starts over here and it ends up right over there. It starts over here and it ends up right over there. Which direction is it moving? How is it moving, Lisa?

Lisa: It's moving when you moved the flashlight, whenever you want to put it up here. If you put it down there, then the light goes down.

Okay. So wherever.

Miss Negro: Okay. Friends, the light, it’s moving in a straight line. It’s not going up and then down and then this way and then this way and then that way. It’s going straight across. So, let’s take a look at what they do with the flashlights over here. Let’s take a look. Come on.

Victor’s response to this activity was that he initially followed as the light shone on the ceiling. He was momentarily behaviorally engaged. Yet even then, when everyone says (line 11), “ceiling,” Victor does not. He never followed along when the light moved to the floor. Victor participated briefly in the activity and then he was off task. When Miss Negro asked (lines 26-27), “Is it going like there and there and then there and then there and then there and then there and there?” Most students responded, “No.” Victor was not among the respondents. The pace of the demonstration was quick, and the language included “there” repeatedly, but not the words *ceiling, board,* or *floor*, that is, the names of the objects the flashlight pointed toward. Then (lines, 29–31), Miss Negro commented, “How is it moving? What direction is it moving friends? What direction is it moving? It starts over here, and it ends up right over there. It starts over here, and it ends up right over there. Which direction is it moving? How is it moving?” Lisa, one of the usual respondents, was selected to respond, and she said (lines 32 and 33), “It’s moving when you moved the flashlight, whenever you want to put it up here. If you put it down there, then the light goes down.” Thus, went the demonstration and description of light traveling.

In this demonstration by Miss Negro, were very rapid statements, with many questions – “Which direction is it moving? How is it moving?” There was no clarification of the specific “here” or “there” location in the demonstration. Note, even Victor’s peer’s responses used “here” and “there.” Throughout the entire demonstration, Victor pursued the same pattern as previously, he looked and listened briefly, but just as quickly, he stopped looking. Victor did not spend much time on the task. The segment concluded with Miss Negro announcing (line 35) how the light traveled: "…moving in a straight line." No one said "straight" other than Miss Negro in this demonstration. In brief, the answer to how light traveled was provided not discovered, and the lesson moved on, yet again.

**More curriculum e-book visuals.** While Miss Negro did her own demonstration and guided the students to understand the concept of light traveling straight, it was not enough. Next, she resorted to showing another E-book visual to teach a new concept. Thus, for the next three minutes the students sat for more explanations and a visual of light traveling straight. The e-book display included an image of light traveling, this time through a fish tank. The e-book presented a still image, and there was no moving light to see. Miss Negro attempted to assist the students in understanding what was being displayed. She commented, "…the light, it's moving in a straight line. It's not going up and then down, and then this way, and then this way, and then that way. It's going straight across." There were no gestures accompanying the language of, "...then this way, and then that way." Here again was imprecise language to explain what was incomprehensible from the visual.

The students needed to trust Miss Negro as she explained how light moved in a straight line, and how it did not go in different directions. Now, Miss Negro engaged the students in an exploration on how light moves initiated by the e-book. While there was just one visual, the e-book prompted the students to make a selection from a possible three choices on how light moves. Hence, the e-book audio asked, "What does the light in the water tank show about light?" Then it offered the following choices: "Light does not travel. Light travels in a straight line. Light never hits objects." There was no discussion of what each statement meant, nor an explanation of “never hits objects.” The next e-book audio comment stated, “It travels in a straight line.” Miss Negro then asked, “ How is the light traveling? How would you describe this light that the light is traveling in?” The student answers that followed were, “It’s going.” And this response was followed by “It’s moving- the direction it’s moving to the right.” Miss Negro moved the discussion to ask about the light’s path. She asked, “Yes, it’s moving in that direction but how would you describe its path, like, the way it’s ...” Immediately two students shouted out. One said, “Right to left.” The other said, “It’s straight.” Notably, even though Miss Negro had just said light travelled in a straight line, she got other responses. Their responses while true were not discussed. There was no further explanation, and Miss Negro played the e-book audio responses again. Then, another response was offered by a student, “Right through the glass.” All the responses thus far were not the ones from which the students needed to select. Miss Negro was looking specifically for one of the following*: Light does not travel. Light travels in a straight line. Light never hits objects*. In brief, Miss Negro sought a specific response to answer the question and she did not receive it.

Once again, Miss Negro attempted to get the correct response. She repeated the responses again, and looked for another respondent. The final segment of reviewing the e-book visuals, concluded as follows:

1. Miss Negro: So, the water tank- Light does not travel. Light travels in a straight line or
2. light never hits the objects. How is the light traveling? How is the light traveling,
3. Sue?
4. Sue: The light’s traveling in a straight line.
5. Miss Negro: Excellent. Can you come click it for me, please?
6. Child 1: It’s B or C or D.

7. Miss Negro: Haley and Vincent, you are not focused.
8. E-book audio: Well done. Light travels in a straight line until it hits an object.
9. Miss Negro: Mm-hm. Okay, friends. So ... Victor, are you all right, friend?
10. Victor: Yes.
11. Miss Negro: Okay, friends. So the light moves straight from Miss Negro’s’ flashlight
12. and hits straight across, right, Iris? It hits straight across. It hits straight across,
13. right, Sue? It hits straight across, right, Briana? It hits straight across, right,
14. Vincent? It hits straight across, right, Haley?
15. Child 2: Yeah.

When this segment ended, the students had now been sitting on the rug for 25 minutes. The brief e-book visuals, text, and audio were an opportunity for Miss Negro to assess the students’ comprehension of light traveling. Here again were questions and responses comprised of unscaffolded language. Finally (line 4), Sue said, “The light’s traveling in a straight line.” Then, Miss Negro selected Sue to choose the correct answer on the board, to the multiple-choice question posed by the e-book. Next, the audio stated, “Well done. Light travels in a straight line until it hits an object.” It is worth noting that the audio said light travels in a straight line, but that is only until it hits an object. This was the end of this segment of the lesson. No one, not the teacher or the students, asked what happens when it hits an object.

During the final e-book segment, Victor began by looking and listening to the e-book. He was behaviorally engaged. Then, he became disengaged by the time the e-book audio commented, “…how the light travels through the water in the tank.” He began swaying, reclining, and rubbing his face. Miss Negro continued her discussion about how light travels in a straight line, and then she noticed his behavior. She asked (line 9), “Victor, are you all right, friend?" Victor responded affirmatively. She continued to tell students how light traveled, and this segment of the lesson concluded shortly thereafter. In brief, the curriculum e-book was another opportunity for the students to learn about how light travels, without doing any hands-on activity themselves.

**Time for evidence.** The final activity of the day was an opportunity for the students to write a response in their science journal, or as Miss Negro called it, their evidence notebook. She shone the flashlight on each child, which indicated that they needed to return to their seats. During the next 14 minutes, Miss Negro walked around handing each child an illustration of a flashlight, gave gluing instructions, handed out rulers, and demonstrated how to use the ruler. Afterwards, the students used their rulers to make a straight line and color the light coming out of the flashlight. The initial directions were as follows:

Child 1: Wait, what?

Miss Negro: Your evidence notebook

Child 2: It's the one with a pencil on front.

Miss Negro: This one right here, friends.

Victor: The black one. Duh. Mine is green. No.

Miss Negro: Vincent, your comments right now are very inappropriate, and I'm sorry, you've already lost your token for science and social studies. Open up to your next clean page, friends. Okay. So, Miss Negro is going to give you a flashlight, a little picture of a flashlight. Okay, friends. Where is the light coming from, friends? What is the ...

Despite not appearing behaviorally or academically engaged for the last e-book clip, and after having been on the rug for almost 25 minutes, Victor listened. He moved quickly, went to his desk, and took out the appropriate notebook. Miss Negro handed out the flashlight pictures and continued to ask the students questions as they returned to their desks. She asked them, “Where is the light coming from? What is the source of my light?” She did not explain what “source” meant, she repeated the question, and directed the students to glue the picture into their notebook. After the directions and pursuant questions, Victor commented out loud, saying, “Oh.” And then he just continued to work. Thus, went the beginning of work in the evidence notebook.

The lesson continued as Miss Negro demonstrated what the students needed to do in their journals with the flashlight picture. While Victor got up from the rug quickly, he did not follow all the instructions the teacher gave.

Miss Negro: Okay. It should be pointing ...you know you can start it at the bottom, you can start it at the bottom, you can start it at the top. Okay. But make sure that you have room wherever you glue it. And I’m going to show you exactly what we’re going to do. Okay. Glue it.

Victor: I never write the date.

Child 1: Do we need to cut it out?

Miss Negro: No, you’re not cutting it out. I already cut it for you.

Victor: Wait, what?

Miss Negro: Yeah, look at. Mm-hm

Child 1: Do we have to have a pencil?

Miss Negro: Friends, that is not your focus. Glue it in. Marvin, where’s your book? Okay. Friends, it needs to be at the top of your book. All right. Come on, friend.

Child 2: Mine is facedown.

Miss Negro: Okay. Great. Everyone’s got their flashlight?

Child 2: Yes.

Victor: Noey. I said, “Noey.”

Miss Negro: Hold on. Victor. Vincent, I need you to sit. Okay. Friends, so we have our flashlight glued in. Lisa, your eyes are over here.

Child 3: Can you make a light?

Miss Negro: I’m going to tell you what to do. Oh friends, you need to make sure that you have room to show ... turn it around so it’s going that way. Good. So, remember we talked about that light travels in what kind of line? What kind of lines?

Victor: Eww, you licked the glue! That’s gross.

Miss Negro: Victor, Victor.

Miss Negro: Linda, it travels in a straight line. So where in the flashlight is the light coming out of, friends? Point to where the light is coming out. Where is it coming out?

Child 3: The light.

Miss Negro: Point to where it’s coming out of?

Victor: Boing

Child 1: Coming out of ...

Miss Negro: Point to where the light is on the paper friends.

Child 1: How do you not know?

Miss Negro: Point to where the light is. Okay. Point to where the light is and if the light is traveling in a straight line, that means

When it was time to work in the evidence notebook, Victor went to his desk, and immediately colored his journal page. Miss Negro was demonstrating what to do on the projector. However (lines 3 and 4), when Miss Negro said, “Glue it,” he was not attending to her demonstration and is out of sync with the instructions. Victor comments (line 8), “I never write the date.” But she never mentioned the date. Next, (line 8) he said, “Wait, what?” He is holding the glue in his hand, but he looked at his notebook, and colored first. Miss Negro proceeded to remark (line 14), “Okay. Great. Everyone’s got their flashlight?” But (line 17), Victor says, “Noey.” Miss Negro acknowledged him and then continued the lesson. She went on, and (line 22) asked, “…light travels in what kind of line? What kind of lines?” However, Victor is not attending to her, but rather to a peer whom he sees licking glue. Victor very clearly commented (line 23), “Eww, you licked the glue! That’s gross.” So, now (lines 25– 27), when Miss Negro asks, “So where in the flashlight is the light coming out of, friends? Point to where the light is coming out. Where is it coming out?” Victor was off task. At line 30, he says out loud, “Boing!” At this point, he was just beginning to glue his flashlight on the page. He was clearly out of sync with the initial instructions and did not follow the directions in the sequence they were given. Furthermore, he did not pay attention to the discussion on how light traveled. In brief, for this demonstration Victor completed the tasks, but not in the prescribed sequence.

**Self-efficacy during journaling.** Victor appeared to work diligently on his evidence notebook. It was an opportunity for him to demonstrate his skills in coloring, gluing, and writing. Often the order in which he completed tasks was incongruent with the rest of the class; he colored when he should have been gluing, and then he had to catch up to what was next. When the teacher gave instructions and demonstrated the light coming out of the flashlight, he had not glued the flashlight into his notebook. Thus, when the next activity began, drawing a straight line, Victor was completing the gluing. The next focus of the activity was how light travels in a straight line. Miss Negro demonstrated how to draw a straight line from the flashlight glued on the page. As she demonstrated how to make a straight line with the ruler, she told the students, “And the ruler is showing me how to light goes straight across. It goes from here to ... it goes across the line and it ends up over there.” Miss Negro followed up her demonstration with a walk around the class to check in on students work. She repeatedly stopped to ask the students how the light was traveling out of the flashlight. However, Victor was out of sync with the class. When they were using the ruler to draw a straight line representing light coming out of the flashlight, he was just beginning to glue. He was not attending to the discussion or her comments. Thus, at the end, when Miss Negro said, “Use your ruler as a tool” and “Can you label the picture, Vincent? Label where the light is.” Victor still needed to complete gluing, draw a line with the ruler, and label the light. Despite being out of sync he continued to work diligently.

**A cloze activity.** Once the flashlight illustration activity was completed, the students were directed to complete another activity in their evidence notebooks. Next, they were directed to complete a cloze activity. Miss Negro demonstrated how they were to write the cloze sentence. The instructions for the cloze activity were as follows:

Miss Negro: So, friends, we’re going to write a little sentence. Let’s write a little sentence.

Child 1: Coloring.

Miss Negro: It’s okay. Light travels, what? In a blank line. What kind of ...

Child 1: A blank line.

Miss Negro: You have to fill in the blank. What type of line does the light travel in?

Does it go all over the place? And you have to ... does it go all over the place, and you have to fill in the blank. What type of line does the light travel in? Does it go all over the place and bounce round?

Child 1: No.

Miss Negro: It goes from one spot to the next. Light travels ... oh, I like your straight line, Victor. Good job. All right. Light is one of our words to know this week. Right?

At this point in time, Victor had caught up to almost all of the demands of completing the evidence notebook – coloring, gluing, and using a ruler to draw a straight line. Now Victor needed to complete the cloze activity, too. However, he was not the only one who did not understand what he needed to write in the journal at this point. On line 4, Miss Negro asked, "Light travels, what? In a blank line." One student gave the answer (line 5), "blank line." Then, (lines 11 and 12) Victor was commended for his straight line. However, he did not label the light coming out of the flashlight, although Miss Negro hinted to Victor, "Light is one of our words to know this week. Right?" But in that moment, she did not direct Victor to the cloze sentence. Later, when I examined his evidence journal, I saw he glued the flashlight, colored yellow light coming out of both ends of the flashlight, drew a straight line, did not label the light coming out, and he never wrote the sentence for the cloze activity. In summary, while Victor was very eager and engaged during the science journal activities, he did not perform all of the required tasks.

**Making meaning of the science lesson.** Subsequent to the students completing the guided activities in their science journals on light traveling, Miss Negro made another request. At this point in time, she wanted to assess the students' meaning making of the science lesson. After all the gluing, coloring, drawing, labeling, and the cloze activity she wanted to see what they understood about how light travels. The next set of directions were given quickly and without demonstration. They were not stressed as strongly as the flashlight illustration and cloze activity. Miss Negro said, “On your next page, if you already drew your flashlight and your straight line, draw me a picture of a different place that you can get light from. What’s a different place that you get light from?” The class had completed the activity with the flashlight image and cloze activity, now Miss Negro moved on to the final element of writing in the evidence notebooks. Victor had just completed making the straight line and was unaware of the oral instructions just given. He shouted out, “What do I make over here?” He was almost caught up, and now there was more work to be done. Immediately, Miss Negro responded, and the lesson continued.

Miss Negro: Okay. What’s another place that you get light from, Victor? What’s another place that you get light from?

Victor: I don’t know.

Vincent: You don’t know?

Child 1: (*whispers*) The sun.

Victor: The sun.

Miss Negro: The sun.

Miss Negro: The sun. So maybe you can draw me a picture of the sun and show me the light coming out of the sun in a what type of line?

Victor: [inaudible]

Miss Negro: A what type of line? In a ...

Victor: *(mumbling very low)* Straight line.

Miss Negro: In a straight line.

When Victor asked what he needed to do, the teacher responded immediately. On lines 1 and 2 she said, “What’s another place that you get light from, Victor? What’s another place that you get light from?” Victor responded, “I don’t know.” In the moment, Miss Negro did not rephrase the question. However, Victor’s peer whispered, “The sun.” Victor repeated the response, and (lines 7 and 8) Miss Negro commented, “The sun. So maybe you can draw me a picture of the sun and show me the light coming out of the sun in a what type of line?” Initially Victor’s response to the question was soft spoken and inaudible. Miss Negro asked again, “A what type of line? In a ...” Finally, Victor mumbled (line 12), “Straight line.”

The lesson was about to end, and Miss Negro grasped Victor’s attention again by asking, “All right, so friends, if Miss Negro wanted the light to shine on Victor, where would I point the flashlight? How would I point the flashlight?” Victor heard his name and raised his hand to answer the question. He was engaged in the discussion, but he was not selected to respond. Finally, the lesson was over, and all the students moved to the rug for the final few minutes of the lesson on this day.

**Culminating hands-on activity.** The only hands-on activity they would have with light on this day would occur in the last four minutes of class. It was a brief opportunity for each child to shine a flashlight on objects in the class. The students returned to the rug, and the lesson culminated with 17 students taking turns with the four classroom flashlights to see light shine on objects in the class. The purpose of this activity was to have students shine a flashlight and see that it shone in a straight line on whatever it was pointed toward. She began the activity by saying:

> Mm-hm. I’m going to give some of us a challenge. Not really a challenge, I’m going to give you a task. So, when I give you the flashlight, I’m going to give four people the flashlight, okay, friends. Marvin. And I’m going to tell you a specific spot, a certain spot where I want the light. How are you going to make it so the flashlight, the light from the

> flashlight, travels to the spot that Miss Negro tells you? Okay, friends? So Lisa, Iris, Sue, and Briana, come stand up here, please. Okay. Everyone is going to get a turn. Okay.

Immediately upon her making these comments, Victor could be heard saying, “Not me. It’s great.” He did not believe he would have a turn with the flashlight. Miss Negro did not respond, and the lesson continued.

As the lesson continued, Miss Negro engaged the students in shining the flashlight on one object first, the American flag. She did not redirect the light elsewhere. Then, she said, “Now I want it to hit, I want the light to shine on the letter N on the alphabet.” The letter N was in the alphabet spread across the upper front wall. The students did as directed. But Miss Negro then asked, “Sue, why aren’t you pointing it at the ceiling, honey?” Sue responded, “Because you said to put it at the N, but it’s not on the ceiling.” Miss Negro probed a little further to get the students with the flashlights to explain why the light did not shine elsewhere. She got two different children to respond. One child said, “It’s not shining right.” The other child said, “The light can’t reach too far.” These responses were not addressed. So, although the lesson was about light traveling, the idea of light not reaching too far was not discussed. Shortly afterwards, Sue was acknowledged when she said, “Because it’s going straight.” Throughout this activity Victor attended to where the light shone. However, at the end of this group activity, he was leaning on his friend Vincent while waiting for his turn. Miss Negro noticed him and said, “Victor, you have lost your token.” Just as quickly, Victor said, “No.” Tokens were used to reward students for good behavior in this class. In fact, although Victor did not think he would have a chance with the flashlight, he watched attentively, waited for his turn, and then he got restless.

Victor’s group would be next to practice shining the flashlight on objects. Once again, Miss Negro had students swap flashlights to prepare for the activity. During the hands-on activity, Victor followed directions. He moved the flashlight as directed and looked to see where the light shone. Again, Miss Negro made a point of telling the students how light traveled. At one point she remarked, “Marvin, can you change where you’re standing so you still hit the Star Student poster?” The exchange continued, and Miss Negro was able to point out that although you can move around, the light kept going straight. In the final few seconds, Victor shone the light in Haley’s eyes and then his own. He did not flinch as he shone the light on himself. Just as quickly his turn was over. One more group of students experimented with the flashlights, and then Miss Negro ended the class with a comment about the next day’s lesson, “We are going to continue to experiment with this tomorrow because sometimes even though light always travels in a straight line ... Even though light always travels in a straight line, sometimes we can make it bounce. And we’re going to talk about that.” Thus, went the final activities in the class.

Victor performed well during the hands-on activity. He followed directions and did as he was told. At the very end, he got silly, and shone the light into his eyes. As it turns out, later on in the study, he would reveal that he did not have a flashlight at home, and this brief activity was his first and only interaction with a flashlight. In summary, the last four minutes with a flashlight were the only hands-on activity the students did on this day to learn about how light travels.

**Victor’s interview: an opportunity for discourse.** The interview and analysis of Victor’s evidence notebook were crucial to determine his ability to make meaning of the academic language and content in science lessons. His interview occurred immediately after the Day Three observation. During my observations, I could not determine what Victor understood of the science lessons. I did not hear him repeat the science vocabulary during whole-group instruction, and he was academically engaged for only short periods of time. The interview with Victor was brief but informative. When asked how he felt when the teacher said, “It’s time for science!" He remarked, "happy." When asked, "Can you tell me something you know about science?" His response was, "Light." When asked, "What do you think it means to be a scientist?" His response was, "Seeing." These questions were not presented in rapid succession, but with time for a response, and yet he provided mostly one-word answers. In essence, he spoke very little during the interview.

The next portion of the interview entailed jointly reviewing his evidence notebook. Upon examining his evidence notebook, it was evident his written responses were incomplete. His journal responses indicated he could 1) accurately copy words from the board, 2) could not read those words, 3) did not complete the cloze activity, and 4) did not always label images. In his notebook, a blank page appeared where the teacher had asked, "…draw me a picture of a different place that you can get light from?" However, when I asked, "What's something in the natural/real world that gives off light?" He responded, "Sun." This seemed to indicate he made some meaning of the lesson on light. During the interview, he only used complete sentences to say, "I don't know." Overall, during the interview, Victor did not use any vocabulary included in the science lessons for the three prior days–neither *reflect, pass through, bounce, shiny, smooth,* or *straight*.

After the interview, I spoke very briefly with Victor. I wanted to explain some of the concepts shared with him during science. I used real life examples to explain *pass through* and *bounce*. I pointed to the doorway and told him when he walks through it, that was an example of pass through, like when light passes through. He smiled. Finally, I asked him, "Are you allowed to jump on the bed at home?" He said, "No, my dad doesn't let me." I let him know that jumping on the bed is bouncing, like when the light bounced. Once again, he smiled but did not comment. The interview ended, and I felt he now had real-life connections to the new vocabulary. I thought that perhaps with this new information, he could begin to make meaning with scientific concepts on light. While this was not part of the interview, it provided me with insight into how difficult it could be for him to make meaning of the incomprehensible academic vocabulary of science.

## More Science instruction within the Herald School

**In the classroom.** Observations for the second student at the Herald School began in February and were conducted in the same classroom with Miss Negro. Since she was interviewed previously to gain her background information, she was not interviewed again prior to the second set of observations. However, she was interviewed again to debrief after the observations for the second student. The composition of the students in the classroom remained the same, that is, 35% of the students in her class spoke or heard a language other than English at home. The remainder were monolingual English speakers. The bi-weekly science schedule at the Herald School remained the same. Thus, one week they would do science for five days, and the next week they would do social studies. Again, the science lessons were conducted in the afternoon after a brain break; teaching began between 1:40 and 1:45, and ended at 2:20, at which time students packed up for the day and prepared to go to fine arts. Therefore, science instruction remained approximately 40 - 45 minutes long.

**Focal Student 2: Iris' Background.** Iris was a U. S.-born six-year old, who came from a Spanish speaking home. In kindergarten, Iris' parents declined bilingual services, and she received no English language development (ELD) support that year. After six months in kindergarten, her English proficiency was assessed using the WIDA ACCESS test (WIDA, 2009). Iris scored a 3.9 on the assessment, indicating she was in the developing stages of acquiring a second language or a level three. As a result, according to WIDA standards, she would be expected to:

> process, understand, produce, or use: general and some specific language of the content areas; expanded sentences in oral interaction or written paragraphs; oral or written language with phonological, syntactic, or semantic errors that may impede the communication but retain much of its meaning when presented with oral or written, narrative or expository descriptions with occasional visual and graphic support. (WIDA, 2009, p. iii).

Thus, Iris had the ability to comprehend and communicate in English, including in the academic content areas, such as science. However, it would not be unusual for her to make errors when expressing herself. In addition, the ongoing use of scaffolding techniques including using visuals or graphics would continue to assist her English language development. As a result of her parents continued decline of bilingual services, in first grade, again, Iris received no ELD support. Since she read below grade level, she was provided with Basic Skills Services. Similarly to Victor, the Basic Skills classes focused on learning how to read with lessons in phonemic awareness and learning how to decode words.  In brief, Iris received academic support in reading, however the lessons were not specifically designed for multilingual learners.

**Iris' Engagement in Science**

**The introduction to the lesson.** The lessons always began with students sitting on the rug.  Iris, like Victor, always sat on the rug in an assigned seat. While science lessons were interspersed with social studies, when I entered Iris' class for the first observation, it was the first day of a new unit: "Unit 4: Plant and Animal Structures" (DiSpezio, Frank, Heithaus, & Sneider, 2018). Over the course of three days, Iris participated in: "Lesson 1: Engineer It: What Parts Help Pants Live?" (DiSpezio, Frank, Heithaus, & Sneider, 2018).  After six minutes of announcements, the teacher began the introduction to the lesson. On this day, the teacher asked students about their prior knowledge of plants.  During the discussion, behind the teacher, on the board stood an e-book image of three large tree trunks with long sprawling exposed roots around them. Behind the large trees stood thinner trees.  The lesson began as follows:

Miss Negro: Okay, friends, so we’re starting. So, we’re starting a new focus on the plants first. Just give me some thoughts. What are plants? What do you know about plants? What are some things that you know about plants? We have an example of a plant right here. What do you know about that, Lisa?

Lisa: It looks disgusting

Miss Negro: Not this plant, a plant could be anything.

Lisa: It’s a- It’s a-

Miss Negro: Answer my. Okay, Lisa.

Lisa: It could smell like a flower.

Miss Negro: Okay, so flowers are an example of a plant. Sue.

Sue: I have a garden in my backyard, so seriously I know about them.

Miss Negro: Oh, so you could

Sue: I have a blueberry plant, but it’s trying to grow. So it keeps

Child: I have a garden.

Miss Negro: You said that plants grow. So, they get bigger. They grow. Marvin?

Marvin: Trees.

Miss Negro: So, trees are another example of plants. Briana?

Briana: Plants need [inaudible] and water.

Miss Negro: They need s-

Child: Soil.

Miss Negro: They need soil and water.

Initially, Iris behaviorally engaged, she looked at the board and Miss Negro. However, Miss Negro's questioning was confusing, (lines 3-6), she asked, "What are plants? What do you know about plants? What are some things that you know about plants? We have an example of a plant right here. What do you know about that?" She had asked four questions: 1) What are plants? 2) What do you know about plants? 3) What are some things that you know about plants? and 4) What do you know about that? Thus, she began with general knowledge about plants, to some details about plants, and then finally to a question— "about that"—the plant on the board. The students' responses reflected her questions. They began with Lisa giving her opinion of the plant on the board on line 7, "It looks disgusting." Then (line 8), Miss Negro clarified her question, "Not this plant, a plant could be anything." The responses continued, and by the time (line 13), Sue said, "I have a garden in my backyard, so seriously I know about them," Iris turned away from the teacher and had turned around. She could be seen visibly counting and not looking toward the teacher. On line 24, when Miss Negro said, "They need soil and water." Iris moved forward and waved at the tablet recording the class, and said, "Hi!" Hence, she stopped looking at the tree, her peers, and Miss Negro.

**Issues that May Help or Hinder Meaning-Making During Science**

**Introduction without repetition.** Next, Miss Negro looked for the students' connections to plants. She referred to the image before the students, instead of just their general knowledge about plants. During this segment, students, including Iris, were looking at the tree images on the board. Then, some students began telling what they knew about trees. Iris was not among the respondents. It was evident that a few students had some prior knowledge of trees to share with the class.

1 Miss Negro: Okay anything else we know about plants? What are some other

things we know about plants, friends? So, Briana just told us that they need soil and they need water, Kate?

Kate: They need sun and light.

Miss Negro: They need sunlight to grow. Sue?

Sue: They also need air.

Miss Negro: So, they need air to grow, okay. What about what you see in the plant? What parts do you see? What parts do you see in the plant, Briana?

Briana: Roots.

Miss Negro: Oh, where do you see the roots.

Briana: Um, right here.

Miss Negro: Okay, you see like these big like a spider web coming down.

Sue: I see some branches.

Miss Negro: That’s a part of the tree. That’s the branches on the tree.

Melissa: I see this

Miss Negro: Oh, we don’t know what that is.

Melissa: Bumps.

Miss Negro: Okay, that’s just. Sit down. Sit down. Okay you [call] it bumpy. Okay, Marvin?

Marvin: Bark

Child: Snakes.

Miss Negro: Okay. Great. That’s on the tree.

Several students gave their prior knowledge. On line 5, Kate said, "They need sun and light." Sue commented (line 6) that, "They also need air." Then (line 10), Briana said, "Roots." Next (line 14), Sue identified what she saw, "I see some branches." Melissa (line 18) said, "I see bumps." At this point, Iris turned away again. By this time, a few students had provided their knowledge of plant necessities—soil, water, sun, light, and air. And new plant vocabulary was stated, *branches* and *roots*. Subsequently, on line 21, Marvin added, "Bark." Finally, one child called out, "Snakes." Miss Negro did not clarify that the "snakes" identified were roots on the ground. None of the new information about plant needs or plant parts vocabulary were repeated by the class. Meanwhile, Iris appeared to initially behaviorally engage, looked at the board, and then turned away. The tree introduction concluded.

**New vocabulary without clarification.** The teacher introduced the notion of structure into the conversation. As part of this discussion, Miss Negro did not explain the word *structure*; instead she relied on the e-book to provide students with background information. She began by saying:

> So, in this chapter, the parts that we see on the plant, they're there for a reason. It's part of the structure of the plant. And it's all there to help it. And it's all there for a reason, to help it survive, to protect it for some reason. And that's what we're going to be focusing on in this chapter. So, let's listen to what they have to say to introduce this to us.

Then, she gestured toward the tree on the board, and initiated the e-book's query, "Have you ever seen a tree like this one?" Many children responded, "No." Iris was not among the respondents, but she did attend to Miss Negro. There was not a discussion of the "no" response. Instead Miss Negro allowed the e-book to continue as follows: "What parts does it have? As you explore this lesson, you will find out how the parts of a plant help it get what it needs. You'll also find out how observing plants can give people ideas to solve problems." While Miss Negro utilized the word *structure,* the e-book utilized the word *parts*. Thus, *structure* was not explained and the e-book continued the introduction to the content and not an explanation of the term structure.

Miss Negro pursued the e-book audio's comments and now directed the students to observe the tree on the board. She gestured toward the tree, and reminded the class that, "…we already talked about some of the parts that we see in this plant. Briana told us the roots. We talked about the branches." However, only two students who provided the parts of the tree had restated them, but Miss Negro was ready to move the discussion along. She pointed toward the tree and asked, "What about this part over here?" She was pointing to the tree trunk and she wanted the class to engage in the identification of the other parts. The conversation completed as follows:

1 Miss Negro: This? Lisa?

2 Lisa: Stem.

3 Miss Negro: It could be the stem. What would be another name that we might

4 call that? Lisa?

5 Lisa: The part that keeps everything on the tree.

6 Miss Negro: Okay. But what's it called when it's on a tree? When it's on a

7 tree, what's it called?

8 Kate: A tree trunk.

9 Miss Negro: Yeah. A tree trunk.

Once again, only two students engaged in a discussion about the parts of a tree. During the exchange, Iris was behaviorally engaged. She looked at Miss Negro when she gestured toward the tree trunk. Iris looked at the tree trunk and then toward the camera. When her peer said, "Stem," Iris was looking. However, by the time Kate said (line 8), "tree trunk," Iris made a choking face at the tablet, and then looked back at Miss Negro. Iris checked in again with Miss Negro when she repeated (line 9), “Yeah. A tree trunk.” Here once again, the class did not repeat the new words, *stem* or *tree trunk*. Neither, did Miss Negro address Lisa’s erroneous comments (line 5), “ The part that keeps everything on the tree.” The word bark did not enter the conversation. Then, after this exchange, Miss Negro directed her attention toward another student whom she thought was disruptive. Iris looked away from the teacher during the exchange. Immediately, Miss Negro refocused the class for another segment of the science lesson. Notably, during this segment the term *structure* was never explained, and the lesson moved on.

**Scaffolding images.** The lesson continued with more e-book images used to deliver content. Iris attended to the next e-book audio. This time, the e-book display included a split screen. On the left side was half of a maple seed and on the right side the still image of a helicopter in flight.  Miss Negro directed the students’ attention to the board, and the audio directed the discussion toward the expectations of the unit, “Observing plants can give people ideas to solve problems. Play each video to explore more.” Next, she repeated the e-book’s audio comments and asked, Let’s think back for a second. Let’s think back a second.  What do we call someone who solves problems? “ Most of the class responded, “Engineer.” Here again, Iris was behaviorally engaged as the e-book audio and visual grabbed her attention. But she did not repeat *engineer*. Once again, Iris did not repeat in chorus with the class.  Did she know the answer? There were no visual cues for this response. The response required recall of previously acquired knowledge.

More e-book images were displayed to continue to engage the students with the content. Miss Negro focused the class toward the board and then went on to comment:

> Engineers solve problems. So, but I would love for people to raise their hands next time. So, friends, "Observing plants can give people ideas to solve problems." So, those engineers, they look at plants and it gives them ideas. Let's take a look at these plants, cause they are plants. Let's see. We're going to see.

Next, she played the e-book's audio, "Have you ever seen the seed of a maple tree?" Someone yelled out, "No." But, Miss Negro did not address the "no" response. The e-book went on to comment, " The seed has wings. The wings help the seeds twirl through the air." The audio was accompanied with visuals and animation. Iris paid attention as the seeds floated through the air. This was one of the few times the e-book displayed real-life objects in motion. Miss Negro did not describe where the seeds were in the visual. Nor did she explain why the audio said "wings," when the visual displayed each maple seed with only one wing. In addition, she did not explain what the word *twirl* meant. Then, Miss Negro acknowledged a student's comment, saying, "Victor was absolutely right when he said that they are seeds." When she made those comments, Iris was no longer looking at Miss Negro. There was very little scaffolding of the language or images shown in this segment. In fact, at the end of this segment, Iris placed her head on her hand, then got up on her knees, and spun around to see what was around her in the room.

**Questions without clarity.** Miss Negro tried to build additional student background knowledge about the e-book images. She went to the Internet and displayed a maple seed. The image she displayed contained a maple seed unlike the e-book's single-winged, floating maple seeds. The maple seed she displayed contained two wings. Iris attended to the board as Miss Negro continued the discussion. During this segment Miss Negro found an image of a maple seed that looked like it had wings. The seed on the board now more closely resembled the blades of a helicopter. She described them as, "…they kind of have this shape and they twirl through the air because of this shape." Then, she asked them several questions:

> Did the seeds grow like that or were they just or did someone change them and create them to look like that? Did they just grow like that or did someone [say?]– I'm going to cut shape of the leaves, so that they all look like this, and make it so they can fly in the air. Or did they just grow like that naturally on its own? What do you think? What do you think?

Miss Negro attempted to guide the conversation toward how plant shapes occur "naturally." She wanted the students to acknowledge the natural ability of maple seeds to float and twirl through the air. She attempted to guide them through the idea that the simple shape of maple seeds was a design inspiration for engineers. But it was unclear if they understood that maple seeds do twirl through the air. She also, mistakenly, said "leaves." Had any of them, other than Victor, ever seen a real maple seed? Did anyone ever try to make a maple seed fly? The school was surrounded by maple and oak trees. She did not reference them, and the class did not go outside to observe nature in three days of instruction. Furthermore, did the students understand the question, "…did they just grow like that naturally on its own?" What did *naturally* mean? Here again, there was no linguistic scaffolding. One student did attempt to respond. Linda answered her question with, "It grows." In essence, the images, line of questioning, and language used created the expectation that students could make an inference about aeronautical design based on limited information or knowledge.

Miss Negro utilized the e-book to further the concept of nature as a catalyst for engineers to design helicopter blades. This was where she had been leading the discussion. She continued the lesson.

Miss Negro: You think they just, they grow like that, right? That's the way the plant is. Great! So, when someone had a problem and they wanted to make something fly like a helicopter.

Child: Whoa!

Miss Negro: A helicopter is not something that just grows. You have to make it.

6 They looked at the maple seeds and they decided. Let’s listen to what they

7 decided.

8 E-book audio: How did observing maple seeds give people ideas to make the

9 the helicopter blades?

10 Child: Whoa!

Now, the class had been sitting on the rug for 18 minutes, 10 of which had been spent discussing plant parts. On line 4, a student said, “Whoa!” The class had just seen a helicopter fly, minus the sound of the propellers that accompanied its flight. The class was behaviorally engaged in that moment, Iris too. Next, Miss Negro gave the students an opportunity to discuss the new e-book comment from lines 8 and 9, “How did observing maple seeds give people ideas to make the helicopter blades?” Then, she went on further and asked, “So, how did that solve the helicopter’s problem? What problem were they trying to solve by looking at the maple seed? Turn and talk to someone sitting next to you, and tell them, what problem did they solve?” Her questions were not clear based on the content or linguistic support provided thus far. The text suggested maple seeds were the catalyst for the design of a helicopter blade. The seeds helped to spur an idea. When she asked, “What problem were they trying to solve with the design of the maple seed?” What was the problem she was talking about? She did not explain the word *design*, nor who the “they” were that were having a problem that needed to be solved. In essence, the text did not present a problem, nor did she, and now the students needed to say how it was resolved.

**Vague turn and talk question.** Over the course of the next minute and a half, Miss Negro went around to the different student groups to listen to their comments. She often repeated the question and steered the students to the response, “flying.” She also, pointed to the board and asked students where the “they” might have looked for help with a design. She said, “Okay, but what were they trying to solve? They made a design. What were they designing? They designed the maple seed. They were designing the helicopter and what problem did the helicopter have?” During the Turn and Talk, Iris worked with Lisa. Lisa was one of the most frequent respondents in class. When Miss Negro came up to them, she commented, “What problem were they trying to solve?” Iris responded, “She was explaining it.” Miss Negro prompted them again with, “What did they want the helicopter to do?” Lisa responded inaudibly, and the Turn and Talk was over.

After the Turn and Talk, Miss Negro continued to guide the conversation toward how nature impacted the helicopter design. The students had been on the rug for almost 20 minutes, and now they were getting restless. Miss Negro’s attention to Iris and Lisa encouraged Iris to listen to the discussion. But this would be short lived. When this segment began, Miss Negro was pointing toward the board and the helicopter. Iris was looking at the board, too. Then, Miss Negro said, “Yeah, maybe the helicopter was having problems. Why? So, where did they look for their design?” She followed up these questions with more questions. “They noticed that what in nature already flies on its own. Lisa, what did they notice that flies on its own in the air?” In that moment, Iris was not attending to the lesson, but rather the tablet. She was pretending she was on a phone, and said, “Hello!” Suddenly, Miss Negro called out Lisa, and said, “You’re not looking at that. You are looking over here. Lisa?” Iris looked up, but only momentarily. At this moment, the students were restless and the questions appeared too unclear for them to respond.

Miss Negro had introduced the idea of *design* without explaining the term to the class, and now she added the word *nature*, too. It was unclear whether the class understood what she meant when she spoke about nature. Miss Negro went on and commented, “What did they know in nature that already has, that's already able to fly and twirl around in the air?" Notably, even her most frequent respondent, Lisa, said, "A helicopter." But, during this questioning even Lisa had looked over at the tablet quickly. Lisa's response did not name an object found in nature, but instead named the helicopter. Subsequently, Sue said, "Maple trees." Again, objects that do not fly and twirl in the air. Finally, Miss Negro pointed with her pinky to the board. She was scaffolding the class with a gesture. Then, Sue correctly said, "Maple seed." Now Miss Negro was making flying and twirling gestures with her arms, and Iris was not behaviorally engaged at this moment in time. She was reclining. She had just heard several questions about design and nature, without the benefit of linguistic scaffolding. Finally, Miss Negro played another e-book audio, and Iris looked up again as the lesson continued.

During this segment of the lesson, it appeared Miss Negro converged two concepts about science and engineering together. In a previous lesson the children had learned that engineers solve problems. The science e-book was presenting the maple seed as a catalyst or inspiration for the design of helicopter blades. The e-book did not indicate that helicopters or engineers had problems that maple seeds solved, but rather that the simplistic, natural design of maple seeds could be replicated to create a flying machine. In essence, because an engineer designed a helicopter, did not mean there was a problem requiring a solution.

**Relatable connections.** The teacher's delivery of the curriculum content so far included the e-book, the Internet, and limited linguistic scaffolding. The objectives of the first lesson on plants were: "…to tell how the parts of the plant help the plant live and be able to explain how observing plants can give people ideas to solve problems." Miss Negro focused the first part of the lesson on how the plant's parts inspired engineering design. That is, how did a maple seed's design solve a problem? Thus far, the discussion around the influence of nature on engineering was not clear.

***Starting at the bottom.*** The discussion moved on to a comparison between the human body and an e-book image of a rosebush displayed on the board. She sought to engage the class with an eager start to the next segment of the class; she asked the students to standup. She began with the sixth e-book audio: “Think about plants you’ve seen. What are some of their parts? Look at this rosebush. Choose a letter to explore each part.” The bush’s parts were labeled with the letters *A* through *F*. The ensuing exchange demonstrated the confusion created by Miss Negro’s analogies, linguistic choices, and limited use of repetition. She began:

> So, we have the different parts of the plant. We have the different parts of the plant. We’re going to go part by part. And when Miss Negro is thinking about the parts of the plant, sometimes I like your body. Like the different parts on the plant are the different parts of your body. So, let’s start at the bottom. What’s at the bottom?

When she made this comment, she stomped her feet, and the students mimicked her movement. Then, she got numerous erroneous responses to her question. Several students shouted out, “A!” They were referring to the label for the image on the board. Then, a student yelled out, “Feet.” And another student yelled, “The bottom of the tree.” Miss Negro’s requests were unclear to the class. Even though she just had them stomp their feet the connection was not clear for them. After all the shout outs, she interjected, “Of you?” The students had been stomping their feet intermittently during this exchange, but Iris stopped stomping and just began twirling. Finally, Sarah said, “Your feet.” Miss Negro then attempted to guide the students to the correct response by asking, “Your feet. The very bottom, feet. What do your feet do?” The answers were, “They move.” “They grow.” “They make you walk.” Indeed, these answers were correct. Clearly, the students still did not understand what the teacher meant about what your feet do.

The students' responses were correct about feet, but not about the rosebush plant. As the lesson continued, most students stomped and jumped up and down repeatedly. But not Iris, she just struck a pose. Miss Negro, then remarked, "Okay, we're not moving because plants. Pretend you're a plant. Ok. What are your feet doing for you? What are your feet doing for you?" Once she told students to pretend to be a plant, the students all stood still. Miss Negro prompted Lisa who said, "Helping you stand." Finally, Miss Negro said, "So, plants have a part, too, that helps them stay in place, and just like our feet are at the bottom. This part is also at the bottom. And look at where it is. The roots. The roots." She confirmed the response and made the connection between the students' feet and the rosebush's roots.

The analogy between human feet and roots did not take into account what the students had just said about moving and walking. In addition, when Miss Negro explained the feet, she explained them as, "They're helping you stand. They're holding you up, they're helping you stay in one-." Then, several students chimed in, "Place." Thus, the roots had several functions: helping plants stand, holding you up, and helping plants stay in one place. These comparisons were not exactly like our feet. Miss Negro continued to work to establish the premise that humans have parts that are similar to those of plants.

The root analogy would create more difficulties as the remaining plant part functions were explained. The lesson continued with plant and human comparisons. Miss Negro attempted to clarify the role of the roots for the students. Now the implications were that roots, like feet, function to hold you in place and do more, too. Next, Miss Negro went on to explain more about the function of roots on plants. She began by playing the e-book audio, "Roots take in water from soil. Roots hold the plant in the ground." The e-book audio explained the dual function of the roots. Miss Negro reiterated the "to the ground" of feet and the "in the ground" of the roots.

No mention or clarification was made that our feet are on the ground, not in the ground. For first grade multilingual learners, the "in" versus "on" distinction would require explicit instruction. In addition, she did not address the statement, "take in water from the soil." No one asked about the root's role in water absorption. The fact humans do not absorb water through their feet was not acknowledged, and the lesson continued. Furthermore, none of the children repeated the word *roots* or its dual role. During this exchange, only one child repeated a single function of the roots, "in place."

**Imprecise language.** The discussion continued with the rosebush analogy. Several students were restless. They moved in front of the tablet and became distracted by the tablet recording the class. Meanwhile, the rosebush remained on the screen, and ongoing references were made to the parts of a plant. The next part was the stem- B. The e-book audio commented, "Water moves through the stem to other parts of the plant. The stem also holds up the plant." After hearing the audio, more students were becoming restless. That is, even though they were no longer sitting on the rug, but rather standing during the rosebush to human analogy. They began touching one another, and one student was called out for looking at the tablet. The students just learned the roots hold you in place and now the stem hold you up, too, but there was no description of the difference between the two. Miss Negro saw the restlessness and repeated the "A" response as follows, "So, A was your feet. They're holding you in place, right? They're holding you in place just like the- like the- Just like the roots. Okay, your feet should be holding you in place right now." But, what was the distinction between "hold you in place" versus "hold you up"? At this moment, explicit linguistic support would have helped multilingual learners in the class.

The teacher wanted to resume the analysis of the rosebush displayed on the board. However, the students continued to move around, jump up and down, and look at the tablet. Even Iris could be seen blowing kisses toward the tablet. Miss Negro reiterated the role of the roots, and said, "So, the water goes through the roots and up the-" Then, a few students responded in chorus, "Stem." Once again, Iris was not among the respondents; she was busy twirling. Now, several students returned to the class, and disrupted the flow of the lesson. Quickly, Miss Negro got the class back on track to discuss the stem and how it differed from the roots.

The lesson would continue with the human and plant analogy. The e-book audio about the stem would be repeated, "…because no one was listening" Miss Negro stated. But the discussion was absent linguistic support. When this segment began, Iris was twirling. The e-book audio stated, "Water moves through the stem to other parts of the plant. The stem also holds up the plant." The analogy continued with a comparison of the stem to the torso, as a part that, "…holds up the plant." Initially, students did not comprehend and compared the stem to their legs. Then, Akhil said, "Your feet." He was followed by Lisa, who said, "Your hips." At this point, Miss Negro gestured to her torso as the part of your body that holds you in place. Again, she prompted students for responses, and she stated, "Yeah, okay. This whole part." Which she followed with, "Yeah, this whole part it holds you in place." Now, Iris was looking at Miss Negro as she said, "this whole part." But what was "this whole part?" It was not named, and the word *spine* never entered the discussion. Once again, clear linguistic scaffolding could have helped multilingual learners comprehend the different parts of the plants and the analogy to the human body. In addition, at no point did the teacher make a distinction between the previously identified "in place" for the roots, versus the now "holds you in place" for the stem. Thus, both the roots and stem had an "in place" function.

**Facts without meaning.** The plant and human analogy ended abruptly as the comparisons were not applicable. The human to rosebush analogy ceased as the thorns were introduced. The e-book audio stated, “A rosebush has thorns. Thorns protect the plant from animals.” Here, Miss Negro quickly clicked through the four remaining responses on the screen. She rushed to completely identify all the parts of the plant. The students had been standing for eight minutes. Although the remaining plant parts were defined as *thorns, leaves, flowers,* and *seeds*, they were not compared to the parts of the body. When the e-book audio said, “A rosebush has thorns. Thorns protect the plant from animals.” There was no mention of what “protect” meant or the human equivalent of thorns. If humans needed or had the tools to protect themselves from animals, no one asked. Miss Negro then proceeded to ask, “What are thorns?” Melissa said, “They’re stuff that like poke you.” Subsequently, Miss Negro identified them as, “Yeah, it’s sharp pointy things.” Iris was looking at her teacher and the board. The words *sharp* and *pointy* were not scaffolded for the multilingual learners in the room. The comparison between the parts of a rosebush plant and the human body concluded. In essence, there was nothing more said about how plants and humans were similar.

While the human plant analogy was over momentarily, the description of the function of plant parts began. The role of leaves was presented, “Leaves take in light and air to make food for the plant.” How did it happen that leaves make food? It was not elaborated upon. Miss Negro eluded to there being a subsequent discussion of these details. Next, the role of flowers presented, “Many flowers grow into fruits. A fruit holds seeds.” Finally, the e-book stated, “Seeds form in flowers. Seeds grow into new plants.” Miss Negro then indicated that the seeds begin the cycle again of creating new plants, and the e-book audio of the rosebush concluded. In brief, all the rosebush parts and their associated functions were identified.

In the aforementioned segment, Iris looked at Miss Negro and the board every time Miss Negro made a new selection on the parts of the plants. She listened to the language about thorns being pointy and sharp, leaves making food, flowers holding seeds, and seeds making new plants. At this point, the lesson had gone on for 28 minutes. Iris had now seen five e-book images and two internet images. In addition, she had heard 12 e-book audio comments. All of these images and comments were an integration of the concept that natural occurrences can act as catalysts for engineering designs. The vehicle for this discussion was plant parts. In this lesson there was a lot of new academic language that was not repeated or explained. The e-book appeared to grasp her attention, but only momentarily. The tablet appeared like a mirror in the class, it allowed her to look elsewhere. In brief, Iris did not fully attend to Miss Negro when the parts of the plant were covered that were not compared to body parts.

**A distraction?** There were multiple tablets being used for this research study in the room designed to capture movements and speech in the class. The tablets were introduced several days prior to the first observation to test their location in the room. One tablet was focused on Miss Negro, and the other was on the focal student. The tablet for Miss Negro rarely moved. She usually stood near or at the front of the room. The second tablet moved to where the focal student sat or stood during class. Therefore, initially it was on the rug with the students, and later, it moved to a desk near the students' desks. While the students were on the rug, it was nearby on the floor, and it looked like a mirror reflecting their movements. It was not unusual for the students to take a quick glance, and then resume their activities. But Iris took it much further with poses, twirling, and sometimes staring at the screen. She got off task quickly, and the tablet recorded her time away from the current class task. In essence, it appeared Iris was often behaviorally engaged, but not academically engaged.

**Time for the evidence notebook.** The next activity was an opportunity for students to label a graphic image of a plant in their evidence notebook. At this point in time, the science lesson was now 30 minutes in progress and students returned to their desks. Similarly, to my observations of Victor's lessons, Iris quickly went to her desk and followed the initial directions for the labeling process. Over the course of the next couple of minutes, the students went back to their desks, sat down, and glued the worksheet onto the next clean page in their evidence notebook.

The image was a long thin flowering plant with three flowers, a long stem, several leaves, and roots visible beneath soil. The title read: "Parts of a Plant." The sheet had a word bank that contained the words: stem, leaves, roots, and flowers. Next, she proceeded to explain the parts of the plants and showed the students how to label the image.

> Okay, friends. So, everyone let's go part by part. Everyone point to, point to the stem on the plant. Point to where the stem is on the plant. Point to the arrow that's pointing to the stem. Where's the stem? Point to the arrow. Alright, remember the stem is like your body, your whole body and how it's holding you up. It goes all the way down. It's connected to your feet, all the way up to your head.

During the evidence notebook activity, Iris diligently glued the image into her notebook and looked on the board for what to copy. Meanwhile, Miss Negro gestured toward her torso and asked, "Point to where the stem is on the plant. Point to the arrow that's pointing to the stem. Where's the stem? Point to the arrow." Iris was looking around the room. She did not point to the stem. I came over to her and asked her where the stem was on the plant. She just looked up at me. Her peer, Sue, looked at her notebook and pointed it out to Iris. Now Iris pointed to the stem. Then, Iris picked up her evidence notebook and shared it with the tablet. The class continued labeling the flowering plant.

**Labeling is very important.** Iris continued to look at her notebook during this segment to correctly label the plant parts in her journal. When Miss Negro asked, "The roots are like what on your body? Like what?" Several children said, "Feet." Iris was not among the respondents. Then, Miss Negro said, “Stay in, hold us in.” Many students responded in chorus, “place.” Iris did not repeat that either. Miss Negro continued to discuss the parts of a plant for the labeling activity that would conclude the class.

Miss Negro: Okay, now look what it’s pointing to. Pointing to
this over here. What is this? It’s a leaf right? Leaves.
Children: Leaves.
Miss Negro: So, you can even kind of think of leaves like your hands. They’re
reaching out.
Iris: I can’t see. I can’t see.
Miss Negro: It’s on your paper Iris.
Child: What about your stomach?

Here again, Iris was very attentive to correctly copy what she needed to label on the plant. Miss Negro introduced the word *leaf* (line 2), then she mentioned *leaves*. She did not distinguish between the arrow pointing to a single leaf and the use of the word *leaves*. Next (line 3), most of the students said, “Leaves.” Iris did not repeat the word. However (line 6), she shouted out, “I can’t see. I can’t see.” She did let the teacher know she could not see the word on the board. Quickly, Miss Negro let her know the word was on the sheet she had handed out. However, the teacher had not previewed the word bank on the worksheet. Did Iris know what the words were or meant? Iris was intent on accurately copying from the board the correct parts of the plants, and she looked up toward where Miss Negro stood modeling the word *leaves* and not her worksheet.

**Checking in on recall.** The teacher now looked to see if knowledge of rosebush leaves would transfer to the discussion about the flowering plant before them. She went on to discuss the leaves and their role in the plants’ survival. The previous discussion about parts of a plant encompassed the rosebush and human analogy. It had been a very brief delivery of facts without any attempt at meaning making and limited scaffolding. Thus, she would go on to demonstrate on the overhead projector how to label the plant.

In conjunction with the labeling, Miss Negro asked the students for the part's function on the plant. She commented, "The leaves on a plant. The leaves on the plant do what? Who remembers? We're going to talk more about this tomorrow. But who remembers, they said it online. The leaves, they do what for the plant?" Melissa responded, "They help like it grows fruit." Miss Negro commented, "The leaves don't grow the fruit. The leaves do something else, they make what for the plant?" The only answer given was incorrect. Hence, Miss Negro opted to guide the class to a correct response by telling the class, "So, it takes in the sun and the air and it turns it into what for the plant? Just like we need to eat, a plant needs to eat. Doesn't eat what we eat. But what does it need? What do we eat?" While she was talking a child shouted out, "It's alive!" And then, another child shouted, "Food." She then went on to add, "The plant needs to eat, too. But the food, it makes it itself in the leaves. The leaves make the food for the plant." The students did not recall the function of the leaves from the earlier rosebush discussion, but Miss Negro scaffolded the discussion with the human comparison.

While Miss Negro discussed the role of the leaves, Iris correctly copied the label and then looked at the tablet that was next to her. She did not look at Miss Negro who spoke about the leaves and their role in the plant's survival. Furthermore, what did it mean that the leaves make the food? People do not make their own food internally. No one asked, and the labeling of the parts of the plant resumed. The students completed labeling the plant parts and quickly began to pack. Iris was among one of the first to close her notebook, place it in her desk, and get ready to go to fine arts.

**Interviewing Iris—an opportunity for discourse.** The interview and analysis of Iris' evidence journal were important to determine her ability to make meaning of the academic language of science content. The journal was a source of pride for Iris. She was able to copy words and labeled the plant's parts. It allowed her to have agency and demonstrate her ability to succeed during science. However, it was not an indication of whether the academic language of science was comprehensible.

Iris was very conversant and eager to talk. After I told her what we were going to discuss, she said she wanted to sing the "Parts of the Plant" song she had learned during science. She quickly turned to her notebook. But, first, I started off by asking her, "How do you feel when the teacher says, "We're going to do science?" Without hesitation she responded, "I feel bored." She commented further, "Yeah, I always get tired." Often during the observations, I noticed she looked away from the teacher, and she performed for the camera. Yet, she always worked diligently in her notebook and wanted to copy everything correctly. At this point, I told her I knew she was learning about plants. She turned to her notebook, told me she knew the song, and pointed to the chorus. Before she began, I asked her to tell me about the plant image in her notebook. Quickly, and without hesitation, she read: the roots, the stem, the leaves, and the flower. Then, she began to sing to the tune of the "Muffin Man":

> Oh, do you know the parts of the plants, the parts of the plants, oh do you know the parts of the plants, that make them grow and grow. Oh, now you know the parts of the plants, the parts of the plants, the parts of the plants that make them grow and grow.

She could sing the chorus quite well. I also noticed, she could not read or recall the actual parts of the plant in the song. Thus, there was no singing about the roots, stem, leaves, or flowers. I commented on how well she knew the song and how well she labeled the parts of the plant. She called it, "…relating them." She did not know the word *labeling*. She went on to share her work on light. I allowed her to share the pages. Although, I was in the classroom during that event, I did not observe her, so I made no comments about her work, but thanked her for sharing. I turned the conversation to plants again and asked her to share her work with plants. She shared a page from her large science workbook. I asked her to tell me what she wrote. She stated, “branches.” I commented that they were long and thin, so she corrected herself and said they were sticks. I prompted her further, and she mentioned “flowers.” Then, I mentioned “protect” and made the *th-* sound, and she said, “thorn.” I noticed that instead of “thorns,” she had written “leaves.” All of her responses were incorrect based on the image in her book and what she wrote. The conversation went on a little longer, and I asked her if she had any plants near her home. She said, “No, just grass.” I commented that grass was a plant. She responded, “Mostly, I don’t have plants in my garden, but I have flowers. We have four flower things.” Overall, Iris, communicated quite clearly. She could read the vocabulary included in science for the three prior days– *roots, stem, leaves,* and *flower*. In brief, outside of what she could read in her notebook, Iris understood very little about plants.

**Interviewing Miss Negro.** While observing Miss Negro’s class for six days, I heard how the language of the e-book was heavily imbedded with academic language requiring further explanation. The new prescribed science curriculum was derived from the NGSS, and it included the integration of science and engineering practices. This integration was a new concept for teachers, and the first year they needed to deliver it. In interviewing Miss Negro, I sought her feedback on how the multilingual learners in her class responded to science instruction and her thoughts on the NGSS curriculum.

We spoke after I completed each student's third observation. Since my focus was her instruction and the multilingual students in her class, I asked her about her overall approach. Her comments after the lessons on light were as follows:

> So, my overall approach was to kind of try and make it as hands-on and interactive as possible. I know, I mean, there was background that I was trying to get across to them. But I wanted, my goal is always to try and get some materials involved and try and get them to do things hands-on and figure things out for themselves.

Miss Negro relied on the prescribed curriculum to provide visuals and linguistic scaffolds. In fact, the lessons I observed regarding light focused on the content presented in the e-book and included limited time spent on hands-on activities.

***Teachers must know students' linguistic background.*** In my first interview with Miss Negro expressed her belief that the resources made available to her in the prescribed curriculum were adequate to teach the multilingual learners in her classroom. She thought the curriculum was adequate in its presentation and delivery of content. In fact, in my debriefing after Victor's observations she commented:

> For the multilingual student, I think it- If you follow the curriculum strictly, I- Of- do it in a little watered-down language. And really, they're supposed to be learning more through the hands-on, through formulating their own ideas that way. So, I don't think necessarily that the vocabulary associated with- is too difficult and challenging for multilingual learners.

She thought the prescribed curriculum was adequate as presented, and therefore, she did not feel the need to scaffold the language in the science curriculum. She believed the curriculum e-book handled the vocabulary well. She commented during the interview,

> Yeah, I mean the way it breaks down the vocabulary, like it says, reflect means to bounce back and-- toward means directions. Breakdown the vocabulary because reflect isn't necessarily a vocabulary word that I would expect them to know, but it does break that down.

Hence, Miss Negro trusted the curriculum as presented. As a novice teacher, she also trusted the district to provide her with the necessary student demographic and academic information to instruct the students entrusted to her.

The last interview occurred after the lessons on plants. We discussed the curriculum again, and her understanding of its impact on students. She remarked on other ways she attempted to present the content:

> Cause I looked up, you know, plans inspired by, I mean a designs inspired by plants or whatever. I tried looking up other examples, you know, something to make it look, to seem more…more exciting because it's so blah. And I mean, I did come across that there was another example in the book. It was the burr, those little spikey balls that fall off the tree, what do they call them? The burr, the burrs.

She reviewed the content before delivering it, and thought about ways to make it relatable to the students. The burrs were ideal, she said adding, "That was like the inspiration for Velcro or something. And that was true. So, I thought, that was interesting, but really there wasn't much online." Our discussion continued. I asked if socioeconomic status would make a difference in what experiences students may have had with the curriculum content. She reiterated her previous sentiments, "Velcro they have experience with. But I mean, like a helicopter? They see a helicopter. It just doesn't connect with them. They don't care." She felt the curriculum did an inadequate job of presenting the content and engaging the students regarding plants.

While her focus was on making hands-on lessons, the curriculum left her ill equipped to do so. She commented, "But I feel like the material that was presented, the material we were supposed to teach, didn't really lend itself much to hands-on learning and anything particularly exciting and interesting." Continuing the discussion, I sought clarification on whether it was the content itself or the presentation of the content in the curriculum. She commented, "I think some of the language is a little harder to pick up, too. But I also think the fact that the content isn't very engaging kind of makes it even worse." Aside from the content itself, she cited the approach taken in the curriculum to teach about plants. She further commented, "I personally don't even think that the maple leaf looks like the helicopter blade. So, I don't know why they put that example in there." She actually meant the maple seed, not the leaf. She went on further to say, "I would have focused more on plants, what the parts do, a little more hands-on with that. So, what they need." Hence, Miss Negro delivered the curriculum and made adjustments to make the content more engaging.

Finally, during one of my interviews with Miss Negro, I also asked her how she gauged comprehension. Her comments were as follows:

> I mean, I guess I can. I mean just by their participation and when I call on them. When- on them to give me an answer, and they don't really respond the way I'm expecting or I mean, like I said, the evidence notebooks, too. Depending on what they're writing in there. I guess I can kind of gauge it from that. And I think, sometimes I don't think they're understanding, but sometimes they'll show me, and other ways so it's kind of.

Here she disclosed the value of the evidence notebooks more so than their discourse in class.

When I first met with Miss Negro, she appeared pleased with the curriculum's presentation of light. However, by the time of the second interview she felt the curriculum did an inadequate job of meeting her needs and engaging students with the science instruction on plants. For the most part, she believed she had a tool that allowed her to see what was happening with the students' comprehension- the evidence notebook. As a novice teacher, she trusted the district to provide her with the necessary student demographic and academic information to instruct the students entrusted to her. After I completed debriefing Miss Negro regarding Victor's classroom observations, I advised her of Victor's English proficiency and multilingual status. The district had not advised her of Victor's ELP, and she was unaware that she needed to scaffold instruction for him to make it more comprehensible. She was taken aback with this information. In response, she appeared very troubled and anguished.

**Science instruction within the Oak School**

**The science schedule.** Unlike the Herald School, science lessons at the Oak School were not interspersed with social studies on a biweekly basis. Science lessons occurred over several weeks to complete whole units. Then they were followed by social studies lessons at various intervals in the year. Science began with NGSS' lessons on technology and engineering. The science lessons would then be followed with social studies discussions of holidays such as Thanksgiving, and then cultural recognition of celebrations around the world such as: Christmas, Hanukah, Kwanza, and New Year's. Thus, as the year ensued and holidays or cultural celebrations occurred, the science lesson sequence would be suspended to incorporate acquiring knowledge about history and culture in the United States.

**In the classroom.** The observations at the Oak School were conducted in two classrooms and each was preceded by a teacher interview. There was one student observed in each classroom. These observations began in February and culminated in March. The first teacher observed was Mrs. Green, a fifth year teacher, entering her fourth year teaching first grade. Her class was comprised of 19 students, of which six were identified by Mrs. Green as multilingual learners during a pre-observation interview. Upon examining the school's database for the class, I discovered that two of the students' home language was Spanish, a third spoke Korean, a fourth Telugu, a fifth one spoke Punjabi, and the last multilingual spoke Bengali at home. Therefore, almost 32 % of the students in her class spoke or heard a language other than English at home.

In Mrs. Green's class, science lessons were conducted in the afternoon, as the last class of the day. Science usually began between 2:40 and 2:45, and ended between 3:10 and 3:14, at which time students packed up for the day and prepared to go home. To summarize, science instruction was approximately 30 minutes long each day, occurring on a daily basis, for several weeks.

**Focal student 3: Juanita's background.** Juanita was a United States born six-year old, who came from a Spanish speaking home. In kindergarten, Juanita qualified for bilingual services, however, her parents declined the services. She received no English language development (ELD) support that year. After six months in kindergarten, her English proficiency was assessed using the WIDA ACCESS test (WIDA, 2009). Juanita scored a 5.2 on the assessment, indicating she was in the bridging stages of acquiring a second language or a level five. As a result, according to WIDA standards, she would be expected to:

> process, understand, produce, or use: the technical language of the content areas; a variety of sentence lengths of varying linguistic complexity in extended oral or written discourse, including stories, essays, or reports; oral or written language approaching comparability to that of English proficient peers when presented with grade level material (WIDA, 2009, p. iii).

Thus, Juanita had the ability to comprehend and communicate in English, with complexity and extended discourse, on par with her grade level English proficient peers. She was considered English proficient, and no longer in need or eligible for ELD. The use of scaffolding techniques, including using visuals or graphics would continue to assist her, but would not be essential for her English language development. She received no ELD in first grade as a result of her WIDA score. In brief, Juanita did not receive ELD support while she was in kindergarten or first grade.

## Juanita's Engagement in Science

**The introduction to the lesson.** Mrs. Green utilized a trade book to teach students about rainbows. The book was a supplemental resource used to provide background information before delivering the district-prescribed curriculum content on light. The class began with the students sitting on the rug, and Mrs. Green introducing the lesson. She began by reminding the students of her expectations for the lesson. “Alright, turn and give me 5. Thank you for being patient. Your legs should be crossed, your hands should be still in your lap, your ears are listening, your eyes are watching me, and your lips are?” The class responded, “Zipped!” She used a hand clap to initially grab their attention. Then she followed up the clap with gestures to the ears, eyes, and mouth to ensure the students did not only hear what was expected, but could also see what was meant. Motivating the class, while scaffolding the lesson from the very beginning, she said, “Show me if you’re excited. Show me!” While she made the comment, she gave a big smile, and then twisted her wrist with a closed hand, with the thumb and pinky exposed. This was how the class showed excitement, a few children screeched, too! When they screeched, she gestured her finger to her lips. The introduction to the lesson continued:

Mrs. Green: Show me. Alright, here we go. What we’re going to do, we’re going to be talking about something, and some of you might know about it, and some of you might be like, “Mrs. Green, I have no idea what you are talking about!” But don’t worry, isn’t that why I’m going to teach you it?

Children: Yeah.

Mrs. Green: But some of you might know a little bit about it. We’re going to be talking about light. Everyone say, “light.”

Children: Light.

Mrs. Green: Oh, my! It’s one of our words to know this week. I’m not talking about light, heavy, or something’s light like a feather. We’re not talking about that kind of light.

Mrs. Green told the students what they were going to be studying. Then, she proceeded to have the class repeat the word, *light.* Juanita, the focal student, was among the respondents. Mrs. Green went on to describe the type of light she was about to discuss. She did not say that light is a homonym word having two meanings, but she told the students "I'm not talking about light, heavy, or something's light like a feather." As she was speaking, Mrs. Green gestured carrying a heavy object with her hands, and then, she gestured toward the pocket chart behind the students. In that moment, Juanita, turned around to see the word *light* on the chart. Thus, during this initial exchange, Juanita was both behaviorally and academically engaged.

During the remaining segment of the introduction, Mrs. Green solicited the class for their knowledge of light. She also repeated responses and wrote down what the students said on the chart paper on her easel. First, Mrs. Green asked the students their ideas about light. Then, she commented, "Alright, we're going to be talking about light. Hmm, there's lights in here. Okay, not like how heavy or light- Or how *not* heavy something is." She reminded them about the type of light they were going to learn about and scaffolded further by outstretching her arms to point toward the ceiling lights in the room as a reminder. Next, she asked the class, "…to close their eyes. Think in your brain." Here she gave them a moment to stop and think. She wanted them to tap into their prior knowledge. The class proceeded to give responses to her question, "What kind of light are we talking about?" When they responded, she intentionally told them she could not hear them, placed her finger next to her hear, and they repeated their responses again. For approximately four minutes, Mrs. Green wrote down the students' responses about light. She always repeated the comments and then wrote them down on the chart paper.

In the course of the discussion, she alluded to the fact light is connected with electricity. She then proceeded to write down: 1) that light is made from the sun, 2) you can make light with fire, and 3) some robots need light. All of the students' responses were placed on the chart paper. Then, Mrs. Green concluded the introduction with final instructions. She said, "If you have something else, whisper it into your hands." The students, including Juanita, whispered into their hands. This was a way to value their ideas and to have them hear their thoughts out loud. She ended the introduction by acknowledging:

> I have a lot of dinosaur enthusiasts in here, and I have a lot of reptile enthusiasts. A lot of you like to tell me all these things that you know about reptiles and lizards and birds, and I have no idea what you're talking about half the time. But *light* – you don't really talk about light a lot. So, it wouldn't surprise me if we don't know a lot about light, because [*whispering*] even Mrs. Green doesn't know a lot about light. But don't worry. A lot of you don't know about light. That's okay. That's why I'm here. I'm going to help you with that.

Thus, she engaged them in a new endeavor to learn about light. Juanita attended to her peers and Mrs. Green. In short, during the introduction, Juanita appeared behaviorally engaged.

**Issues that Helped and Hindered Meaning-Making During Science**

**Reading about light.** Now, seven minutes into the lesson, Mrs. Green brought out a trade book to read to the students. During three days of observations, most of the class' time was spent building background prior to engaging with the district's science curriculum materials. The second segment of the lesson proceeded with her repeating what they had just said, and she had written on the chart. "…*light can be bright*. *It can be hot like the sun. Some light can be turned off*. *Light is connected to electricity*. *Light is made from the sun. You can make light with fire*, and *some robots need light*." In addition, she let them know they could, "…add some things to our list of things that we know about light."

The introduction to the book began by discussing what the students had just said about light and then previewing the cover, and both students and teacher stated the topic: *light*. Mrs. Green read the first four pages of the book. The text contained vivid images where first the sun was introduced on a sunny day. This was followed by images in a night sky, including neon signs, billboards, lightening, fireworks, and fireflies. These pages showed the contrast between day and night. Mrs. Green used these pages instead of the district e-book to introduce the topic of light. She did not just read the text, but she highlighted the images in the book and made connections to the students. She scaffolded the images and language. She also, commented, “You might know Moe’s. I think it’s a different kind of Moe’s here, though.” Here she referred to a local fast food restaurant the students might visit. While she read that text, the students wiggled their thumb and pinky in recognition of their connection to the comment. Furthermore, while she tapped into the students’ prior knowledge, she referenced images in the text. At one point she asked, “See the glowing octopus? How are you able to see that sign at night?” The response, “light,” helped her assess if they understood how they could see images in the night. She discussed images, asked questions about them, and referenced the text. This was a literacy lesson, and Juanita attended to the book displayed on the projector.

**Scaffolding the technical language of the text.** The trade book would begin to get more technical and use science academic vocabulary. First, the text began with simple images—families on the beach on a bright sunny day. It was introducing basic concepts about light, and then it would take a turn to more technical and abstract discussion of light. Mrs. Green scaffolded the language of the text for her students. She segued to more complex notions about light beyond providing visibility at night. She read from the text, . “During the day, light from the sun brightens our world; but did you know that the sun is 93 million miles away?” (Pfeffer, 2015). Then, she asked, “Is 93 million miles close, or is 93 million miles far away?” Juanita and the class responded, “Far away.” Mrs. Green was trying to get the students to think about this fact, and then she went on further. Next, she asked, “How do they get the light here? If it’s 93 million miles away, how am I able to see that light? Can you make a prediction?" Some of the students had read a text earlier in the day about travel to the moon, and they were somewhat versed on the topic. The students gave several responses providing their knowledge of light. The responses were: "It's the biggest planet. It's a star. It's made out of fire, and it's a giant star." And the final comment, "It's really big and it's really bright, so maybe it shines." Throughout all of this conversation, Juanita attended to the text, and when her peers spoke, she looked at them as they spoke. The students continued to attend to Mrs. Green as she carefully guided the discussion based on the information presented in the text.

**Tapping into students' knowledge.** Mrs. Green chose a text that she thought could connect to the students' knowledge about speed. She wanted them to understand several concepts about light and speed. The book provided several concrete examples. First, she tapped into their general knowledge to make connections to the science content about light. One child connected the speed of light to The Flash, a DC comic superhero. Mrs. Green encouraged the connection, and asked the child to draw the symbol of The Flash. The focal student raised her hand to volunteer. However, George was selected, and he proceeded to draw The Flash's symbol on the board. As he did this, his peers, including Juanita, looked on. She was behaviorally engaged. His drawing did not resemble a lightning bolt. Then another student indicated that it should be lightning, and Mrs. Green went on to comment, "He's as fast as light, and we just learned light comes super-" The students responded, "Fast." Juanita did not say, "Fast." Next, Mrs. Green would now go on to a short demonstration regarding the speed of light. In fact, the book had more examples to explain light.

**More complex concepts shared.** The trade book, while containing simple images, began to explore and explain more complex concepts about light. Mrs. Green would go on to read the next two pages. The pages were rife with information in the form of images and academic language. On these pages were sprawled images and labels to describe the speed of cars, airplanes, sound waves, and light. Page 14 showed the Statue of Liberty with a light emitting from the torch, and on the road in front of it was a van filled with a family. Above the van was an arrow with the label, “1 mile a minute.” Overhead and due east, was an airplane, with an arrow and the label, “8 miles a minute.” Across the two pages was the light emitting from the Statue of Liberty’s torch in a straight line from page 14 to page 15 toward a smiling moon. The light from the torch then curved back from the moon in a continuous line now parallel to the line on page 14. An arrow at the end of the line pointed to the words, “In one minute: light from Earth could travel back and forth to the moon 46 times.” The teacher would go on to read that line and do a one minute demonstration about the speed.

Mrs. Green worked to have the students understand the content of the text. The students began talking and she wanted to explain the text with a demonstration. She read, “In one minute, light from Earth could travel back and forth to the moon 46 times.” Then she asked, “so are you ready? Let’s count out a minute. Ready?” Next, she asked them, “Stay quiet for one whole minute, starting now.” She opted to have them wait for a minute to understand how light travels to the moon and back. However, absent any demonstration of movement, it was an exercise in watching time go by. The students had been sitting on the rug for 13 minutes and they were restless. When she said, “Hold on,” only 30 seconds had passed, and the students could be seen squirming, waving their hands, and some began giggling. In fact, there were a lot of images and much information to consume.

The teacher would attempt to scaffold the language and information from the two pages of text. Here Mrs. Green shared the information from the text. She connected the reading of the text to an earlier comment from language arts, and said, “It takes you four days to get to the moon. So is the moon really that close?” The class answered, “No!” And Juanita did, too. Then the teacher asked, “The moon is kind of far. If it takes us four days to get to the moon, but in one minute, light can get to the moon 46 times and back. Do you think that’s fast, or do you think that’s slow?” Here again, when the class said, “fast,” Juanita did, too. Next, the text addressed speed by making various comparisons among different forms of transportation. The book displayed images of the different forms of transportation with their respective travel times per minute. The teacher read, “Cars on highways travel about one mile a minute. Passenger jet planes travel eight miles a minute.”  I was unsure the students understood the comparisons. If they had flown in a plane they might understand. For those students who had never flown, this was surely incomprehensible.  After, Mrs. Green read about how fast cars and planes travel, Juanita commented, “What?” Throughout the discussion, Juanita was behaviorally engaged. She responded when the class did, too.  There were a lot of numbers and data to digest on these two pages.  In fact, the images tried to make meaning of the speeds and distances mentioned.

**Connecting to the text.** The text contained simple images with many facts about speed that captured Juanita’s attention.  Now, she prepared to engage with the teacher and provide her own understanding and connection to the text. First, Mrs. Green gave more facts about how sound waves and light travel.  Then, Juanita followed with her own response.

Mrs. Green: And “sound waves travel 13 miles a minute.” We talked about sound waves. “Light travels over 11 million miles a minute. Nothing travels faster than light.” So light is the fastest thing of all.  Even faster than me. Yes, Juanita.

Juanita: One is kind of like slow. Eight is kind of fast. Thirteen is like medium. Eleven million is so quick!

Mrs. Green: Super quick –

Juanita: My brother thinks like he's the fastest person in the world that can, rrrr, rrr. I'm like going to tell him, no. Maybe I can tell him that today that I learned that light travels from – what – one minute, um –

Mrs. Green: It can travel to the moon 46 times.

Juanita engaged with Mrs. Green and the concept of the speed of light. Juanita's references to the text and her brother were a connection she made to herself. Juanita made sense of the comments when (line 4), she said, "One is kind of like slow. Eight is kind of fast. Thirteen is like medium. Eleven million is so quick!" These were the numbers that Mrs. Green had just used based on the text and images in the book. Juanita's next comment indicated how complex the comments remained. On lines 8-9, she commented, "…light travels from – what – one minute, um." Now Mrs. Green attempted to clarify her comments. On line 10, she said, "It can travel to the moon 46 times." But she introduced a new number, 46. Juanita did not mention 46 and whether it made sense to her was not clarified. The teacher chose this time to recap the lesson thus far.

**Recapping the text thus far.** The book had introduced many concepts, relatable images, and many abstract ideas. The many numbers in the text seemed to converge. Mrs. Green chose this moment to see what the students understood. She asked, "Alright, think in your brain. Tell me one thing that you learned about light". Their responses indicated their understanding was murky. During this segment, the students were presented with many numbers that they could not all comprehend. the students tried to contextualize their comments with some of the data they had just heard. The students were trying to grasp concepts of distance, time, and speed. The ideas presented remained abstract; these were immense numbers, as were the distances they were discussing. One comment was that the sun was 46 miles away, to which Mrs. Green commented, "That would be like me driving home. That's not far right? It would take me 46 hours to get there. It would take me less than two days to get to the sun." Other comments about the time or distance to the sun were: "Four days. "A million days." And "96 million miles." There was an acknowledgement of the time and distance, but the numbers did very little to contextualize the facts around speed. There were a lot of numbers and data being shared in this moment. The comments required another reset of the lesson, and Mrs. Green took it.

Mrs. Green had been reading the trade book for 14 minutes. It contained factual information about the sun and travel to the moon. It also provided facts and images related to the speed of sound, light, and a car. While the book contained clear images, and Mrs. Green was very precise in her support of the text, these were very large numbers with very little relevance or relatability to these students. She had just read pages 14 and 15. The students had many questions and some misunderstandings. Therefore, she decided to reread the two previous pages, 12 and 13, to clarify the comments made previously. She would go on to repeat, "The sun is 93 million miles away," three times. And yet, she would be interrupted with a student's own recall of facts. Mrs. Green went back to the book and reread the pages to correct some of the discrepancies in the students' remarks about the sun. She also wrote the following on the chart paper, "The sun is 93 million miles away and makes Earth's light." Next, she wrote, "Light can travel to the moon and back 46 times in one minute." The students did not repeat the comments from the chart paper, but they were visible for all to see. In concluding this segment of the lesson, Mrs. Green asked the students to whisper into their hands what they were thinking. Juanita did not whisper into her hands in this moment, she had her hand up during this entire segment, and finally she was able to get up to get a tissue. Meanwhile, the rest of the class took this opportunity to get their ideas across, even if only to themselves.

**Incomprehensible language and abstract ideas.** This was just the introduction to the lesson, and the students had been sitting for more than 20 minutes. Next, Mrs. Green would go on to read two more pages, 16 and 17, to give the class more background about light. The text now presented simple images of measurement: a thermometer, a yardstick, and a stopwatch. Included on these pages were a dog being measured, a child with a thermometer in his mouth, a runner completing a six-minute mile, and a prize-winning pumpkin weighing 82 pounds. The discussion moved from the speed of light to measurement, all kinds of measurements. The text tried to connect the students with what was perceived to be familiar to them. The text began with the length of a dog, "Look Sparky, you're 32 inches long." The notion of inches was introduced in the text, but Mrs. Green clarified the visual. she said, "Yardstick." She never brought out a yardstick, but she described it to the class. The text went on to discuss temperature as another measurement. The visual included a little boy in bed and his mom taking his temperature. Mrs. Green interpreted the visual and told the students, "He's very hot." While she did not mention the word *temperature,* she went on, and said:

> Well, when you're sick, and you have a fever, your body's normally cold. And he has a fever. When you're hot, you normally feel cold, as you said. Now, "to find out how hot something is, we measure it in degrees." Did we talk about them, the two different kinds? I can't remember – degrees Fahrenheit and degrees Celsius – we use Fahrenheit in America. So "we measure time in minutes and weight in pounds.

She now provided information about fevers and its measurement in degrees. She also chose to add in the words Fahrenheit and Celsius. There was no discussion of the meanings of the words: of *degrees, Fahrenheit* or *Celsius*, but the words were part of the discussion. Juanita looked on at the images in the book. But the language was irrelevant to light. They were discussing measurement. Whether this meant anything in the context of a discussion on light or whether they grasped it was irrelevant. It would not be discussed further, and the reading of this text would culminate with more academic language about light's intensity.

**Maybe making connections.** Once again, the text chose to connect the new, with what the students were familiar with: the light bulb. The next two pages in the book, 18 and 19, displayed a huge sun that covered one page, and on the other page was an image of planet Earth with people on various parts of the planet turning on a light. Juanita was away briefly for part of the discussion. When she returned, the class was discussing lumens. She was both behaviorally and academically engaged. The teacher said, "Let me write this number on the board." Juanita and the class looked on as the teacher wrote the number 35 octillion. It was the number 35 followed by 27 zeroes. Juanita was very animated and grabbed a nearby classmate as the teacher wrote the number on the board. It looked like she needed support to deal with the number. It was a humongous number and it grabbed their attention. The class also repeated the number, "35 octillion." Mrs. Green went on further and said, "So, if everybody on the earth put on all of their light bulbs, all of their lights, all of their flashlights, everything, all of the lights in your house, all the lights in my house, all of your friend's houses, around the world, the sun is still brighter." This was the last page read from this text. It would not be read from again in the course of the next two days. Mrs. Green concluded the lesson by commenting, "That's how bright the sun is. That's why you should never look directly at the sun. So, if you're outside, what should you be wearing when you're outside and sun might be out?" Andrew answered, "Sunglasses."

The class had been sitting for almost 27 minutes on the rug. They had just read 12 pages of a trade book. The book was a teaching resource selected by the teacher, and a great deal of the language in the text needed scaffolding. Mrs. Green scaffolded most of the content, however the section on measurement was not scaffolded. Much of the measurement information provided was not essential to understanding light. Now, before the final activity, Mrs. Green concluded the discussion, prompted by student comments, with some further details about the sun. The final discussions of the sun supported the students' own prior knowledge of the sun. There was talk of blindness, burning, and potential melting caused by the sun. There was a connection to the solar eclipse the summer before by a few students. Mrs. Green acknowledged these connections and the strength of the light from the sun. Quickly, she completed the discussion and reset the class to conclude the last few minutes with a final mini lesson.

**R-O-Y-G-B-I-V without the rainbow.** The teacher wanted to tie all of the day's discussion to the new topic in science: *light*. The trade book was put away, the students turned toward the front board, and now an image from the e-book was visible on the screen. she introduced the e-book and provided students with a taste of what would come in the next two days: *rainbows*.

1 Mrs. Green: So, our whole new chapter is all going to be about what?

2 Children: Light.

3 Mrs. Green: We're going to be talking about rainbows.

4 Child: Whoa.

5 E-book audio: "How can you make a rainbow? We're going to investigate to find out."

6 Hands down for one second. What is a rainbow? Yun, what's a rainbow?

7 Yun: When it rains, it makes a rainbow.

Mrs. Green prompted the students for what they would be discussing in this new chapter in science. they responded, "Light." They had just sat for 30 minutes listening to a book about light. Notably, the trade book did not mention rainbows. When Mrs. Green mentioned that they would be learning about rainbows, the students were excited and said, "Whoa!" Juanita was behaviorally engaged. She looked on as Mrs. Green spoke. However, the discussion of rainbows was absent an image. The students' responses were based on their prior knowledge of rainbows, the e-book displayed tall buildings at sunrise, and there was no rainbow to be seen. Yet, Mrs. Green read from the e-book on line 6, "How can you make a rainbow? We're going to investigate to find out." Thus, here was another example of a text, without images to support the text. The teacher chose to briefly tap into their prior knowledge before the next lesson on the following day. In fact, she utilized this opportunity to assess the class' prior knowledge of rainbows without seeing one before them.

During the discussion Mrs. Green learned that they knew a rainbow required rain and the sun. Next, she wanted to reinforce the colors of the rainbow, and extend their interest. In the final two minutes she proceeded to teach them an acronym about the colors of the rainbow.

Mrs. Green: The sun also needs to come out, and we'll talk about why you can see a rainbow. Does anybody know what colors you can see in a rainbow? Oh my. In one of my reading groups we talked about this. Subhan.

Subhan: Red and orange.

Mrs. Green: Close. You were almost – alright. So, you had red, orange, yellow, green. Alright, now there's two more –

You said blue. Then there's two more after blue. Tell me one. Cameron.

Cameron: Indigo

Mrs. Green: Indigo – that's such a fancy one – and last one. Jefferson.

Julio: Violet

Mrs. Green: Violet – very good. Now there's a little trick. Which one of my reading groups remembers the trick? Juanita?

Juanita: (*Clears throat*). R-O – wait.

Mrs. Green: Nelson.

Nelson: ROY-G-BIV –

Mrs. Green: ROY –

Child: R for red, O for orange, Y for yellow, G for green, B for blue, and I for indigo, and V for violet.

Mrs. Green: Everyone say ROY.

Children: ROY.

Mrs. Green: G.

Children: G.

Mrs. Green: BIV.

Children: BIV.

Mrs. Green: That's the order of the rainbow. The rainbow is always red, then orange, then yellow, then green, then blue, indigo, and last violet. Indigo and violet – indigo is almost like a blueish purple. You have that in your crayons. We can show that tomorrow. Then violet's a lighter purple. Alright. I know you guys are super excited, but we have to pack up. Otherwise, we're never going to get home on the bus.

The students were very excited to learn about rainbows. On line 1, Mrs. Green commented, "The sun also needs to come out..." Immediately, several of the students could be seen wiggling their thumb and pinky in the air, indicating they made a connection. Juanita was among the students wiggling her hand. On line 5, when Mrs. Green began reciting the colors, she also wrote the words for the colors on the board. Then, on line 13, Juanita responded with her recall of the acronym. She said, "R-O." Juanita did not complete the letters for the acronym. Mrs. Green moved on, there was no wait time. The class was almost over. On line 15, Nelson said, “ROY-G-BIV.” The teacher had spurred on the class’s interest and asked the students to repeat the acronym. On line 20 the children said, “ROY.” Then, on line 22 they said, “G.” Finally (line 24), they said, “BIV.” Hence, with the last minute repetition of the ROYGBIV acronym, it was time to go home, and this was the end of the science lesson.

While technically the lesson was over, Mrs. Green deployed a little memory trick for the students, as follows:

> So, hold all of your thoughts. Ready? Open up your brain. Find the file folder that says “light.” Pull it out. Open it up. Put all of the information that we learned today in it. On the other side of the folder, put all the things that you want to tell me tomorrow in it. Ready – close it up. Make sure it’s zipped up – … put it back in the brain. Zip up your brain. And show me that you’re ready – hands down.

The final trick was for students to store what they learned in a file folder they withdrew from their brain. Mrs. Green demonstrated the movements of opening the brain, taking out the folder, placing ideas into the folder, and zipping the brain closed. While she did this, she pointed to the board where she had just written the colors of the rainbow. The class mimicked the movements and prepared to pack up and go home. Science was over without discussions about experiences with light by most of the students. I was unsure of Juanita’s experience. She appeared to be engaged throughout the various segments of the lesson. She engaged in discussions and answered questions. At the end, she even tried to provide what she could recall about the colors of the rainbow. But what did all the information she heard during science mean to her? In fact, her only extended discourse on the topic of light would occur during our interview.

**Juanita’s interview: an opportunity for discourse.** The purpose of the interview was to learn about Juanita’s experience in science. The interview was an opportunity for Juanita to communicate her understanding of light. She was the third student interviewed for my study.

She was interviewed two days after the final observation. On the last day of observations in her class, science began late and ended late. There was no time to interview her on that day. On the following day, she was absent. Hence, when I interviewed her, it had been five days since the observations began.

Juanita had previous experience with science, that was clear. I began the interview as I always did by introducing myself again and allowing her to speak before I commenced with my standard interview protocol. Juanita was very talkative and not at all shy. I started out by asking her, “How do you feel about it when Mrs. Green says, ‘It’s time for science?’” She responded:

> I feel kind of relaxed because when we do science, we just sit there and point, but like we also have to say things. And when we do science, I think it’s fun because sometimes, because I always been dreaming of making a volcano experience and... Experiment, I meant. And I have never got to do that, so I’ve been studying all about volcanoes.

Clearly, Juanita had her own ideas about science. But what she acknowledged was sitting and pointing. Her remarks were consistent with what I observed for three days. I probed a little more and then commented, “Oh, so when we do science, and you sit there and you are pointing, what do you mean by you’re pointing? You’re point to?” She said, “The words.” Her understanding of science was based on her past experience. She further commented that she had attended a daycare program where, “Because the way we do science at my after school program. Like at the daycare program. We actually do not use books. We just like use computers. We have 24.” In this moment, I interjected. I wanted to understand how her daycare program was different from science at the Oak School. She explained, “We have 24 Chromebooks, and we all go on the same page and start reading about what we are going to be like learning about.” This was different from school. She commented, “We don’t, we use Chromebooks instead of like regular books.” So, in school she read a trade book versus using a Chromebook to learn science. Nevertheless, based on our conversation, her experience of science was reading at school and at daycare.

**Science was about reading, not doing.** Juanita understood that science was about doing, not just reading. When I asked her how science was different from reading, she answered, “Because, like um, when it’s science, like we learn things that we can do and like in um, reading we learn things that are like narratives.” Then I said, “So reading, you’re thinking is like a narrative.” She immediately responded, “Not true.” I tried to clarify, and said, “So, ‘cause science is real, a real thing, as opposed to like narratives, which can be fiction. Is that what you are thinking about?” She said, “Because in science we learned about, like I don’t know what we learned about. Ok. In science we are learning about light.” She went on to explain what she had read in language arts, and said, “And like in the Journeys, we learned about things that are from the moon.” She was explaining how she had read a nonfiction text. Juanita understood that reading a nonfiction text was not the same as reading in science. Then she said, “And what’s different about it that like the moon rocks are from like hard things. And like science is like you can do. Um. You can do. Let’s say. Like you can do. Um. You could um. You could um. Why do I not get this?” I then tried to help her get her meaning across. I commented, “Well, it sounds like you’re saying when you read something in science, I’m sorry, in Journeys, like it was talking about going to the moon. It’s just a story about some information.” Juanita said, “Ahmm.” I then went further, “But when you do it in science or when you read it in science, it sounds like you are saying there is some activity.” She said, “Yeah! That’s what I’m trying to say.” Hence, Juanita understood science to be doing, not just viewing.

Juanita believed science was about doing activities, and I wanted to find out what she had done in the last few days. We spoke further, and then I asked if she felt like a scientist during science class. She said, “No, ‘cause we really don’t do nothing.” I asked for further clarification. “Like, we don’t use our hands, like to make experiments/things. Like, I’ve always been dreaming of making an experiment, and I never, ever, ever, ever did." She really stressed the *never, ever* when she spoke. She made it clear that her experience with science did not include hands-on activities, but she knew that is what should be happening. In fact, what I heard was that her experience with science at school and elsewhere did not entail ever doing an experiment.

**Understanding and prior experience.** Juanita's experience in science was limited to reading books, and the reading did not necessarily lend itself to understanding the content of science lessons. When asked, "What do you think it means to be a scientist?" she paused and then responded, "I think what a scientist does is like make new things for the Earth." She had combined her knowledge about what engineers do with what scientists do. Learning about engineers was one of the first lessons in the new curriculum based on NGSS. Thus, the conversation continued in my attempt to try and understand her most recent experience in science. Since she did not participate in any discourse where she made meaning, I thought we might look at her science journal to see her understanding of the lessons thus far.

Juanita did not have an opportunity to communicate her understanding of light, and her science journal further reflected this fact. As she searched in her journal, she found the page that contained the objectives of the lesson. I asked her what she could recall being told about the page. She responded, "That we were going to explain how light travels. How it helps us see and how it blocks light." I prodded Juanita further, asking, "What did you do, with regards to light so far?" She said, "We hadn't really done nothing." Then, she went on to tell me what she did recall. "I do remember something about rainbows. That they're tricks made by light." I knew this was a direct quote from the text the class had read about rainbows. I then asked, "Tricks made by light. And why do you say that they're tricks made by light?" She turned to her book for the answer, "Be-causzzzze- cause, we really can't see them." I asked her, "Can't see?" She remarked, “But we can’t touch, because when like.” I interjected, “We can’t see the rainbow? Okay.” “Like, I’ve never seen a rainbow before, so.” She really could not conceive of a rainbow of colors in the sky; it was something she had not seen. However, Juanita could repeat what she had read: The rainbows were “tricks made by light.” In fact, her experience with rainbows was very limited, but she could easily repeat some of the messages she had heard during class.

The images of a rainbow in a book could not replace the real life experience of seeing one in the sky. Juanita had never seen a rainbow and she did not have the experience. Thus, she did not understand the trick or why you cannot touch them. She further revealed, “But I have seen one when we were like taking a shower, at my daycare.” She went on to say, “And like when we get close to them, they like seem to move away.” I asked her, “Do you know that or were you told that?” She remarked, “We were told that.” I commented, “Okay and why can’t you touch it? Why can’t you touch it? Because it really doesn’t say why.” I then asked her, “Why do you think you can’t touch a rainbow? What is it?” She responded, “Because I have this feeling that a rainbow is like sometimes going to change color.” Juanita did not comprehend the reality of rainbows. She simply did not understand that you could see different colors in the sky. She did not understand ROYGBIV as being constant. In fact, her experience with a rainbow was in a very limited and specific setting: a shower. In the end, a young multilingual learner was unable to understand the phenomenon of a rainbow.

**The Interview with Mrs. Green.** The lessons conducted by Mrs. Green comprised building background in literacy-based lessons. She was a skilled first grade teacher who had been teaching first graders for four years. Thus, in my interview, I wanted to comprehend her choices in delivering lesson content to multilingual learners. During our discussion I asked about the curriculum, she commented, “It's awful. It's very choppy. It doesn't make any connections for those kids." I asked for further clarification, "But are you also saying it's the way the material is presented in here or the vocabulary or the way it's put together?" When she said, "in here" she was referring to the textbook for the curriculum. She elaborated:

> And there's not enough pictures for them. We do have an Interactive Glossary in the back of their book. But, I was even just looking-- When I went to the training I asked for the vocabulary cards. The same company made Fusion. That's the company we had before. And we had vocabulary cards that we could print out, and it gave the definition. And then underneath it, we would either draw a picture to match it, connect, cause and effect, or compare it to something else. And when I asked for that for this one, 'Oh, we don't have those yet.' So, there's no support for those language learners. I mean we have those science readers that collect a lot of dust up there. They're way too hard. They are not on their level. They're just, blah. But even, if you look at the pictures, there's no pictures that explain, you know, explain what this is (*teacher thumbs through text - Unit 3 Light*). Our next chapter is going to be on light. Even before, I have to take pictures for this science lesson. I'm going to have to--this is what we sat and discussed with the science coach at that one workshop. I have to go around in the morning and take pictures of what the classroom looks, like in the morning, so they could see how dark it is. What it looks like in the afternoon. What it looks like at night. Because it's talking about-- why couldn't we do an experiment with light here? With like a flashlight. Something that they-

Hence, Mrs. Green opted to use different materials to deliver her introduction to a science unit lesson. Thus, enactment of the science content differed from the prescribed curriculum. The use of these supplemental resources, she explained, was due to a lack of support from the district's purchased curriculum materials. The teacher felt the district-provided curriculum resources contained insufficient and inadequate images. For example, the introduction to the topic of rainbows included an image of skyscrapers at daylight, absent any rainbow image. In addition, she described a lack of support for multilingual learners in a text without an interactive glossary or mechanism to fill in the gaps of comprehension for the images and language presented. As a result, she enacted the curriculum with supplemental resources.

The lessons were not inquiry based. The lessons contained no hands-on activities or enactment of NGSS recommendations for teaching and learning science. Mrs. Green's comments about the hands-on activities in the curriculum were:

> And the Hands-On activities are, I don't want to use the word stupid, but they are really not teaching kids. Like we feel like, it's more play time. And I get, we're supposed to let kids, you know, be creative and design using the design process. And create something that's going to change the world. But like, when they're using a string to hold headphones onto a computer. A lot of the kids go, why can't you just use a hook? We have those hooks already. Just put a hook there. You know what I mean like they are creating these things that really have no meaning to them.

She described an engineering and design activity in the beginning of the year where the students needed to solve a problem with tangled headphones. She felt the activity, and the fact the students readily provided a solution, did not provide an educational challenge. As such, she thought the inquiry-based activities in the curriculum were not meaningful. Hence, during three days of science, students instead listened to two texts about light and did not engage in any hands-on activities. The teacher scaffolded most of the texts and the images contained therein, in a skillfully delivered literacy lesson.

**Lack of professional development.** The resources and curriculum were untenable, even for a skilled lead teacher who worked on the team to select the text. Mrs. Green commented, "We need proper training again." She was very frustrated with the curriculum and the lack of training to use it. She further commented on her choice to use interactive science journals instead of the curriculum prescribed evidence journals, "I feel like that makes more sense to them. These evidence journals are– I get it, we want them to think deeper and critically. But when you don't even understand the concept, how can you think deeper and critically?" Furthermore, Mrs. Green felt the multilingual learners were not engaged in the lesson, "I feel like I get the blank stare. Like I'm watching you, I'm absorbing it, but I'm really not. It's going in one ear, and it's not doing anything once it's in that ear." I went further and asked her assessment of the multilingual learners' ability to comprehend the content. She responded:

> And there's really no time to be 'Alright let's pull you over. And let's talk about what you didn't understand in science.' Because it's like they didn't understand the whole thing. So, it's like you don't know where to start from there. Like, I can't just pull, like, a small group, and say 'let's talk about engineers today.' But they don't even understand that. And that's the basis of what we are talking about.

The new science curriculum integrated science and engineering practices to engage students in understanding scientific phenomena by asking questions and solving problems. Mrs. Green felt that the integration of engineering into the science lessons made it difficult to for the multilingual learners to understand the content. She believed she understood the limitations of her multilingual learners.

**More Science instruction within the Oak School**

**In the classroom.** In the Oak School, Mercedes was the last student observed in this study. She attended first grade with Mrs. Love, a 19-year veteran teacher. This year, Mrs. Love had 18 students in her class, and nine students were multilingual learners. Four of the multilingual students spoke Spanish at home, two students spoke Tagalog, two spoke Gujarati, and one spoke Hindi. The remaining nine students spoke English at home. Thus, 50% of her class was comprised of multilingual learners. Mercedes was among the Spanish-speaking students in Mrs. Love's first grade classroom.

**Focal Student 4: Mercedes' Background**

Mercedes, a six-year old, born in the United States, came from a Spanish-speaking home and was the only participant who attended a bilingual kindergarten class in the school district. Her placement into the bilingual program was determined by an assessment tool from World-Class Instructional Design and Assessment (WIDA) (WIDA, 2018). After five months in kindergarten, she was re-assessed using the WIDA ACCESS test. She received a score of 4.9 on the ACCESS test, with six being the highest score (WIDA, 2009). The district utilized a cutoff score of 4.5 along with other measures to determine a student's eligibility for bilingual services each year. According to WIDA, Mercedes had the ELP of a student at the expanding stages of acquiring a second language. Thus, according to the district's established criteria, she was deemed English proficient, and was exited from the bilingual program into a mainstream classroom for first grade.

As a result of her score on the ACCESS assessment, Mercedes did not qualify for bilingual services in first grade. Her designation as English proficient made her ineligible for ELD support in first grade or for Basic Skills lessons. Thus, Mercedes was a bilingual student in the Oak School who was deemed English Proficient and received no additional services for first grade.

**Mercedes' Engagement in Science**

**The introduction to the lesson.** When I entered Mercedes class for the first observation, Mrs. Love was commencing "Lesson 4: How Do Plants and Animals Respond to Their Environment?" (DiSpezio, Frank, Heithaus, & Sneider, 2018). This lesson was part of "Unit 4: Plant and Animal Structures (DiSpezio, Frank, Heithaus, & Sneider, 2018, p. 137). The topic had been introduced two weeks earlier, and this lesson began with students sitting on the rug. Mrs. Love had the students engaged in a discussion to introduce the lesson. Mercedes, like all students in the class, always sat on the rug in an assigned spot. Over the course of three days, she participated in three lessons regarding how plants and animals respond to their environment. On the first day of Lesson 4 of the unit, the students were engaged in a discussion as follows:

1 Mrs. Love: So, we said an environment is the place where an animal lives. All the

2 living and non-living things are part of the environment. But, we also said that,
3 environments, some environments, stay the same all the time. Thinking, please for a
4 moment, think about an environment that stays the same, all the time. What place did
5 we say the environment stays the same all the time? Where things do not really
6 change, outside? Where the weather doesn't really change, the land doesn't really
7 change...? What's a place where the environment doesn't really change?
8 Child 1: Arctic?
9 Mrs. Love: Thank you (*whispers*). The Arctic. It doesn't really change in the Arctic,
10 does it? It's always cold, snowy, and icy. Now, think. What's another environment
11 somewhere on Earth where it doesn't really change? Adrianna?
12 Adrianna: The rain forest?
13 Mrs. Love: Yeah, the rain forest. What's it almost always like in the rain forest,
14 Mercedes?
15 Mercedes: Rainy.
16 Mrs. Love: Rainy and...?
17 Mercedes: Hot.

During this introduction, Mrs. Love was using visual cues to scaffold her instruction. At lines 3 and 4, when she referred to thinking, she was pointing to her temples. Several students mimicked the gesture. Then (lines 5-7) when she referred to change outside, she hugged herself and shivered to gesture "cold." Suddenly, students began to raise their hands, and one child responded (line 8), "Arctic?" Mercedes was following along and provided two follow-up responses to the question (line 13), "What's it almost always like in the rain forest?" Mercedes said, "Rainy." She also responded to the follow-up question (line 16), "Rainy and what?" with

"Hot." By all appearances, Mercedes was behaviorally and academically engaged in the lesson introduction. Mrs. Love was building background knowledge regarding the meaning of environment. These responses were based on students prior learning and knowledge. There were no images on the screen of a rain forest or frozen tundra. Therefore, the responses demonstrated how students were able to recall natural environments previously discussed or learned from memory.

## Issues that Helped and Hindered Meaning-Making During Science

**Making connections.** Mrs. Love created a basis for discussing the environment, but now she scaffolded the lesson by providing students with a connection to their own lives and their environment. Mrs. Love transitioned the discussion from places where the environment does not change to a more tangible and visual reference for these children who live in a location where the weather changes. Mrs. Love commented, "Now, what is an environment that does change?" She was looking toward the classroom windows and pretending she had binoculars. In the discussion, Mrs. Love created opportunities for students to tap into their prior knowledge about environments. She supported the students during the lesson with gestures to guide them to notice their own environment outside of the window. Here, once again, Mercedes responded to queries. When Mrs. Love stated, "Tell me how the weather changes where we live in our environment," Mercedes raised her hand to respond to the question. First, another child responded, "It changes colder and hot." Then subsequently, Mercedes said, "The seasons change." During this exchange Mercedes had an opportunity to respond to a query and contributed to the discussion with her own knowledge.

The response about seasons prompted Mrs. Love to segue into a discussion regarding the plants in the local environment versus the rain forest. Once again, she provided students with more knowledge and worked jointly with them to establish a connection between themselves and the content they would be covering. She was scaffolding the instruction by building on prior knowledge and making connections to students' own experiences. During the following segment, Mrs. Love also moved the discussion toward animal migration, then shifted the conversation toward the content to be covered in the day's lesson. She began:

> The trees change also. That was something that we talked about, how the change of seasons is also a time of change for plants. In our environment, the plants are not the same in every season, are they? But in the rain forest, the plants are the same pretty much most of the time. Everything is the same. Then we were really focusing on what do animals do when their environment changes? One of the things we read about is some animals actually move when their environment changes. They move. What were some of the reasons that animals – why would animals move? Why would they, Laura? Why would they go somewhere else?

The discussion ensued with a few students responding as follows:

> Laura: To try and find food.
>
> Mrs. Love: Absolutely. What was another reason?
>
> Child 1: To get away from a predator?
>
> Mrs. Love: Well, we're not just talking about moving like running away from danger. Here we're talking about where they travel a long way. Does anybody remember why whales... Why do whales move to warmer weather – the grey whales? Melody?
>
> Melody: Because they normally have babies, and they want the babies to be born in the warm water.

Here the discussion had gone from defining and explaining environments to the impact of the environment on animals, and why the animals move. This switch in the discussion was also scaffolded with a change on the board to an image of a gray whale from the e-book. Mercedes looked at Mrs. Love during the exchange and attended to the image on the board when it changed. Notably, the lesson had transitioned from the environment changing to animals moving to adapt to changes in their environment.

**From human adaptation to animal adaptation.** The focus of the lesson on this day was animal adaptations. With nearly five minutes of background built, Mrs. Love then shifted the instruction to enable students to make connections to the way humans adapt in their environments. This was another scaffolding technique. In what followed, she made connections to how students respond to their environment. The discussion on human adaptation went on to include connections the teacher and students noted about the ways they themselves make adaptations depending on the weather—wearing coats in colder weather and boots on snowy days, and opting for T-shirts and sandals in warmer weather. The discussion also highlighted that students make adaptations for things other than weather, such as changing into sneakers to go into the gym on PE days.  It concluded with Mrs. Love underscoring the concept for students, adding, “Adaptation is something that you change to match your environment, okay?” She then had them take out their big science workbook. The introduction to the lesson was over.

In this segment, Mrs. Love said “adaptation” eleven times. She built background knowledge, repeated key vocabulary, and assisted students in making connections to what they already knew about environments. The instruction was both supportive and scaffolded for the students in the class. Note, when Mrs. Love commented about wearing boots, she pointed to her own feet, displaying her boots. She made the connection from environments to animal adaptations, and then combined the two in a discussion on how humans adapt to the environment. However, at no time did the students say “adaptation,” an important scaffolding technique for multilingual learners. Repeating the vocabulary would have provided them with a comprehensible output opportunity of academic vocabulary.  During the introduction, Mercedes responded to queries with responses about the rainforest and the seasons. She appeared to engage in making connections and meaning of the content presented. The lesson then segued to the science workbook, a thick book where students could write responses and see the same images that appeared in the e-book on the front board now in their own workbook.

**The essential question creates confusion.** During the next segment of the lesson, Mrs. Love provided the students with the essential question to focus the lesson. The question is long, paraphrased, repeated, and modified along the way. She stated:

> So, friends, our big question that we're thinking about is, how do plants and animals respond to their environment? How do they react? How do they change with their environment? Now, some animals leave their environment when their environment changes. When their environment is a place where they can't get food, it's not warm enough for them to have their babies. They will move somewhere else so they can get food, and they can get a warm place to have their babies. Now, some other animals actually stay in their environment the whole time, no matter what. So, what adaptations help animals live in the same place all year?

At this moment, Mercedes was holding a pencil in her hand and not looking at Mrs. Love. Then, she looked up at Mrs. Love when she posed the essential question. Mercedes looked on as Mrs. Love commented, "…how do plants and animals respond to their environment?" In fact, this question referred to both how plants respond and how animals respond. There were two questions for Mercedes to ingest, not just one. In this question, the "they" again refers to "how plants react," and then "how animals react." Again, the reaction of plants and animals will require two responses, not just one. Furthermore, the word *respond* was not addressed. Did Mercedes understand? Next, came the second question, "How do they react?" Notably, the language in the question, specifically, the word *react* was not specifically defined or explained.

At this point, Mercedes and her peers now had two more concepts to consider: "... how do plants and animals respond to their environment? How do they (plants and animals) react?" Then, in yet another question in this segment, Mrs. Love asked, "How do they change with their environment?" Again, the "they" of this question also referred to both plants and animals. Students were requested to respond to how the plants change with their environment and how animals change with their environment. Ultimately, the three questions posed required six different responses. It's important to note, too, that thus far, the discussion had primarily focused on animals changing, and not on plants—and how "they change" will be different for plants and animals. In this third question, Mrs. Love changed the language slightly. She asked, "How do they *change with their environment*?" The words *react* and *respond* were no longer used, instead the word *change* occurred instead in the question. Was Mercedes able to distinguish between *respond, react,* and *change*? The discussion still centered around "they change." In addition, the comment, "…with their environment" was not explained. What did it mean for plants and animals to "…change *with* their environment?" Much of the language in this segment of the lesson was not scaffolded, and Mercedes had a lot of language to consider *–respond to, react, change,* and *with their environment*. In fact, during this segment, the students just sat and listened.

During this exchange, the questioning was not scaffolded, the vocabulary not explicitly defined, referents were repeatedly used, and multiple questions made it difficult for the students to respond in the moment. Meanwhile, Mrs. Love continued to speak. And after all these questions, did the students make a connection to their PE adaptation as a change they make "with their environment?" The students may have been confused with so many questions. Mercedes may have had difficulty with the academic vocabulary— r*espond* and *react,* the repeated use of referents (*they* and *their*), and finally the use of the term, *change with*. Indeed, as the question evolved it became "How do animals and plants change with their environment?" However, Mrs. Love did sum it up with, "…what adaptations help animals live in the same place all year?"

Perhaps the lack of student response here prompted Mrs. Love to further clarify the essential question with more information. She chose to narrow the question to just animals and attempted to clarify her question with the following:

> Now, some animals leave their environment when their environment changes. When their environment is a place where they can't get food, it's not warm enough for them to have their babies. They will move somewhere else so they can get food, and they can get a warm place to have their babies.

She moved the discussion to animal migration. She had now asked the children seven questions in a brief span of time without anyone responding to her lecture. The children sat silently in their seats, and no one responded to any of the questions posed to them so far. She continued to discuss and explain adaptations.

> We live in the same place all year. You might go on vacation. You might go even for a long time to visit some place. Like, in summertime, I go to Florida to see my family, and I'm there for like a month, sometimes five weeks even. That's a nice, long time to be away, but I don't live there all the time. It's just I go there for a long time. So, some of you might go visit family in a different country over the summer. That's just going to visit. That's actually not leaving your environment. We really live in the same place all year. Because our environment changes, we have to do different things so we can match our environment. We talked about that. Our clothes have to be different. Even our activities can be different. Can I go home and go swimming outside today?

Mrs. Love had been speaking for two minutes. She began with the six-element questions, "…how do plants and animals respond to their environment? How do they react? "How do they change with their environment?" She concluded with, "So, what adaptations help animals live in the same place all year?" Now, she was also discussing vacation in Florida, or elsewhere, and how that was not a change of environment. Subsequently, she attempted to explain "vacation" as not a form of leaving your environment, by commenting, "So, some of you might go visit family in a different country over the summer. That's just going to visit. That's actually not leaving your environment. We really live in the same place all year." I was not sure that made sense to these first graders. I could understand how they could see changing location as leaving your environment. Were they not leaving their environment when they changed location? Finally, amidst all the questions and explanations, Mrs. Love connected to the students when she mentioned swimming outside in the winter.

**The silence was broken.** Now, a few children shouted out, “No!” Then, Mrs. Love referred the class back to the workbook sitting in front of them. She would use the workbook to clarify her question, but also to change the topic of discussion again: switching from “moving as an adaptation” to “hibernation.” She proceeded to do so as follows:

> I can't do that. I have to match my environment. My environment does not look like I'm going to go outside and go swimming today. So some animals, they have to change also so they can live in their environment. So here we have the groundhog. “To get ready for winter, a groundhog eats a lot of food. Then it digs a home under the ground and sleeps all winter long.” Does anyone know the science name for when animals sleep all winter long? What's the science name for that? Jordan?

In this segment of the lesson, Mrs. Love read some of the text from the workbook, and then Jordan responded to her question with, “Hibernation?” Yes, now the class was going to discuss hibernation. Yet, no one, but Mrs. Love and Jordan, said “hibernation.” However, everyone, including Mercedes gave her a thumbs up acknowledging they had heard the word before. Did they understand? Perhaps, and then the lesson transitioned, yet again, to a new topic: hibernation.

**Talk about hibernation, not adaptation.** Thus far, the lesson sequence had gone from the environment to adaptation, then migration, and finally to hibernation. Although the focus for the lesson was “…How Do Plants and Animals Respond to Their Environment?” the topic of the lesson was how animals and plants change *structurally* to adapt to their environment. Mrs. Love had just read from the text, “To get ready for winter, a groundhog eats a lot of food. Then it digs a home under the ground and sleeps all winter long.” This is a behavioral adaptation, whereas the focus of the lesson should have been structural changes in plants and animals to meet their environment. Previously the class had studied animals’ body parts as a precursor to learning about adaptation. Thus, in the workbook example, the groundhog changed its structure by storing fat to survive the harsh weather, in addition to changing its location underground. However, no information about fat storage was specifically stated in the workbook or addressed by the teacher. Instead, the discussion now centered on animal hibernation.

Mrs. Love: What other animals besides the groundhog – because they just told us – what other animals do you know of that hibernate in the winter? They eat a lot of food, and then they sleep all winter long. Tom?

Tom: A squirrel.

Mrs. Love: If I went outside in the winter, could I possibly see squirrels running around?

Ms. A [Teacher’s Assistant]: Oh, I just saw one yesterday.

Mrs. Love: Yeah. Actually, give me a thumbs up if you've seen a squirrel outside in the winter. Yeah, so squirrels don't really hibernate. Melody?

Melody: A fox?

Mrs. Love: Some foxes do, yes.

Child 1: Bear?

Mrs. Love: Bears definitely hibernate.

Mercedes: Sea otters?

Mrs. Love: Well, a sea otter lives in the sea and swims. Could they sleep all winter long?

Mercedes: [Shakes head no]

Mrs. Love: That doesn't make sense. Some kinds of snakes hibernate. Yeah, they do. All right now, so that's one.

Ms. A: I have a list.

Mrs. Love: Go ahead, Ms. A. Help us out.

Ms. A: My phone says skunks, bees – they stay in their hive – snakes, groundhogs, bears, bats – they don't come out when it's cold – and that's it. And a rat.

The discussion focused on hibernation but the word *adaptation* was not used. The idea that hibernation is a form of adaptation was not explicitly stated. The only scaffolding that occurred was visuals from a page of the workbook. The visuals were of two separate images on the same page in the workbook. One image was of a groundhog and the other a fox. The text focused on what the animals did to adapt. she asked, "What other animals besides the groundhog – because they just told us – what other animals do you know of that hibernate in the winter?" The students' responses included: *squirrels*, *fox*es, *bears,* and *sea otters*. Notably, several of the responses were incorrect, so at this point it was clear that many students lacked knowledge of hibernation and the animals that hibernate.

The discussion on hibernation contained limited linguistic or content scaffolding. There were no explanations of which animals hibernate and why. Based on the discussion, it appeared squirrels do not, some foxes do, bears do, sea otters do not, and snakes do. What was the common thread? Why could some hibernate and others not? These questions were not asked by the students nor addressed in the text. Towards the end of this segment, Ms. A., the Teacher's Assistant, chimed with the results of an Internet search from her phone on animals that hibernate. She read, "My phone says skunks, bees – they stay in their hive – snakes, groundhogs, bears, bats – they don't come out when it's cold – and that's it. And a rat." Thus, the students' knowledge of animals that hibernate was limited to a list, not well supported by the text, the content of the lesson, or meaning making.

**Explaining adaptation without saying the word.** The discussion switched to explaining animal adaptation as a physical change that enables animals to endure a change in their current environment. Mrs. Love continued the lesson from the workbook, and read as follows, “A red fox grows thick fur and eats more to get ready for winter.” However, the word *adaptation* was not used, nor was the animal’s response to the cold weather explained as a form of adaptation. Then Mrs. Love commented:

> So, some foxes might hibernate, or sleep a lot, but mostly a red fox – it's fur will get really, really thick, and it'll get kind of fat, because it wants to be able – it's not going to be able to find a lot of food in the winter, is it? I have, at my house where I live, there’s a family of cats. They live outside. They don't belong to anybody. Nobody takes care of them, but they have picked my neighborhood to be their home. And we actually had a very nice lady—she kind of puts food out for them to help them out. She actually did something where she caught some of them. She brought them to the vet so that they got fixed, so they don't keep having more and more babies. There's just this one family of cats, and they stay in my neighborhood all year long, but they look really different in different parts of the year. Right now those cats actually kind of look like that fox. They're super furry, fluffy, big, and poofy. [Laughter] But when I see them in the summer, their hair is short, there's no poof, and I can see their bodies a lot better. Why do you think they get so big, poofy, and hairy in the winter?

This was an explanation of animal adaptation, but the word was never used in the discussion. Mrs. Love also gave erroneous information about foxes whose fur actually does get thicker, but they do not hibernate. She said, “…some foxes might hibernate, or sleep a lot, but mostly a red fox – it's fur will get really, really thick, and it'll get kind of fat, because it wants to be able – it's not going to be able to find a lot of food in the winter, is it?” The switch to discuss cats may have been a simpler manner to discuss adaptation among animals. The comment contained information about animals commonly visible to students. However, she also used “furry,” “fluffy,” and “poofy” to discuss the cat’s fur. During this long and unscaffolded explanation of animal adaptation, Mercedes maintained a pencil in her hand and repeatedly erased the cover of her workbook. When Mrs. Love approached her while commenting, “I have, at my house where

I live, there's a family of cats. They live outside. They don't belong to anybody," Mercedes looked up at Mrs. Love and stopped erasing her workbook cover. Then, Mrs. Love concluded this segment with a question: "Why do you think they get so big, poofy, and hairy in the winter?" One student responded, "To keep them warm?" Mrs. Love concluded by commenting, "To keep them warm. Absolutely. Some animals' bodies will naturally grow some more fur, or their fur might even change a little bit to match their environment. And guess what? Their body knows how to do it all on their own. Isn't that cool?" Now, eight minutes after the students first began reading the page from their workbook, they put their books away, returned to the rug, and sat to watch a video on hibernation. The prior discussion took many turns as it switched between adaptation and hibernation without adequate scaffolding.

In the lesson thus far, the focus was on animals changing to match their environment, *adaptation*. However, the discussion became convoluted between adaptation, migration, and hibernation. The expectation of the science unit was for students to discuss how plants' and animals' structures assist them in living in their environments (DiSpezio, Frank, Heithaus, & Sneider, 2018, p. 112). Thus, the discussion should have been about what parts of an animal experience a structural change to meet their environment, not necessarily where they go to adapt to their environment. The topic of migration was not a focus of the unit. The vocabulary for the unit was: *lungs, gills, mimic, adaptation*, and *environment*. The words *hibernation* and *migration* were not part of the discussion in the chapter, nor were they used in the text. While Mrs. Love used "hibernation" extensively, the students' knowledge was assumed via a thumbs up on having heard the word. However, only two students who responded provided correct responses for animals who hibernate. The lesson here contained limited scaffolds. Migration was explained as a change of environment, and not the animal's structural incapacity to endure the change of environment. Hibernation was not explained as a structural change for animals, but rather an environmental change. Indeed, the focus would turn from the district's curriculum rsources to a non-curriculum resource video.

**Using videos to deliver science content.** Mrs. Love utilized Internet videos about science content on two of the three days I observed her class. She chose to use animated videos to provide students with background information. She thought the videos provided the language of science in a clearer manner. On this day, she prefaced a hibernation video with an explanation of adaptation using the following comments:

> Alright friends, we are thinking about our question, *How do plants and animals respond to their environment?* Really, we're focusing on animals and the seasons right now. So, some animals—when their environment changes—they will leave their environment and then come back when it gets warm enough. Other animals will stay in their environment all year long, and they will change. They will change. That's that "adaptation." They will change what they maybe look like and what they do to match their environment. So, we're going to watch with Annie and Moby about hibernation. One of the ways that they match their environment is to hibernate. So, we're going to watch a video about hibernation. When we are done, depending on how much time we have, I'm going to ask you to go back to your science notebook. You're going to draw a picture or write about something that you learned about hibernation from watching this video. So, you need to pay attention. Say you already know about hibernation, maybe there might be something new that you might learn.

Mrs. Love's explanation ended with instructions. The students needed to listen and prepare to draw a picture about what they learned from the video. The four-minute, animated hibernation video from BrainPop did not clarify hibernation (BrainPOP, 2018). The video provided additional information about hibernation, and it also created new obstacles to identifying which animals hibernate and where they hibernate. The characters, Annie, a young girl, and Moby Max, a robot, spoke throughout the video. The two walked through the woods and discovered there were no animals visible. As the video began, the first animal the main characters came across who was hibernating happened to be a squirrel. Immediately, Mrs. Love interjected "Ground squirrel." Previously the class had decided squirrels do not hibernate because they are visible in the area of the school all winter long. The video depicted numerous animals who hibernate bugs, frogs, hedgehogs, and groundhogs. However, the video challenged commonly held beliefs about animals who hibernate. For example, the video depicted squirrels hibernating, and commented that, "Bears wake up in the winter? So, some scientists say they don't really hibernate?" These comments were not further addressed during the video. The video concluded with hibernating animals awakening for spring. Specifically, the squirrel awakening in its den. However, at this point the word *den* is not discussed in contrast to the trees inhabited by local squirrels in the school's neighborhood. Thus, the video presented a small selection of animals who hibernate, and it briefly mentioned bats, turtles, and dormice Yet the only animal depicted hibernating was the ground squirrel. In brief, Mrs. Love utilized this animated video to provide students with background information about animal hibernation but did not stop it at various junctures to scaffold its content or language.

The video added new information to the students' repertoire regarding animal hibernation. It explained how the animals manage to survive the cold weather, "Animals need to store their own food. They eat a lot of food when it's warm. Store up fat in their bodies. Then when the animals hibernate, they can live off of their fat all winter." This was new information regarding the structural changes that the animals endure, but it was not specifically recognized in the follow-up discussion. The video concluded almost 23 minutes after the lesson began. Mrs. Love's summary of the video did not address the ground squirrel, animals storing fat, or the new information the students heard about bears possibly not hibernating. She explained hibernation and then proceeded to present the final activity to the students, as follows:

> Alright. So, thinking about what we just watched, okay, and thinking about how do plants and animals respond to their environment, one way animals respond to their environment

> is to hibernate. Hibernate means that they eat, eat, eat until they're really nice and fat. They grow lots of fur, and then they sleep through the winter. So, what we're going to do – we only have a little bit of time – is, when I say move, I want you to go back to your desks and get out your science notebook, the notebook that has purple on the bottom, okay? And I want you to turn to the next blank page that you have. Once you're there, please wait until I give you the next directions.

This summary continued to focus on animals hibernating in the winter. Mrs. Love also conflated an animal's physical adaption to endure in harsh conditions versus eating more to mostly sleep through harsh weather. Furthermore, she did not clarify the word *den* or explain that the squirrel's den was on the ground. At this point, there was no discussion about any new information the children had just seen or heard. There were no questions either. Notably, the word *adaptation* was not utilized and, instead, the lesson focused on hibernation. In fact, throughout the video, Mrs. Love did not stop to scaffold or further clarify the new information it contained.

**Mercedes engaged and felt agency during science journal activities.** After the video was completed, the lesson continued. Mrs. Love waited for the students to return to their desks and open to the next blank page in their notebooks before she gave them additional instructions. The lesson needed to be completed quickly; the day was almost over. Mrs. Love gave the following directions:

> Mrs. Love: Alright friends, at the top corner of your next blank page, please write today's date. At the very top of your page, you have a little corner. There's a red line. Then there's a little white space – that little square in the top corner. Fit the date nice and easy right in there, okay? When you read, go left to right. Right in that little corner, right there. Okay, stop flipping. Thank you. When you read, you read the left page and then the right page. It's the same thing in your notebook: the left page first. Okay, at the top you have that big,

white space, that first blue line. We are going to write the word “Hibernation” on that line, starting with a capital *H*. This is a heading. This is the topic of what we are doing in this page, so it gets a capital letter. *i-b*. You have that '*r*' sound, that r-controlled vowel. It's an *'er' n-a*. Sorry.

Mrs. Love: Is it broken?

Mercedes: I think I broke it.

Mrs. Love: I don't understand how everybody's pencils stopped working at the exact same time. *t-i-o-n – Hibernation*.

While Mercedes appeared behaviorally engaged during the science lesson, when it came time to follow oral instructions, Mercedes had a lot she needed to attend to in the directions. There were a lot of dictated instructions without many visual scaffolds, although Mrs. Love did walk around and assist students. The directions (see lines 2–5) were, “…at the top corner of your next blank page, please write today’s date. At the very top of your page, you have a little corner. There's a red line. Then there's a little white space – that little square in the top corner. Fit the date nice and easy right in there, okay?” Mrs. Love pointed on the board to today’s date, and then she gestured to the line and corner.  Mrs. Love walked around and helped students to understand the concept of print going from left to right as they wrote the date in the precise corner required by the directions.  Meanwhile, Mercedes wrote, erased, hovered over the page, and flipped pages. (At line 5 Mrs. Love said, “Okay, stop flipping. Thank you.”) As the teacher spoke, Mercedes was locating: the little corner, the red line, the little white space, the little square in the top corner, and the date on the board. In that moment, Mrs. Love did not notice Mercedes’ error, and neither did I.  As I walked around the room, Mercedes appeared to be following instructions, however, upon closer examination of her journal, afterwards, that proved not to be the case. In fact, Mercedes did not write the date in the corner, but instead the number “5” appeared circled.

The directions for setting up the response page in the students’ science journals continued. Mrs. Love was deliberate in her slow spelling of the word *hibernation*, and she waited for all students to complete the task. The setup of the page was not modeled on the board; students needed to listen to adhere to the precise requirements to complete the final activity of the day. The instructions continued:

1 Mrs. Love: Okay friends, you have a nice, big page there. The word
2 *Hibernation* is at the top. I would like you to please kind of find where you
3 think the middle of this page is, and I want you to draw one straight line
4 across the middle so you have two spaces. You have a top and a bottom. Draw
5 a line from side to side across the middle – from side to side, okay?
6 This is going to be really big, and this is going to be really small, right? So,
7 you might want to go a little higher. Mercedes, I said make one line from side
8 to side so you have a top and a bottom. I did not say four spaces. You just
9 want to have two spaces.

At this point, Mrs. Love completed her directions for setting up the page. When she said (line 5), “a line from side to side across the middle – from side to side…,” she scaffolded her directions with a gesture. In that moment, Mercedes drew one line horizontally across the middle, and then she went ahead and drew another line vertically; she had four quadrants, instead of two. She was not attending to oral instructions, and just drew what she thought were the correct lines. Almost immediately, Mrs. Love detected Mercedes error and commented (lines 7–9). Right away, Mercedes began to erase the vertical line. She understood her mistake.

With the lesson almost over, Mrs. Love modeled writing summer and winter on the board to complete the setting up of the journal. She directed students as follows:

> Alright, now you have two spaces on your page, the top part and a bottom. The top we are going to label “Summer”: *S-u-m-m-e-r*. Don't make it huge. You have lines. You have nice, whole spaces. You are March 1st first-graders. You can write smaller letters. The bottom space we are going to label “*Winter*.”

Mrs. Love wrote the words *Summer* and *Winter* on the board, and Mercedes copied them accurately. Again, when guided with specific information to complete a task, Mercedes was successful. Now came the final instructions of the lesson:

Mrs. Love: I want you to think about the animals that were mentioned in the video that hibernate. Raise your hand if you know. What is one of the animals that they said hibernate in the video?

Child 1: A squirrel?

Mrs. Love: The ground squirrel.

Child 1: Yeah.

Mrs. Love: The squirrels we have by us are actually grey squirrels. They're different kinds of squirrels. But a ground squirrel...

Child 2: I saw a black one.

Mrs. Love: Okay, but that's not what was mentioned in the video.

Child 3: A bear?

Child 4: [inaudible] turtles.

Mrs. Love: Yes, turtles.

Mercedes: Groundhog?

15 Mrs. Love: Okay.

The students went on to list some of the animals presented in the video. And then Mrs. Love continued:

> So that's what I want you to think about. Pick one of those animals that hibernates. And I want you to draw a picture. What does that animal look like, and what do they do in the summer? Then I want you to show, what does that animal look like and what do they do in the winter? So, in the summer that animal is probably out. It's hunting. It's eating. It might be with its other animal friends. In the winter that animal has found itself a nice shelter. I want you to show me hibernation, okay? What questions do you have about the directions? Okay, go ahead and get started.

The final instructions focused on the students making meaning of hibernation and what hibernating animals do in the winter and summer months. There were no images on the board to support the response. Students needed to rely on what they already knew about these animals or could recall from the video. They needed to understand the animal’s appearance and activities during two seasons. Mrs. Love prompted students for their responses and selected those who had raised their hands in response. One student (line 4), responded with, “A squirrel?” Mrs. Love corrected the student and said, “The ground squirrel.” She went on to state, “The squirrels we have by us are actually grey squirrels. They're different kinds of squirrels. But a ground squirrel...” This completed her commentary on squirrels, and there was no further explanation or distinction between ground squirrels and the tree squirrels that live in the students’ neighborhoods. The students continued to provide examples of hibernating animals and then drew their example in their journals.

The science lesson was almost over. The final minutes were completed with Mrs. Love walking around to ask students about their animal choices. As Mrs. Love walked around, she stopped to ask students about their animal selection. When she stopped to look at Mercedes work, she asked if it was a bat. Mercedes said, “Yeah.” Shortly afterwards, the lesson ended, and students were instructed as follows, “All right, friends, that's all we have time for right now. This is something that you may do tomorrow if you have time. If not, we'll have some time to finish tomorrow afternoon.” This concluded my first day observing Mercedes in Mrs. Love’s class as she completed her response in her science journal.

Mercedes appeared to be engaged during science lessons, both behaviorally and academically. She answered questions and attended to visuals on the board and in an animated video. Finally, she completed a response in her journal. The lesson consisted of various components: discussions of environments and animal migration, looking at the workbook, and viewing an animated video on hibernation. During the concluding activity, Mercedes worked diligently in her journal to demonstrate her comprehension and meaning making during science of hibernation. Hence, although the essential question was how animals respond to their environment, the focus became one type of response, an adaptation: hibernation. In fact, in the course of the next few days, the journal was never referred to again to determine what animal Mercedes drew or her understanding of which animals hibernate.

**Examining Mercedes’ Experience with Science Learning**

**Mercedes’ interview: an opportunity for discourse.** The interview and analysis of Mercedes’ science journal were essential to determine her ability to make meaning of the academic language in science lessons. During the interview, Mercedes was willing to share her journal and converse about science. As it turns out, when I interviewed Mercedes and we looked at her journal, I learned how incomprehensible some of the input during science lessons remained for her.

The interview provided insight to Mercedes’ experience during science. It occurred the day after the third observation, and it lasted for 15 minutes. Mercedes was a little soft spoken initially, but she was conversant. During my observations, I could see Mercedes interacting within the classroom and responding to Mrs. Love's queries. Mercedes provided responses during the discussion on the environment, and she had some misconceptions when she spoke during the first lesson about sea otters hibernating. I also knew she did not include the date on her journal page on hibernation, and she originally incorrectly formatted the page into quadrants. One of my goals in this study was to learn about the experiences of multilingual learners during science, so I started by asking her, "So, when the teacher says, "It's time for science!" How do you feel about it?" She responded by saying, "Good." I prompted her further, "*Good*. Why do you say that? Why do you say 'good'?" Then, Mercedes replied, "Cause, I love science!" Why did she love science? While I was there for three days, her class did not do any hands-on activities. The lessons always followed the same format: lesson introduction, discussion, reading the e-book or workbook, use of an additional resource, and a concluding activity. The additional resources were either an animated video or flip book. The concluding activity engaged students with their science journal or a matching activity. Thus, the lessons included curriculum content and varied in their delivery, but the lessons did not engage students in any discourse.

During the interview I continued to prompt Mercedes for more information about her love of science. I commented, "Aah! You love science! Really? What do you love about science? I like that you said that. Why do you love science?" She said, "Because, like, we read stuff about plants and stuff." I asked her to recall if something she learned this year really made her like science. Something she did. I asked her, "Do you remember what you did this year?" She responded with what she was learning, "Like plants that we are learning right now." As it turned out, Mercedes began the school year in another school in the district. In the other school across town they began science in September. She transferred to the Oak School in October.

Science began in Mrs. Love's class in January. Here it was March, and it was possible she had done something more in her other school, but she could not recall it. I asked her, "How is science different from other things you learn about? How's it different?" She responded, "Because we have the big heavy book." The big book was the workbook and an extension of the teacher's e-book. The big book provided students with an opportunity to write short responses to visual content or to select a multiple-choice response to a question. During my three days in the classroom, the students viewed pictures in the book, but they did not write any responses in it.

Since Mercedes equated science with reading, I wanted to understand her comments and her experience during science. I proceeded to discuss her love of science and the use of the big book.

1 PI: You have a big, heavy book. Okay. How else is it different?

2 Mercedes: I don't know.

3 PI: Well is it the same as doing math?

4 Mercedes: Yeah.

5 PI: Science is the same like math? How is it the same?

6 Mercedes: Like we have to do the stuff.

7 PI: So, like what stuff do you have to do in science?

8 Mercedes: We write.

9 PI: Ok. So you write in science.

10 Mercedes: Ahmm.

11 PI: So in math you do writing.

12 Mercedes: No.

13 PI: No writing in science. I mean in writing.

Mercedes: It feels like writing.
PI: [inaudible] feels like writing. Okay. What about language arts, when you do reading? Is that like science, too?
Mercedes: Yeah.
PI: ’Cause you said science is the same, like other things. It’s not different.
Mercedes: We also have to, like, read the science, the science things.
PI: Ok.

During this conversation, Mercedes told me that science was about the big book. Science was about, as she said (line 14), “… like writing.” She also commented, “We also have to, like, read the science, the science things.” In Mercedes’ mind, science was about reading and writing in the big book. The big book was a 300-plus page science workbook. It truly was the biggest and thickest book in her desk. In addition, she knew what she had just studied. Earlier in the discussion, she said, “Like plants that we are learning right now.” She knew she had learned about plants.

The conversation about science was about reading and writing in the big book. The discussion did not really encompass what a scientist does. Mercedes did not have anything further to say about being a scientist. The big book was the reason for science being different, and in it was the explanation of how scientists were brave. In our discussion, I did not come to understand how Mercedes saw the scientists as depicted as brave in the big book. I was unsure about whether she knew what scientists did on a daily basis either. Notably, during my three days of observations, the students looked at pages in the big book, but never wrote in it. They only utilized their science journals for responses. Finally, our discussion of the big book concluded, and we turned to her science journal.

While I was in her class for three days, my analysis of her journal, here, will only focus on the journal contents from the narrative on day one of observations. When I asked to see something she had done recently, she immediately commented, “Here is hibernation.” I commented, “Wow! That's a big word. So, what did you draw about hibernation? I think I was in class that day, so what did you draw?” She said, “I draw the squirrel.” She went on further, “He’s out finding food for hibernating. And he’s sleeping ’cause it's winter.” I could very clearly see her page on hibernation was split in half. She had followed most of the directions on how to format the page. The top of the page, however, did not contain the date as she was required to do. Although this was the end of March, she had written a “5” in the left corner and circled it. The upper-half contained the label “Summer” and a drawing of an animal with a bushy tail walking near a tree with a full canopy and exposed roots. The bottom half of the page included “Winter,” and the bushy-tailed animal was inside the canopy of the tree. I found her actual drawing confusing, because when Mrs. Love had asked her what she was drawing, Mercedes said, “bat.” Now, when I asked what she drew, she said, “squirrel.” The squirrel response was consistent with the video content. However, it did not reflect the brief discussions about the types of squirrels, that is, ground versus local tree squirrels. Thus, I saw a discrepancy between her journal and the content of the lesson on hibernation.

Understanding Mercedes’ journal was important to understand her meaning making of the science lesson. The class did not engage in discourse regarding their journal responses. There was no opportunity to explain drawings, to give evidence about their content, or to revise drawings based on new information. Thus, this was Mercedes’ first opportunity to communicate her sense-making of hibernation. I wanted to understand Mercedes’ experience during science—engage her in explaining her model of an animal hibernating, have her use evidence to explain where the animal was hibernating, and finally relay information on this animal's adaptation. What was her meaning making of the lessons on animal adaptations? The discussion proceeded as follows:

PI: Ok. Now, do squirrels hibernate?
Mercedes: Yeah.
PI: They do! They don't come out in the winter. Never? You don't see them at all, no?
Mercedes: First, they eat like all the food and then they go to sleep.
PI: For the winter.
Mercedes, Yeah.
PI: So, do you have any squirrels around where you live?
Mercedes: Yeah.
PI: You do? Do you see them right now or no?
Mercedes: No.
PI: They're sleeping.

Mercedes' journal did reflect her meaning making during science. She understood hibernation as the fact that animals eat and then sleep. She saw and heard that information on the video. She did connect the squirrel in the video to the squirrels in her neighborhood. However, the squirrels in her area go up trees and appear all winter long. Her neighborhood squirrels do not hibernate, and the local trees did not have full canopies in the winter. She did not understand that the squirrel in the video was in a den. The word *den* was not explained during the lesson. In addition, the lesson had focused on hibernation and not adaptation, that is, what animals do to adapt to changes in their environment. For example, they find a den. In essence, Mercedes' understanding of hibernation applied to all squirrels, and not to the adaptations made by different types of squirrels.

The discussion with Mercedes revealed she was able to make some meaning during science, but that she also had some misunderstandings. Her written responses reflected her erroneous understanding that all squirrels hibernate. However, she accurately copied words from the board and read some academic vocabulary: *hibernation*. Overall, during the interview, Mercedes displayed knowledge of the word “hibernation” and its meaning.  In summary, the topic of the lesson—*adaptation*—was not included in her notebook, nor was it discussed during our interview.

**The interview with Mrs. Love.** The post-observation discussion with Mrs. Love was an opportunity to understand her pedagogical choices. I asked, “Were there tools or resources available from the science curriculum that helped the multilingual learners connect?” She responded, “No, not that I was able to find. I feel like the supplemental materials that I found were more beneficial.”  Then she went on to comment: “So, I think the Brain Pop and Mystery Science videos were much more kid friendly, much more language friendly for those ELL students. And the book, the adaptations book that I found was presented in a clear, more clear way, and in language I think that was more understandable.” Mrs. Love chose to use “supplemental materials” whose language she thought could more easily reach the multilingual students in her classroom. As a result, her objective was to make her lessons more accessible and to facilitate the students’ acquisition of science content knowledge.

**Lack of support.** Mrs. Love felt she did not receive adequate PD to support the multilingual learners in her class. Over the years, Mrs. Love had taught many multilingual learners. This year, almost 50% of her class was comprised of multilingual learners. When asked about professional development offered in the district to teach multilingual learners she commented:

> Nothing specific. I just remember that there were just a few things, like about maybe some social things to be aware of with students from a different cultural backgrounds. And whenever a new series was introduced, they would always say, "There's an ELL component. There's an ELL component." You know and to say if there was information we needed about the ELL students that it was in the teacher's manual.

In the past, the focus was on recognizing cultural differences. More recently, the curriculum resources the district provided contained supportive elements to teach what she called ELLs. When asked, "So, what isn't working?" She went on to state:

> There's not enough support for how to use the ELL components in the classroom. You know, they've said that they're there. And they're there for us to read. But there's really not a lot of support or guidance in how we are suppose to be implementing that portion of the different series and curriculum that we have. Um, and I think that it's hard to give the kids the help that they need because you can't send things home because they don't speak English at home. They don't have an understanding at home so, then there's really no time that you can take these kids and give them extra help that they really need. We're not allowed to take them from recess or fine arts or anything like that. Um, so there's really no…I think that even though they might not be ESL or they might not bilingual or something like that, they do have more than language at home. Sometimes they just need that extra help or that extra explanation or time that we can't give them.

Based on her comments, Mrs. Love felt that supporting the students was up to the individual teacher. She felt she had not received adequate training on working with multilingual learners, the newly purchased NGSS curriculum, or how to use components of the program to directly support students in her class.

When asked about the curriculum specifically, Mrs. Love commented on how inappropriate it is for all first graders:

> I think that it is a terrible program. They're assuming that the students have a lot more background and experience with science topics and just activities in general. So, when there are student activities or projects or things that they want the kids to do there's a lot of things that just is not practical. And that children are not able to do on their own. So it's assuming.

Here, Mrs. Love a 19-year veteran in the district, described how inappropriate the curriculum was for first grade students. In fact, she completed the interview by describing the paucity of support to deliver NGSS for the first time.

## Summary of Findings: Pedagogy, Student, and Enacted Curriculum

The Oak and Herald Schools resided in a school district where student data were regularly reviewed with teachers. Mrs. Green and Mrs. Love were cognizant of their multilingual learner students' linguistic background. Both their students were deemed English proficient, and therefore did not require ELD support. Meanwhile, Miss Negro a novice teacher, was not advised of Victor's or Iris' multilingual learner status. Both were students who were not deemed English proficient and whose parents declined bilingual services. The fact these students did not receive ELD support, despite being considered English language learners, was not discussed at meetings about their performance. However, these students received Basic Skills Services to improve their reading skills. Thus, Miss Negro was not prescribed tools, resources, materials, or training to address their limited English proficiency in a data driven district.

**Pedagogy of science instruction.** The delivery of science content varied based on the pedagogical expertise of each teacher. All the participant teachers strove to make the lessons more accessible by utilizing language, gestures, additional resources, and materials. As a novice, Miss Negro relied on the prescribed curriculum to provide visuals and linguistic scaffolds. Mrs. Green and Mrs. Love did not choose to rely solely on the prescribed curriculum to provide background, visuals, or linguistic scaffolds for their lessons. Mrs. Green and Mrs. Love thoughtfully selected supplemental resources to deliver content and scaffold their lessons. In brief, the more experienced teachers' pedagogical choices relied on their knowledge of first graders, the science curriculum, and the multilingual leaners in their classes to deliver the lessons.

***Miss Negro's approach.*** Miss Negro maintained routines, tried to make science hands-on, created additional graphic organizers, utilized visuals supplied in the curriculum, and demonstrated worksheets on the overhead for students to complete pages in their evidence notebooks. However, the language and images of the e-book audio were heavily imbedded with academic language requiring further explanation. Her reliance on the curriculum created linguistic barriers for her students. Often the language in the curriculum was incomprehensible for the level one multilingual learner and vague for the other focal student. In fact, Miss Negro's over reliance on the curriculum created several missed opportunities for her to provide linguistic scaffolds to the focal students in her class.

***Mrs. Green's approach.*** Mrs. Green chose to use a supplemental resource to provide background information before delivering the district prescribed curriculum content. For three days she utilized a trade book to teach students about light. She went beyond the prescribed curriculum in her introductory lessons. Frequently, she provided linguistic supports to multilingual students in her class and made connections to their prior knowledge. Occasionally, the language of the texts required more explicit instruction than Mrs. Green provided. Overall, the lessons I observed included scaffolding of much of the language and images in the texts read.

***Mrs. Love's approach.*** Mrs. Love frequently utilized videos with simple images, in addition to the e-book to deliver science content. The lessons were scaffolded when the teacher made connections to the students' prior knowledge. She supported her students by utilizing resources she believed made the science content available and comprehensible to the multilingual learners in her class. Her choice of videos while presenting simplistic ideas of science content, also created barriers when unexplained content was not explicitly taught. In brief, Mrs. Love's lessons included linguistic scaffolding of the curriculum, but not necessarily the content included in videos.

**Barriers for Miss Negro's students.** During observations, the focal students appeared to engage, however, the duration of the participation, that is, their time on task was often limited. The lessons lasted approximately 40 minutes and contained on average 10 e-book audio segments. The e-book was used as a mechanism to engage the students. However, the same pattern existed during all lessons. The use of the e-book appeared to capture the focal students' attention. Notably, when Miss Negro made a gesture toward the board, or a new image appeared on the board, they appeared to attend to the teacher. Frequently, they looked and listened briefly as a segment became visible on the board, but just as quickly, they stopped looking. They would listen for the teacher's comments and then turn away from her. When unscaffolded language or images appeared in science instruction, these multilingual learners did not continue to attend to the task. Thus, the language and lack of scaffolding appeared not to keep Victor and Iris engaged.

***Victor was unconnected.*** The absence of linguistic scaffolding left Victor unaware of many of the transactions occurring during science instruction. When I observed Victor, Miss Negro reviewed previous lessons, but she did not build background, use additional images, or make connections to students' backgrounds. Furthermore, when she gave instructions orally, she did not always reinforce them with visual references. The absence of adequate support for a level one multilingual learner was especially tragic for Victor. He needed more than just the e-book provided curriculum. In addition, when instructions were given orally and not reinforced with visual references or oral repetition, Victor lagged behind the class. While there was an extensive use of academic vocabulary, Victor did not chorally repeat new vocabulary. Although the curriculum only included three vocabulary words for the unit on light, additional vocabulary was essential to comprehend the lessons. Much of the language used during the lessons was unfamiliar to him, as was evident by lack of response in class, his evidence notebook, and during the interview. He experienced the academic language of the curriculum without explicit instruction to assist him in meaning making. In fact, Victor was often disengaged from science instruction.

***Iris was disinterested.*** During the second round of observations in Miss Negro's class, she applied more scaffolds to make the science content more comprehensible. That is, compared to the lessons with Victor. At this point in time, she knew more about the multilingual learners in her class. Over the course of three days observing Iris, Miss Negro reviewed previous lessons, built background, used more images, and made connections to students' backgrounds. And still, Iris performed for the camera as often as possible. Interestingly, while Iris' attention to the e-book audio clips was intermittent, her focus on correctly copying into her evidence notebook was consistent. As a result, she attended to the board and labeled the parts of a plant as directed by her teacher in her notebook. However, during the interview Iris disclosed that while she participated in lessons about plant parts and their functions, she was unable able to distinguish the parts or acknowledge their existence around her home. In summary, Iris cared greatly about her notebook and less about the science content knowledge presented during a lesson.

**Barriers for Mrs. Green's student.** Mrs. Green utilized non-curriculum resources to deliver science content. While the supplemental texts contained factual information about light, some of the content required more scaffolding, especially in the area of measuring light. When not adequately scaffolded many texts shared with students often contained incomprehensible input of the visuals or the language. Furthermore, many of the facts stated in the trade book were irrelevant to the lesson's objectives. The objectives required students to know: 1) how light helps us see, 2) how light travels, 3) and how materials block light. Hence, facts about the speed a car or plane travels, the speed of sound waves, and the speed of light were irrelevant. While the information was engaging, it was not tied to the district curriculum. Furthermore, some of the language contained in the text was not understood or scaffolded for the students. Ultimately, the lessons were an exercise in literacy versus scientific inquiry.

***Rainbows: not Juanita's reality.*** For Juanita, there were no personal connections in her journal or real life to the light made by rainbows outside of the classroom. The interview with Juanita confirmed what I had seen after three days of observations. She appeared engaged while reading during science instruction. However, her ability to engage with the content of science lessons was limited. Her science journal did not reflect any responses to the lessons. She made no journal entries of light or rainbows. She made no drawings, wrote no labels, and had no comments about a connection she had to light. While she participated in reading two books, she did not understand the phenomenon rainbows and the reality of a fixed set of colors visible in an arc across the sky. In fact, after several days studying light, her science journal and our conversation did not reflect the reality of rainbows in the sky.

**Barriers for Mrs. Love's student.** Mrs. Love worked diligently to make connections to students' lives and the topics she was presenting. The use of supplemental resources was clearly an attempt to make the science content comprehensible. When Mrs. Love utilized a BrainPop video to explain hibernation, it excluded an explanation of adaptation. When the video included squirrels hibernating, there was an inadequate explanation of an animal den as a place an animal could reside during cold weather. Therefore, without an explanation of some of the video’s content, it worked to confound the NGSS content presented in the e-book. The presentation of facts absent a discussion of how the animals made structural modifications to adapt to their environment was incongruent with the lesson’s NGSS objectives. Students needed to be able to explain the adaptations animals make to adapt to their environment. In fact, while the teacher opted to supplement lessons with additional, non-district provided resources, they were not always compatible with the NGSS.

***Mercedes gets hibernation?*** The discussion with Mercedes revealed she was able to make some meaning during science, but that she also had some misunderstandings. The focus of the animal adaptation lesson became animal hibernation, and not animal structural changes to prepare for hibernation. The journal activities in Mrs. Loves class were opportunities to label, void of any explanation, evaluation, or argument. Therefore, without scientific inquiry and opportunities to discuss drawings, the lessons did not include comprehensible output by students. Mercedes’ written responses reflected her erroneous understanding that all squirrels hibernate. There was never any discourse in class to discuss her drawings of animals hibernating or opportunities to revise her drawings. However, she accurately copied words from the board and read some academic vocabulary: *hibernation*. Overall, during the interview, Mercedes displayed knowledge of the word “hibernation” and its meaning. In summary, the topic of the lesson—*adaptation*—was not included in her notebook, nor was it discussed during our interview.

**Science without discourse.** At no point during 12 days of observations of four focal students during science, did they engage in meaning making. In my observations of Miss Negro’s class, when a science activity occurred, it often concluded with evidence notebook entries. The entries were opportunities for Victor and Iris to write facts they had heard or seen during science lessons. Meanwhile, in Mrs. Love's class, journaling was a consistent component at the conclusion of the lessons. Mercedes and her peers wrote responses to the lesson based on input from the curriculum and videos. Meanwhile, during science, Juanita sat for the entire time on the rug listening to science trade books. Throughout the lesson, Mrs. Green checked in with the students and got some feedback on their understanding. In Mrs. Green's class, journaling was not a component of the lessons I observed. Instead, students glued lesson objectives, questions, and vocabulary into their journals on one occasion. Across all the classrooms, there was never a moment where students individually gathered their thoughts or described or clarified their thinking.

The opportunity to engage in discourse to explain models or engage in making meaning did not occur during science instruction. Students did not engage in meaning making of models created or investigations completed. Thus, no explanations, evaluations, and argument occurred. They did not produce comprehensible output regarding their meaning making of light, plants, rainbows, or animal adaptation/hibernation. There was no diagram created to evaluate or discuss with a peer. There was no peer feedback to check understanding. In the final analysis, the lessons did not conclude with meaning making or communication by each student to demonstrate an effort at understanding.

**Missing- scientific inquiry.** The fact that the science lessons were not inquiry based, as prescribed in NGSS, limited the focal students' access to scientific understanding. The district curriculum included the integration of engineering with science, but the teachers focused their lessons primarily on delivering facts. That is, facts about light, plants, rainbows, and animal adaptation/hibernation. Miss Negro relied on the curriculum e-book for content. Mrs. Green presented science content from informative texts that were supplemental resources to the district curriculum. Meanwhile, Mrs. Love based her instruction on the curriculum e-book and non-curriculum sourced videos. Only Miss Negro strictly adhered to the district curriculum., while the other teachers utilized the district curriculum to focus their lessons. Albeit, none of the lessons were centered around scientific inquiry.

The enacted curriculum and activities of the lessons did not lend themselves to meaning making. Unlike inquiry-based lessons, students were not presented with a phenomenon to query, define, model, investigate, analyze or, subsequently, communicate their understanding (NSTA, 2013). The students did not have opportunities to ask questions about phenomena, create experiments to answer their questions, problem solve, or communicate their ideas. The lessons, based on the curriculum, comprised the teacher talking or reading, for more than 20 minutes. The fact only one class included hands-on activities in 12 days of observations, and the activity lasted for five minutes, was indicative of science lessons designed to be literacy based. Unlike inquiry-based lessons, in these lessons facts were stated and sometimes repeated. In essence, whether a multilingual learner could make meaning of the facts was not addressed.

Inherent in inquiry-based science is the requirement that students engage in classroom activities centered around acquiring science knowledge and engineering practices, in other words, not just learning facts. During the lessons, students did not have an opportunity to ask questions to develop models and plan an investigation of the phenomenon of light, plant structures, rainbows, or animal adaptation/hibernation. The expected outcomes were not an analysis of data based on an investigation, followed by explanations, evaluations, and argument based from evidence to communicate information. The lesson outcomes varied, but were exercises in gluing, copying, reciting facts, and drawing. In summary, the curriculum and lack of training provided to the teachers prevented the lessons from being inquiry-based and, therefore, from providing the best instructional practices in science education per the NGSS.

**Challenges with the curriculum.** The curriculum was heavily imbedded with academic language and images that required further explanation. Often it required linguistic scaffolding. Explicit instruction to connect images to their intended purpose could have helped to enhance the science content. For instance, when a lesson introduction culminated with an image of a lit lighthouse overlooking a waterway, there was no discussion or description of the lighthouse. There was no reference to the e-book language of the image. For example, what in the image was smooth? What is a surface? What was the light reflecting upon? How does a lighthouse communicate with light? Indeed, there was no discussion of the lighthouse and its role in maritime navigation, that is, how the light is used for communication at sea. The image was never referred to or elaborated upon after a brief display. In this instance, the multilingual student's knowledge about the images and the language of the e-book audio was presumed.

**Inadequate and missing professional development.** The teachers believed the materials available in the science curriculum left them ill equipped to adequately deliver NGSS content to multilingual learners. Participant teachers found the content of the curriculum unrelatable to first graders. Notions of maples seeds serving as a catalyst for engineers to build helicopter blades did not make sense to these teachers. While they utilized the objectives of the prescribed curriculum to guide instruction, they were unable to deliver inquiry based lessons based on its guidance. They felt the ideas for hands-on activities were not appropriate. Deficiencies in the curriculum and inadequate training, support, and materials frustrated teachers required to deliver science standards using new methodologies. In fact, the more veteran teachers utilized supplemental resources as a strategy to deliver content.

In conclusion, inadequate training with a new curriculum and insufficient training to work with multilingual learners disenfranchised the students. In short, all the teachers agreed about the deficits in the district with regards to training, support, and materials to adequately support the multilingual learners.

**Findings Conclusion**

The study provided a lens into how student characteristics, content resources, pedagogy, and curriculum impacted the ability of multilingual learners to access the content of science lessons. While the linguistic characteristics of the students were different, they were all multilingual students in various stages of English proficiency. Similarly, the content resources while varied, also required adequate linguistic support for these students. Furthermore, the pedagogy in each class relied on teacher experience and expertise, absent training to deliver content to these specific students. Finally, the delivery of the curriculum, was not supported with adequate training for participant teachers to deliver NGSS or inquiry-based science lessons.

While all the students had access to the prescribed curriculum, for a multilingual learner in the early stages of academic English acquisition, often the images and accompanying language required scaffolding, for example: an image of skyscrapers around a shiny sculpture to demonstrate the “reflection” in the curriculum e-book. The image contained several concepts that required scaffolding for a multilingual learner in the early stages of English acquisition. The absence of adequate visual and linguistic support, left one to wonder, what was the most important concept for a child to take away from this interaction? Often, the child in this case would turn away from viewing visuals that were not relatable or scaffolded for understanding. While students in the study may not always have engaged with scientific concepts during lessons, when they were asked to participate in journaling activities, they demonstrated great self-efficacy in completing tasks immediately and with care. In essence, all study participants, regardless of their English proficiency were academically engaged at the end of a lesson.

The study also supported notions of the importance of utilizing appropriate resources when supplementing lessons. All teachers in the study supplemented the lessons' resources to make the ideas accessible to multilingual learners. The teachers felt that without these additional resources the lesson's contents remained inaccessible to the students. These resources took various forms: books, trade books, flip books, videos, and Internet images. The fact that none of the lessons was inquiry-based resulted in lessons that were centered around learning facts rather than integrating science and engineering practices into the learning. While the use of supplemental resources was laudable, the content was not always aligned with NGSS and the district-prescribed curriculum. Thus, while supplemental resources made the science content accessible, they omitted ideas supported in the curriculum.

The study also supported the importance of good pedagogy when working with multilingual learners. The participant teachers each engaged in delivering lessons that they felt were appropriate for all the students in their classrooms. Key to delivering content is knowledge of the students in the room. While two-thirds of the teacher in the study knew their students' linguistic background, one did not. The lack of knowledge of the students' background, severely hampered the teacher's ability to deliver adequate linguistic support to a beginning English learner. Without knowledge of the student, the teacher was unaware of the student's needs. Furthermore, teachers were ill-equipped and trained to teach multilingual learners NGSS content. One of the goals of NGSS is communication of understanding in science. Missing at the end of a lesson was closure, where students engaged in meaning making of the science content in the form of discourse. While the teachers worked to make the content accessible and provided supplemental resources, missing was comprehensible output on the part of the multilingual learners.

Finally, the study revealed how the curriculum's contents impacted the teacher's and students' ability to engage with the curriculum. The curriculum contained language and images that required scaffolding. For example, the teachers commented that they believed some were unrelatable to first graders. One teacher noted that the connection between a maple seed and a helicopter blade were not within a first graders purview. Another teacher, who thought the curriculum content was inadequate, chose to engage in three days of background building before teaching the curriculum's lessons on light. Furthermore, the teachers did not feel the curriculum did an adequate job of presenting scientific ideas to first graders. In fact, the teachers were never provided with adequate training to conduct inquiry-based lessons with multilingual learners.

The multilingual learners in both elementary schools received support from teachers who assisted them in gaining access to science content. The assistance occurred in various forms, with various materials and technologies. Teachers utilized: Internet, e-books, trade books, flip books, and videos. This additional support provided students with access to science concepts in a format with fewer linguistic barriers. However, the multilingual learners still experienced barriers to making meaning and building an understanding of science content. The barriers to meaning making in science were visible in lessons with limited linguistic scaffolding. In addition, teachers chose carefully curated resources, however without adequate consistency or cohesion to the district-approved curriculum. Furthermore, the absence of discourse in the lessons limited the multilingual learners from using language to explain their models and refine their understandings. Thus, while the teachers attempted to provide these students with comprehensible input, absent opportunities for communicative exchanges, the multilingual learners had limited chances to make comprehensible output and, therefore, to make meaning of science. Multilingual learners missed opportunities to make meaning of science content when lessons were inadequately scaffolded.

# Chapter 5: Discussion and Implications

The impetus for this study came after working with former ESL students in a middle school and observing their limited knowledge in the content area of science. As a 14-year veteran ESL teacher, I had seen the great emphasis placed on language arts and math in the elementary grades. Those content areas were central to state and school accountability requirements. Meanwhile, in the background lay the subject area of science. While administrators and teachers agreed on the importance of science, it was not a tested area, and thus was not a primary educational focus. Often, its placement in the schedule, at the end of the day, allowed it to be precluded with a review or the continuation of content, presented earlier in the day, in the tested areas. However, I understood the importance of science in the general education of all students, and how limited exposure at the elementary level created middle schoolers ill-prepared to write or speak from evidence in areas with which they were unfamiliar. Ultimately, this lack of preparation and presentation with basic knowledge of science could prevent these students from pursuing science careers.

To do so, I needed to see first-hand, how science instruction was delivered in the early years.  I had noted that mainstream teachers who work with multilingual learners every day received limited, district-provided professional development to work with them. These teachers, while committed to meeting their students' needs, were ill-prepared to provide their multilingual students with the scaffolding they needed in the tested areas, much less in science. I decided to focus on the access these students had to science content knowledge in the first grade. Through this study, I wanted to explore and develop a deeper understanding of these students' opportunities to access science content, and of the teachers' abilities to limit barriers and support science learning.

## Summary of the Study

This study took place in two mainstream classrooms in Central New Jersey. In this study, I explored the OTL of 1st grade Latino multilingual learners in science. I examined their experiences to determine if they had access to the content, resources, tools, and language of science. In addition, I observed what barriers and scaffolds existed for these young learners. Further, I was interested in how first-grade mainstream classroom teachers scaffold science content to make it accessible to Latino multilingual learners. The study comprised classroom observations, as well as participant teacher and focal student interviews. Also, focal students' parents were interviewed. The classroom observations were videotaped and the interviews were only audio taped. All the observations and interviews combined to create a holistic picture of the child and their experience during science lessons in a mainstream classroom.

The findings of the study suggested that multilingual learners lacked accessibility to the content and were unable to make meaning of the topics presented during instruction. The teachers relied on the district curriculum to sequence lessons and determine the focus. However, the prescribed curriculum created linguistic barriers with dense language that was often incomprehensible to multilingual learners.

Further, participant teachers clearly expressed the shortcomings of the new curriculum and its inability to connect with first grade students. When teachers chose to use supplemental resources, their lack of training in working with multilingual learners left the children unable to grasp some concepts presented. The teachers were unable to scaffold instruction and make the NGSS curriculum accessible to the focal students.

Overall and based on my analysis, the students in this study did not engage in activities to communicate their understanding of science lessons. The vast amount of time was spent viewing content, and not engaged in inquiry or hands-on activities. Furthermore, this study supports the importance of comprehensible output in making meaning.

## Discussion

### A school culture absent culturally responsive pedagogy

The focal students in the study resided in a school where the administration supported English proficiency over multilingualism and multiculturalism. The goal of the bilingual program was English proficiency over first language maintenance. Too often schools perceive limited English proficiency as an intelligence deficit (Callahan, 2005). The school district implemented national and state standards, but did not support second language learning principles for their burgeoning multilingual learner population. As a result of these policies, these students lost opportunities to learn (Lucero, 2012; Olson, 2007). In a school district, where at least three teachers taught in classrooms where more than 30% of the students spoke a language other than English at home, it was incumbent upon the leadership of the district's schools to support CRP.

While the district was data driven, the role of language and culture was secondary to academic achievement. There existed a dissonance between the dominant culture of the school and the multilingual learners who walked its corridors (Carter, 2013). For example, not all teachers were provided with their students' linguistic background, nor was it a focus of discussions regarding individual student achievement. The annual PD on how to support multilingual learners in the classroom did not center on well-known CRP practices such as: know students' lives, support differences, build upon students' prior knowledge and experiences, and make connections to those lives to design and deliver instruction (Coady, Harper, & de Jong, 2016; Ladson-Billings, 1995; Moll, Amanti, Neff, & Gonzalez, 1992; Villegas & Lucas, 2002;

Walqui, 2006). The participant teachers noted that PD was lacking in its ability to provide them with support to teach the multilingual and multicultural students in their classroom. The role of language and culture as assets to build upon to meet the needs of the multilingual learners were not discussed (Gandara, 2013). Thus, while the district eagerly adopted newly mandated science standards, at the same time, they neglected to provide comprehensive, professional development to their staff to enable them to make science content comprehensible for all students.

**Access does not equate to accessibility**

Focal students were present and engaged for science instruction, and yet, access did not equate to accessibility. When teachers scaffold learning and connect what the students know to what they will be taught, they create opportunities for learning to occur. The conditions for student access were minimalized in an educational environment where science lessons lacked: inquiry, adequate scaffolding, student discourse, hands-on activities, and curriculum materials adjusted for multilingual learners.

The study supported previous research on OTL that outlined the need for content coverage as an essential to create learning opportunities (Stevens, 1993). Although, the multilingual learners sat in a classroom exposed to the content, adequate support was lacking. Research has shown that modifications to instructional content and methods, or scaffolded instruction by teachers, create a learning experience that is accessible and comprehensible to all learners (Cervetti & Kulikowich, et al., 2015; Coady, Harper, & de Jong, 2016; Echevarria, 2006; Gibbons, 2003; Walqui, 2006). Notably, to deliver science content, the participant teachers persevered and adjusted lessons to engage students in learning. However, the barriers to accessibility remained. The barriers included incomprehensible input, limited linguistic and content scaffolding, no connection to student knowledge, and no student discourse. That is, the lessons lacked many second language learning best practices. In fact, the many barriers ultimately made the content inaccessible to the multilingual learners in the room.

**Understanding NGSS is crucial to delivering science content**

The new standards required educators to learn new strategies and methods to deliver science content. Unlike the standards utilized for the previous 20 years, NGSS highlights practices where students work to ask questions, define problems, develop models and designs, construct explanations, argue from evidence, and in the end communicate the findings of their investigative process (National Research Council, 2012). In this new vision of science and engineering, teachers guide students to make meaning utilizing the students' own ideas about a system or phenomenon to build understanding (Lee, Quinn, & Valdes, 2013).

Previously, when students engaged in science lessons the teacher provided: 1) the problem or question to investigate, 2) the specific materials, and 3) procedures for the students to then conduct an investigation (Lederman, 2009). The end results were the same models completed by different students, and the lesson ended with a completed investigation. Today, NGSS wants students to ask the questions and define a problem. Subsequently, students decide how to investigate the phenomenon or system. The teacher can guide the students toward a problem or question to investigate based on the curriculum, but does not prescribe the materials or procedures. In an iterative process, students can design and re-design models to answer their questions. In contrast, NGSS does not end with an investigation and a model, rather students need to describe their process, and successes or failures to peers. Jointly, students can build understanding as they communicate based on the evidence and findings from their investigations.

The NGSS' practices require a new skill set for teachers. The fact a prescribed set of materials and instructions are not presented to students requires teachers to accept successes and failures. The discourse required at the end of NGSS differs from the previous science standards where lessons ended with an investigation. The discourse requirements mean teachers need to allow time for students to share their models and discuss their understandings. In addition, for multilingual learners, teachers need to use CRP to assist students in meaning making.

**Meaning Making is essential**

The opportunity to engage in discourse to communicate ideas is essential to build understanding of science topics. Previous research has demonstrated that when students have opportunities to discuss the events of an inquiry, in an effort to communicate their learning, they have an increased understanding of science (Weinburgh, Silva, Smith, Grouix, & Nettles, 2014). Thus, when students are instructed on specific concepts and skills in the content area, they are provided with content emphasis, an essential to create learning opportunities (Stevens, 1993). In fact, when lessons were not inquiry based, and students did not create models or plan investigations, then no explanations, evaluations, or arguments based in evidence occurred.

While students in the study were instructed in various scientific concepts, without access to the requisite skills of meaning making, the lessons lacked adequate content emphasis. The absence of discourse limited multilingual learners' opportunities to produce comprehensible output (Fillmore & Snow, 2000), and communicate with peers for the purpose of meaning making (DiCerbo, Anstrom, Baker, & Rivera, 2014; Lee, Quinn, & Valdes, 2013; Osborne, et al., 2019). While teachers in the study strove to engage their students in science learning within the confines of a prescribed curriculum, without inquiry, the lessons did not emerge into discursive endeavors. The culmination of the lessons was quick and did not result in communication among students. In fact, the instruction did not provide the scientific skill-meaning making.

**Viewing is not doing**

The lessons observed included more viewing than doing. The NGSS' expectations are for science content delivery to be inquiry-based. However, in this study the students did not ask questions to develop models and plan investigations. The study supported previous research on OTL that outlined students need to spend time on tasks covering the content, thereby providing content exposure as an essential to create learning opportunities (Stevens, 1993). There were no hands-on activities. With hands-on activities, students have more opportunities to engage with science content in an experiential manner (Lee, Quinn, & Valdes, 2013; Gibbons, 2003; Walqui, 2006). Instead, the lessons followed what Paulo Friere called "…the banking concept of education" (Freire, 1997, p. 53). The lesson delivery entailed students sitting dutifully and receiving the academic science content. Thus, although the lessons needed to involve more experiential opportunities, that did not occur.

Frequently, to engage the students, science content was delivered via screen projection. Immediately upon seeing the screen light up in the front of the room, the students looked at the display of a video, the e-book, or a trade book. They sat passively as they viewed images that often lacked clarity and cohesion to the science lesson. Many visuals required scaffolding to explain the connection to the science content. The additional information in videos was sometimes contradictory to the required curriculum, and the discrepancies in the videos were not always clarified. When participant teachers went on to discuss a visual's content, what occurred was not scaffolding the images, but rather a re-reading of texts or the teacher asking questions. That is, more screen viewing time. As has been noted, there were no follow-up inquiry based activities to connect to the visuals.

**Alone, carefully curated resources do not make meaning**

The resources utilized to deliver science content, whether supplemental or prescribed, required scaffolding. The district curriculum was specifically aligned to NGSS and curated by administrators for first graders. Participant teachers relied on their expertise to select additional resources, supplementing lessons with trade books, worksheets, teacher-created materials, and videos. Subsequently, they adjusted the lesson content and their delivery in accordance with the additional resource. The resources utilized were not designed to be taught directly from the source without a pedagogical adjustment. Overall, the lack of appropriate curriculum and materials disenfranchised multilingual learners and made the content inaccessible.

Often, the carefully curated resources contained language and visuals that required deconstruction to make the content accessible for multilingual learners. The sometimes complex language of science was often better suited for visuals (Lemke, 2002). Even when the e-book visuals were utilized to deliver the science curriculum, they were inadequate. The resource required teachers to scaffold challenging science content to make it accessible (Gibbons, 2015). That is, consistent with the pedagogical recommendations of Walqui (2006), to contextualize content and build schema. When teaching multilingual learners, the purpose is not to dilute the content, but build background, tap into students' prior knowledge, and make connections for new learning. In essence, the requirements were to include second language learning best practices in instruction.

While all teachers recognized the limitations of the curriculum, they each chose different methods to support their students. Ultimately, each teacher had her own approach to delivering science content to first graders, though in fact, professional development could have assisted the teachers who lacked expertise on NGSS or training in CRP.

**Enduring commitment to PD is essential**

The participant teachers in this study received inadequate training to support multilingual learners in a mainstream classroom. Without the appropriate pedagogical training to work with the students in their classrooms, teachers and students were at a disadvantage (Aguirre-Munoz & Amabisca, 2010; Gibbons, 2003; Lucas & Villegas, 2013; Walqui, 2006). These students required more background information or elaboration to assist them in making connections to science concepts. The language contained in the district curriculum included dense phrases that required deconstruction. Likewise, the additional resources that the participant teachers provided to help the focal students make meaning also presented linguistic barriers. The supplemental resources, like the district curriculum, required more scaffolding and direct instruction for multilingual learners. In fact, the participant teachers had insufficient training to work with multilingual learners to support the prescribed curriculum or supplemental resources.

The district's strategy of one and done PD, prior to the implementation of the NGSS curriculum, did not adequately support teachers or the multilingual learners in their classrooms. Furthermore, the district only offered one hour of PD each year to support mainstream teachers' acquisition of best practices to work with multilingual learners. Thus, the annual training was not sufficient to build a knowledge base of best practices among mainstream teachers. The staff needed highly structured PD, focused on providing teachers with strategies on how to teach multilingual learners: academic vocabulary, discussion techniques, writing, and conceptual understanding of content instruction, and guided inquiry (Johnson, et al. 2014). They needed training on CRP where they acquired second language learning best practices in instruction. In conclusion, without an enduring commitment to assist teachers throughout the year in acquiring expertise on a new curriculum, or how to work with an ever increasing multilingual learner population, administrators excluded teachers from attaining sound pedagogical knowledge.

## Study Limitations/Potential Bias

### Research Limitations

The choice of case study for research makes it subject to questions of reliability, validity, generalizability, and investigator integrity (Merriam, 2009). The fact that I was a participant observer, engaged in the data collection and analysis of classrooms with young children in my place of employment, could certainly raise ethical questions. In addition, the fact that two of the participant teachers were my colleagues for over five years at the time of the study could raise questions about my objectivity. Given these facts, I recognize the vulnerability of my analysis and findings in this study.

The choices of duration, population, and location were limitations to the validity of the research study. First, the data collection in this study was conducted over a brief period of time, three consecutive days in each classroom during science instruction. A longer, ethnographic study over an extended period of time— months versus days—could provide different results. Second, the fact only four children met the criteria limited the population for the study. It is possible that with more children, a different reality could be unearthed. Third, since the data collection occurred in only one Northeastern United States school district, it is possible that in other regions of the country or world with different populations, the students' experiences would vary. In essence, a short study, with a few students, in one location were noticeably limitations to the study's validity.

The data gathered in a case study are derived from looking at specifics, and are not necessarily generalizable (Merriam, 2009). Because the study occurred at a single school district, the data may not be generalizable to other schools. And since the students observed were Latino multilingual learners, the findings may not be indicative for different populations. Therefore, the analysis and explanations found in this study are not prescriptive but rather descriptive.

The case study included the audio and video taping of participants with their knowledge. Although all participants were aware of the recording devices, this could have led to a certain amount of performance and could have created a lack of authenticity in my observation results. Perhaps the opportunity to have more devices recording activities would have limited the possibility of performing to a camera. Certainly, reconsidering the placement and number of recording devices could have enhanced the study. In essence, I can only speculate on how these modifications could have altered my analysis.

Finally, a case study relies on the integrity of the researcher for credibility (Merriam, 2009). In my role as participant observer, I interacted with the subjects. I recognize that this could have created bias on my part as I had interactions with the various participants. Furthermore, in the past, in my position as an ESL teacher, I have been solicited for advice by the participant teachers on how to teach multilingual learners. Knowing my area of expertise could have prejudiced my analysis of the data toward methods I prefer to use in my own practice. Finally, my construction of the findings could easily be biased by my gender and ethnicity. In fact, as a Puerto Rican female, who was once a computer scientist for AT&T, the role of STEM and its importance in the potential future careers of these young learners was a bias on my part.

## Implications

The findings of the study illustrated, that while schools may be eager to adopt newly mandated standards, they must also provide comprehensive, professional development to their staff. This is especially true when the standards require learning new strategies and methods to deliver content. The study's findings also showed that when multilingual learners are engaged in scaffolded activities, they can experience self-efficacy. Thus, even when teachers use all the tools in their toolbox to teach multilingual learners, if they are not adequately trained, then they may not succeed in making content accessible. Therefore, it is incumbent upon school districts to train staff on strategies and methods that make content engaging and comprehensible to all students.

**Classroom pedagogy**

The findings of the study demonstrated how science classes terminated abruptly without opportunities for discourse among students. While science lessons require the use of specific strategies and methods to deliver content, educators must allow time for students to communicate their understanding of science content. Thus, multilingual learners when given the opportunity to engage with peers or share journal responses can develop a depth of understanding, as they strive to make meaning and produce comprehensible output.

Further, when educators deliver inquiry-based lessons and include time for discourse, they create opportunities for shared understandings among peers. Hence, when planning lesson delivery, teachers must be cognizant of time constraints and include time for student discourse, as an opportunity for students to make meaning of the science content delivered.

**District leadership**

Administrators set the tone of schools and have the responsibility of ensuring teaching staff is effectively trained to deliver content. In a school district where the demographics changed considerably, the need for CRP in schools is essential to provide OTL to multilingual learners. In conjunction with introducing PD on CRP and NGSS, prior to implementing new science standards, the curriculum content should be examined for its appropriateness to teach multilingual learners in the district. One mechanism to accomplish this is reviewing it to determine scaffolding needs. The purpose of the analysis is to assess the ease of use of the intended curriculum for multilingual learners. The analysis should include an examination of the language and visuals in the resources to be utilized in lesson delivery. Hence, the objectives of these analyses would be tools for teaching staff on how to deliver science content to make it comprehensible.

The focus of the analyses would be English language development with attention to the best practices for delivering content to multilingual learners. The analysis can occur with the assistance of ESL staff trained in SLA. They can provide recommendations on how to explicitly teach academic language and assess what curriculum content to scaffold. In addition, they can provide guidance on how to make cultural and linguistic connections to students. The ESL staff might recommend the use of first language (L1) to help build background and assist students in making connections to new learning in science. Hence, with their expertise, teaching staff will be equipped with the appropriate tools to reach multilingual learners in their mainstream classrooms.

Finally, an additional outcome of the curriculum analysis could be a determination that additional resources may be necessary to teach the required concepts and skills. Once again, teachers and ESL staff can collaborate to examine additional resources and assess their value in lesson delivery. As professional development begins, administrators should seek staff feedback to assess the efficacy of the training as it progresses. The creation of a staff feedback loop could be utilized to identify and address ongoing training needs. Hence, by creating a communication channel the administration can assess the value of the professional development provided to staff.

## Future Research

The goal of this study was to examine the OTL of multilingual learners during science instruction. Given the role of STEM in our culture, future studies could examine teacher practice and student outcomes relative to the resources and curriculum utilized to deliver science content. Researchers could engage in studies where teachers of multilingual learners in mainstream classrooms provide opportunities for discourse after receiving training in delivering NGSS. Future research could examine the role of inquiry-based lesson delivery and the inclusion of discourse on the ability of these students to make meaning of science content. In addition, studies could also examine the quality of materials for use with multilingual learners relative to student outcomes. This research could examine whether for a particular science content topic: 1) visuals and graphics independently deliver meaning, or 2) the text and presentation of content necessitate building background or tapping into prior knowledge. These studies could then be utilized to determine how best to provide OTL for the vast majority of Latino multilingual learners who are not currently on a trajectory to participate in STEM.

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## Appendix A

## Parent Interview Protocol

## Qualitative Interview Fall 2017

Hello, Mr./Mrs. _________________. Thank you for taking the time to meet with me. I cannot thank you enough. As I mentioned in my letter of introduction, I am a doctoral candidate at Rutgers University, pursuing an Ed. D. in Education, Culture, and Society. I am interested in the learning experiences of students who enter a mainstream first-grade classroom after leaving a bilingual kindergarten program.

Specifically, I'd like to learn about their experiences in first grade while acquiring knowledge in the area of science—how they utilize tools and resources, and how they communicate in the classroom. Since the school-family partnership is essential to a child's experience and success in school, I would also like to speak with you about your perceptions of your child's experience with the school, especially now that ____________ is in a mainstream classroom.

Please know that this interview is completely confidential. It will only be used for the purposes of my dissertation study. Neither your name nor your child's will be identified or in any way affiliated with my dissertation study. I would like to record the interview, with your permission, of course. It should take no more than 60 minutes. If, at any time you feel uncomfortable or would like to stop, please let me know. Do you have any questions before I begin?

Date: ____________Start time: ______:__________

I would like to begin by getting a little information about language use at home. I know you chose to conduct this interview in ___________________________________.

1) Is __________________ the language you prefer to use at home?

Probe: Is that the language you use with __________________?

What language does ___________________ use at home?

Thank you for letting me know. Now, I would like to speak with you about schools.

2) I know _______________ attended kindergarten [in ____________________].

Probe: Did _____________ attend another school before kindergarten? (If yes, where?)

3) How do you feel about the communication between you and _________'s classroom this year?

If ____________'s school is a different school, do you feel welcome at the school?

Probe: Did you attend the Back to School Night event?

Did you get the information you needed to help your child succeed this year?

Probe: How does the school communicate with you? English/_____________

We have discussed your background and overall communication with the school(s) and district. Now I would like to discuss your perceptions of academics and support for ________________'s educational growth in the school and district.

4) Does ______________ get homework every night?

Probe: Does _______________ need help with homework?

Probe: Who helps ______________________ with math homework? Science?

Probe: Can you help?

Probe: Do you get directions for helping with the homework?

5) How is _______________________ performing academically this year in school?

Probe: Is that better, worse, or about the same as last year?

How do you feel about _________________'s performance?

6) Do you know what ________________________________ is learning in science?

Probe: Does _______________ discuss what he/she is learning in science?

Probe: Does ______________ enjoy science?

Does ______________ ever ask to do a science activity at home?

Well, your responses have been very helpful. Thank you for sharing your thoughts with me. You have helped me gain insight into your child's feelings and experiences in the school and, more specifically, in a mainstream classroom. I appreciate your time and candor. Do you have any questions or comments before we end?

End time: ______:_________

## Appendix B

## Teacher Pre-Classroom-Observation Interview Protocol

## OTL Qualitative Interview Fall 2017

I want to learn about the experiences of exited bilingual kindergarten students who get mainstreamed for first grade. In particular, I would like to explore their experiences while acquiring knowledge in the content area of science. I am interested in how they utilize tools and resources, and how they communicate in the classroom. Since the teacher is a major component of the experience, I would like to get your perceptions of these former bilingual students who are now in your mainstream classroom.

This interview is completely confidential. It will only be used for the purposes of my dissertation study. Your name will not be identified or in any way affiliated with my dissertation study. I would like to record the interview, with your permission, of course. It should take no more than 30 minutes. If, at any time you feel uncomfortable or would like to stop, please let me know. Do you have any questions before I begin?

Date: ___________Start time: ______:_________

I would like to begin by getting a little information about your teaching experience.

1. How many years have you been a teacher?
    a) How many years in first grade?
    b) How many years in this school district?

Now, I would like to know about your experience with multilingual learners in your classroom.

2. Do you currently have multilingual learners in your classroom?

    Probe: How many?

    How many students who were formerly in the bilingual program are in your class this year?

3. Did you receive any training prior to working with multilingual learners?

    Probe: College? Workshops?

4. In terms of working with multilingual learners, what do you think is going well?

    Probe: What isn't?

    Probe: What are areas of concern for you?

We have discussed your experience as a teacher, and your work with multilingual learners specifically. Now let's discuss science lessons in your classroom.

5. What is your opinion of the new science curriculum introduced this year? What might need improvement, or a different approach?

    Probes: Textbook? Resources?

6. If I entered your class during a science lesson, what would I see <u>you</u> doing?

    Probe: Activities prescribed in the curriculum?

    Probe: Are they interactive, hands-on, or inquiry-based?

7. What tools or resources do you think are available in the science curriculum to help multilingual learners connect to the content?

    Probe: Are they useful?

    Probe: Do you use them with your multilingual learners? How?

You've told me what you would be doing. Now I want to discuss what happens with students during a science lesson.

9. If I entered your class during a science lesson, what would I see <u>students</u> doing?

    Probe: Initially (preview)?

    Probe: During content learning and follow-up?

Thank you for describing for me what you do and what the students do. If possible, could I ask you to reflect on what you think happens during a science lesson specifically for the multilingual learners?

10. Do you think multilingual learners understand what you are teaching in science?

Probe: How do you/Can you gauge their comprehension in science?

11. Do your multilingual learners participate with peers?

Probe: Do they interact with and collaborate with peers?

Probe: Are there some students with whom they prefer to work? If so, why?

Well, your responses have been very helpful. Thank you for sharing your experiences. You have helped me gain insight into the experiences of multilingual learners in your mainstream classroom. I appreciate your time and candor.

End time: ______:_________

# Appendix C

## Teacher Post-Classroom-Observation Interview Protocol

## OTL Qualitative Interview Fall 2017

Thank you for letting me observe your class for the last few days. It was a pleasure being in your classroom during science. Now, I'd like to get your perceptions of the specific science lessons over the last few days. I am particularly interested in how you think the lessons went and what you think was the experience of the multilingual students who are now in your mainstream classroom.

This interview is completely confidential. It will only be used for the purposes of my dissertation study. Your name will not be identified or in any way affiliated with my dissertation study. I would like to record the interview, with your permission, of course. It should take no more than 30 minutes. If, at any time you feel uncomfortable or would like to stop, please let me know. Do you have any questions before we begin?

Date: ___________Start time: ______:_________

1. What was your overall approach to teaching these science lesson(s) to the class?

    Probe: Did you need to adjust instruction as the lesson progressed?

   We have discussed your experience as a teacher working with all students in your classroom. Now let's discuss this week's science lessons with respect to your multilingual learners (MLs).

2. What is your opinion of the science curriculum for teaching that lesson to MLs?

3. Were there tools or resources available in the science curriculum that helped the multilingual learners connect to the content? Did you utilize them?

    Probe: Were the tools or resources adequate for these students? How? Or Why?

Probe: Did you need to supplement these? Why?

You've told me about your approach to the lesson(s). If possible, could I ask you to reflect on what you think happens for the multilingual learners during a science lesson in your classroom.

4. First of all, how did you feel about the work all of the students did during the science lesson?

    Probe: How did the MLs respond to the lesson?

5. How did the multilingual learners interact with their peers?

    Probe: How did all students interact with resources? How did multilingual learners interact with resources?

You've told me what you do, and what the students do during a science lesson. If possible, could I ask you to reflect on the experience of the science lesson(s) for the multilingual learners?

6. What is your opinion of multilingual learners' ability to comprehend science the science lessons taught this week? Do you think they understood what you taught?

    Probe: Did they understand the vocabulary?

7. How did you gauge the comprehension of MLs during science this week?

8. What is your perception of how well the multilingual learners will retain the science content taught this week? Why?

9. Do you feel that the multilingual learners had any barriers to learning the science content this week?

    Probe: Did they have the requisite prior knowledge?

10. Did the multilingual learners have the necessary language to participate in meaningful, communicative exchanges about science?

    Probe: Do you think they interacted and collaborated with their peers adequately?

Your responses have been very helpful. Thank you for sharing your experiences. You have helped me gain insight into the experiences of multilingual learners in your mainstream classroom. I appreciate your time and candor.

End time: ______:_________

## Appendix D

### Observation Protocol

<table>
<tr><td>Observation Protocol:<br><br>Start Time: End Time:<br><br>Attendees:<br><br>Focus Student:</td><td rowspan="4">Diagram of the Room</td></tr>
<tr><td>Lesson Objective</td></tr>
<tr><td>Activities Planned</td></tr>
<tr><td>Work Completed</td></tr>
</table>

| | | |
|---|---|---|
| | | |
| Speech | Non-verbal Behaviors (visual and gestural) | Researcher Notes/Impressions |
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# Appendix E

## Student Interview Protocol

## OTL Qualitative Interview Spring 2017

So, we have been together for a few days this week learning about science. I know this week you studied ___________________. I thought you might be able to share with me what you think about science in first grade. We are going to talk, look at your interactive science journal, and discuss some of the tools and other things you might use during science instruction. I thought you could tell me about some things that happened here this week.

This interview is completely confidential. That means no one will know what we talk about. It is just between you and me. The conversation will only be used to help me with my own studies. I am a student, too, at a university. I am doing my dissertation research related to young children learning science. In other words, I'm learning about how young children learn science. Your name will not be mentioned in my dissertation study; it will be kept private. I would like to record the interview, but only if I have your permission. It should take no more than 20 minutes. If at any time you feel uncomfortable or would like to stop, please let me know. Do you have any questions before we begin?

Start time: ______:_________

1. When the teacher says, "It's time for science!" How do you feel about it?

   Probe: What do you think?

2. You have been doing science since September. How is science different from other things you learn about?

   Probe: Can you tell me something you know about science?

3. Do you feel like a scientist during science class?

Probe: What do you think it means to be a scientist?

I asked you to bring your interactive science journal so we could talk about the

____________________ activity you did this week.

4. Could you show me what you drew/wrote this week?

Probe: What can you tell me about what you drew/wrote in your journal?

Probe: What tool(s) do you remember working with during this lesson?
(Display tools used during the week; for example: lens, ruler, compass).

Thank you for sharing your journal with me.

5. Whom did you work with during science this week? _______________________

Probe: Do you always work with the same person?

Probe: Did you work with the teacher during science this week?

Well, you have been very helpful. Thank you for sharing your experiences about science with me. You have helped me understand what happens to multilingual students during science in your classroom. Thank you for your time. Do you have any questions for me before we end?

End time: ______:_________