

“Explicame”: Examining Emergent Bilinguals’ Ability to Construct Arguments and Explanations During a Unit on Plate Tectonics

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Abstract

This paper explored the integration of science and language instruction during a unit on plate tectonics in a 7th grade transitional bilingual classroom. As not many studies have explored engaging bilingual learners in the Next Generation Science Standards practices of argumentation and explanation, we sought to analyze emergent bilinguals’ construction and communication of scientific arguments and explanations in oral and written forms. We collected both classroom video data and student written work. We first analyzed student work associated with the unit’s culminating task as evidence of the students’ developing proficiency with science ideas, cognizant of what emergent bilinguals at varying levels of language proficiency are able to do with respect to producing the language functions of explain and argue. For video data, we created event maps of all classroom interaction and then narrowed our focus to key moments of interaction to shed light on the relationships among classroom instruction, written work, and writing reflected in the culminating task. With respect to argumentation, findings indicated that students demonstrated success in constructing claims throughout the unit and on the culminating task and were able to provide some type of evidence to support their claims. This was evident when students could tap into all their linguistic repertoires, using home language and new language to make sense of science. Although most students were still developing to provide sufficient evidence and incorporate scientific reasoning, the use of both home and new language allowed students to articulate initial understandings about scientific concepts such as convection currents and plate boundaries. Students who used home language were also able to provide more extended explanations, moving from using language immediately tied to the environment to attempting to use scientific discourse to explain phenomena. We recommend that teachers celebrate emerging skills and build on the rich linguistic and experiential resources emergent bilinguals bring to optimize participation in the practices of science and facilitate scientific understanding.

Key words: emergent bilinguals, home language, argumentation, explanation

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Introduction

Despite the fact that globally it is more common to be bilingual than monolingual, there is an ongoing debate in the U.S. about the need for bilingual education in schools for English language learners. Yet studies have shown that bilingual students' home languages are not only positive when developing a second language, but also benefit their overall learning at school (Cummins, 2005). Findings from a large meta-analysis study (Slavin & Cheung, 2005) revealed that literacy instruction in students' home language improved literacy in students' second language (English). A substantial body of research suggests that literacy and other skills and knowledge transfer across languages (August & Shanahan, 2006). However, science education for students who speak more than one language in the U.S. is often conducted in English only, despite the fact that bilingual students' learning in science is directly related to the language of instruction (Lee, 2005).

Indeed, the use of home language is not the focus of most of the instructional pedagogies and suggestions for teaching with the Next Generation Science Standards (Valdés, Menken, & Castro, 2015). Lee, Quinn, & Valdés (2013) described the language demands inherent in one of the three dimensions of the Next Generation Science Standards (NGSS): the science and engineering practices. The authors called four of the eight practices – including constructing explanations and arguments - “language intensive” (p. 229). While the NGSS standards identify when language is used for argumentation and explanation, there is no discussion at present in the standards themselves providing teachers with assistance in how to scaffold and meet the needs of bilingual students. This is especially true regarding the use of home language. It is left up to districts, schools, and teachers to develop curriculum that incorporates specific and timely supports for bilingual students.

There is a need to explore ways in which bilingual students grow in their understanding and use of home language, new language and science. Research should explore specific conversations and writing to examine how bilingual students engage in academically rich practices using home and new language to construct arguments and explanations for scientific purposes (García, Sylvan, & Witt, 2011). Guided by ethnographic as well as classroom discourse principles (Bloome, Carter, Christian, Otto, & Stuart-Faris, 2004), the present study addressed this need through a fine-grained analysis of student written work and classroom discourse within a two-week plate tectonics unit implemented in a 7th grade transitional bilingual classroom. The unit was designed with recent recommendations for integrating language and science in a bilingual class setting. We explored the question: To what extent were bilingual students able to construct and communicate scientific arguments and explanations in oral and written forms? In particular, we focused on bilingual students' initial attempts at argumentation and explanation to identify what they were able to speak and write about with respect to their science understandings. In doing so, we moved beyond focusing on what bilingual students could not do from a deficit model perspective to embrace what bilingual students *could do* with respect to their emerging language and scientific understandings (Lee & Llosa, 2015). Through this lens, bilingual students become “emergent bilinguals,” a term that highlights the ongoing nature of language development while stressing the linguistic and cultural assets students who speak other languages bring (García, 2015). This study examined the “strengths and stretches” among 7th-grade emergent bilinguals during a first attempt in engaging in constructing scientific explanations and argumentations.

Conceptual framework

Our work resides at the intersection of research in language and science instruction. We drew from two bodies of research to inform our study: discursive practices of scientific explanation and argumentation and bilingual learners in science.

Discursive Practices of Explanation and Argumentation within Science

Drawing on ideas developed by Vygotsky (1978), we adopted a sociocultural perspective on language learning. We argue that language is always embedded and used in context to accomplish certain communicative purposes, not in isolation or disassociated from socio-cultural situations (Block, 2003). Grammatical forms are at the service of communication, and are best learned in the context of meaning-making (Halliday & Matthiessen, 2004). Therefore, science instruction necessitates attention to students' use(s) of language. For Halliday and Matthiessen (2004), language use has two basic functions: making sense of human experience and acting out social relationships. Quinn (2015) argued that well-designed science lessons ask students to articulate their developing understanding; thus, learners "refine their language to communicate the ideas they have formulated. The attempt to do so drives them to clarify their thinking as well as to stretch their language capacity" (p. 13-14).

The centrality of evidence in constructing explanations and arguments has long been documented within science education reform documents. The National Research Council (2000) described five "essential features" of classroom inquiry, several of which indicate the importance of evidence (see Table 2-6, p. 29). The Next Generation Science Standards (NGSS Lead States, 2013) are organized into performance expectations which push students to use and apply their developing science understandings; one way this is achieved is through the inclusion of the eight Science and Engineering Practices (SEPs). The SEPs aim to assist teachers design opportunities during which students can deepen their understanding of science ideas as well as how scientific knowledge is constructed and communicated (Bybee, 2011).

In middle school, the NGSS (NGSS Lead States, 2013) indicate that students are expected to construct explanations of real-world phenomena that describe relationships between variables (i.e., develop a causal mechanism for a natural phenomenon). Such explanations should be grounded in evidence and align with scientific principles. Science explanations are refined through the use of argumentation (Berland & McNeill, 2011); however, middle school students have been shown to struggle with argumentation. For example, Hogan and Maglienti (2001) found that middle school students assigned a higher ranking to claims consistent with their prior knowledge and their own interpretations of the evidence, whereas scientists focused more on whether the claims were appropriately supported by the data provided. Berland and Reiser (2009) found that some middle school students struggled to separate inferences from evidence, which impacted their ability to persuade an audience of the validity of their science understanding.

With such an emphasis on using evidence to construct explanations and arguments, it is not surprising to see a strong line of research focused on these practices. However, Osborne and Patterson (2011) have stressed the need to clarify how argumentation and explanation serve different epistemological and discursive functions. Berland and McNeill (2011) agreed, stating:

Sense making, or knowledge construction, focuses on developing an understanding of the phenomenon that is being investigated. ... Persuading emphasizes the social construction of

knowledge in that scientists need to convince their peers of the quality of the explanation, using evidence. (p. 809)

the former embodies the practice of explanation, the latter, argumentation. However, Berland and McNeill (2011) highlighted that these practices have a “complementary and synergistic relationship” because scientists refine their explanations through the process of argumentation (p. 809).

We agree with both Osborne and Patterson (2011) and Berland and McNeill (2011) that researchers must provide description of how the practices of explanation and argumentation are conceptualized within a study. Therefore, we define these practices as follows: “Scientific explanations are accounts that link scientific theory with specific observations or phenomena” (Schweingruber, Keller, & Quinn, 2012, p. 67). How students link these theories with observations, we argue, necessitates an attention to academic language, which is a tool to engage in the discipline's characteristic sorts of thinking and acting, such as theorizing and observing (Gee, 2008). In this perspective, academic language involves not only linguistic forms, but also functions and perspectives adopted by language users in academic contexts and situations. For example, when engaging in constructing arguments in science classrooms, students need to be able to understand that the language of argumentation involves not only vocabulary related to scientific concepts, but also specific phrases, sentences, and texts that connect and convey a persuasive message to a scientific audience (Halliday & Martin, 1993). This language is interconnected but different from everyday spoken language as it relies less on the immediate cues and references present in the face to face context of conversation (Gibbons, 2015). Lee, Quinn, and Valdés (2012) suggested that the language of science includes unique features that might pose an extra layer of difficulty for language learners. These features go beyond technical vocabulary to include oral and written discursive practices specific to the discipline and grade reflected in the register of textbooks and classroom talk. In addition, textual features involve the use of multiple modalities, such as graphs and visual representations, and paralinguistic and linguistic features for text organization and style (e.g., nominalization, passive voice, and logical connectors). All of these specific features make academic language associated with scientific practices in school very specialized and unique. As such, the specific practices and language of science need to be explicitly taught to and enacted by students.

Researchers (e.g., Gonzalez-Howard & McNeill, 2016) envisioned a scientific argument as containing the following components: a *claim* supported by *evidence* and *reasoning*. In particular, the reasoning is the justification why evidence can be used to support a particular claim. We argue then that articulating one's reasoning also requires a close attention to academic language. Our study explored the academic language students used to connect applicable science concepts to the explanation or argument students were constructing. As sophistication of content increases in middle school, academic language associated with the functions of argumentation and explanation changes and becomes more complex (Gee, 2008).

Bilingual Learners in Science

Research on bilingual learners in science has traditionally focused on identifying strategies and recommendations for scaffolding instruction. A few studies have focused on explicitly supporting English language learners (ELLs) in the practices of scientific argumentation and explanation. Fewer studies still have focused specifically on bilingual students. In this section, we explore extant literature and argue for a more nuanced approach to research on emergent bilinguals' use of language in science.

A focus on strategies. Many studies around language learners in science have focused on identifying effective support strategies and ways to tailor instruction for ELLs, particularly at the elementary level (e.g., Brown & Ryoo, 2008). Recently, members of the NGSS Diversity and Equity team (2015) highlighted a vignette of elementary science instruction to advocate for the use of: (1) literacy strategies, (2) language support strategies, (3) discourse strategies, (4) home language support, and (5) home culture connections (p. 101). At the secondary level, Tolbert, Stoddart, Lyon, and Solís (2014) highlighted the need to better prepare secondary science teachers to integrate science and language learning, advocating for the use of scientific inquiry as a way to provide ELLs contextualized, content-based language instruction. Their SSTELLA Framework included four interrelated practices: (1) framing learning around contextualized activities that incorporate ELLs' linguistic and cultural backgrounds; (2) engaging ELLs in scientific sense-making; (3) fostering ELLs' use of scientific discourse; and (4) providing ELLs targeted language and literacy development. The authors provided an extended example from a chemistry classroom to highlight each of the four practices and demonstrated how commonly recommended strategies (e.g., think-pair-share, sentence frames, primary language support) were used. While the aforementioned works provide concrete illustrations of *kinds* of supports for ELLs, we argue that it is important to look at the actual discourse of classroom interaction and to what extent students engage in these language-rich practices to paint a clearer picture of what they can do and what they are still learning to do. The only way to map these developmental proficiencies is to examine the actual discourse within classroom instruction

Supporting language development in argumentation and explanation. Research on language development, particularly with respect to supporting argumentation and explanation skills at the secondary science level, remains relatively rare. Duran, Dugan, and Weffer (1997) highlighted the importance of the teacher's role in instruction as well the use of explicit semiotic tools to support students in engaging in science meaning-making. The authors designed instructional activities to support Mexican American language minority high school students in using explicit semiotic tools such as patterns for linking concepts and diagrams to construct and express conceptual meanings. As students became proficient with semiotic tool use, the teacher withdrew as science authority, and students assumed responsibility for constructing meaning. Similarly, Zhang (2016) examined how science understanding was constructed in science lectures in a sixth-grade sheltered classroom through multiple semiotic resources, including oral language, gestures, and visual products. Zhang found that the gap between the multimodal representation and communication, as well as the disconnect between teacher discourse and student discourse, provided limited evidence of the students' knowledge reconstruction.

Gonzalez-Howard and McNeill (2016) investigated the relationship between English-learning students' argumentation and their middle school sheltered English immersion (SEI) science classroom community. Authors identified classroom characteristics that both hindered and facilitated students' opportunities to engage in argumentation. For instance, frequent changes in classroom roster made it difficult for newer members to watch and engage in argumentation with more experienced peers. However, when students worked in smaller group structures, such as pairs, and they utilized both their home and second languages as a linguistic resource for engaging in science discourse, their engagement in argumentation was promoted. Similarly, Swanson, Bianchini and Lee (2014) investigated the argumentation experiences of high school ELLs and the instructional strategies used to support them in this practice. Authors found that the teacher routinely implemented three types of scaffolds to promote students' argumentation: primary language support, deliberate language scaffolds, and small group instruction. ELLs experienced both successes and challenges participating in class, crafting arguments

from evidence, and reading and producing written texts: while ELLs constructed aspects of arguments in small groups, the substance of their discussions was not necessarily reflected in their whole class participation or written products.

Taken together, findings emphasize the need to more closely attend to the teaching and learning of discourse to support language learners in science. Our work is distinguished from those mentioned above in focus and method. While Swanson et al. (2014) focused primarily on teacher supports of argumentation and what happened as a result, our study focuses on student discourse, examining the extent to which bilingual students were able to construct scientific arguments and explanations in both home and new language. While Gonzalez-Howard and McNeill (2016) analyzed argumentation through a communities of practice lens, this study follows traditions in studies in microethnography and classroom discourse (Bloome et al., 2004). We argue for the need to move beyond strategies and more closely examine the ways bilingual learners engaged in the practices of argumentation and explanation in their written and oral discourse using their home and new languages as a resource.

Moving towards what language learners can do with argumentation and explanation. For the practices of argumentation and explanation, Lee, Quinn, and Valdés (2013) described both analytical tasks as well as receptive and productive language functions through which learners engage in scientific sense-making. To achieve meaningful learning in both science and language learning, the authors argued that teachers should focus on language-in-use to provide meaningful opportunities to practice language associated with scientific sense-making: “[ELLs’] contributions should be accepted and acknowledged for their value within the science discourse, rather than critiqued for their ‘flawed’ use of language” (p. 231). Fradd and Lee (1999) suggested that a single approach may not be appropriate for many students whose language and cultural backgrounds are different from the mainstream. Teachers need to be able to tap into students’ cultural norms and practices and mirror those in their instruction in order to better meet students’ learning needs. Indeed, teachers should draw upon their students’ diversity as a resource rather than as a disadvantage (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Warren et al. (2001) argued for the “importance of taking seriously the ideas and ways of talking and knowing that children from diverse communities bring to science” (p. 546). It is therefore important for all science teachers to encourage ELLs to tap into and utilize all features of their linguistic repertoires, including features of their home language’ syntax, lexicon, and discourse, that is, their translanguaging “hooks” (García, Johnson, & Seltzer, 2017, p. 2).

Use of home language in science. Recognizing and building upon students’ cultural experiences as intellectual resources in science instruction can help provide them with “equitable learning opportunities” (Lee, 2003, p. 465) by creating congruence between the students’ home language and culture and the scientific language used in the classroom. In fact, it has been found that the students’ home language can function as a means to monitor their understanding, assist in vocabulary development, and validate their experiences (Valdés, 2001). For this reason, according to García (2015), it is more accurate to consider ELLs as *emergent bilinguals*, a view that celebrates the diversity and dynamic bilingualism of all ELLs while rejecting deficit model perspectives. This view also acknowledges the complex nature of communication and language learning by considering all forms and varieties of language used by emergent bilinguals. This intentional use of emergent bilinguals’ linguistic repertoires is important when they negotiate and make meaning out of disciplinary knowledge and when they interact with each other and the teacher in classroom contexts. In particular, translanguaging practices where bilingual speakers and writers build on their home language repertoires to actively construct meaning in the new language or discipline

should be considered the norm, not a deviation from sense making in the bilingual science classroom context these students are located (Canagarajah, 2013).

A handful of studies have explored how emergent bilinguals learn both language and science. For example, Ciechanowski (2014) studied a third grade dual language class as they explored a unit on rocks over the course of six months. Lessons were explicitly designed by a team of a language specialist, classroom teacher and researcher to follow an interconnected model which included content, linguistic forms and functions. Findings from pre/post tests showed gains in language and content and increased engagement with targeted language, word choice, scientific vocabulary, and number of words. While the greatest gains were achieved by students with stronger English proficiency, even those at earliest levels experienced modest gains. Evidence from observations showed students communicating about experiments as there was a pressing need to engage in talk to share discoveries and negotiate with peers.

Similarly, Poza (2016) found that by allowing fifth grade students in a bilingual education program to make ample use of their bilingual repertoires, extensive collaboration, and authentic experience and exposure to target language, students were supported in their learning of new content and linguistic forms. Stevenson's (2013) study of fifth graders transitioning out of a bilingual education also found that students purposefully adapted their use of linguistic resources in order to facilitate their participation in science learning. The author highlighted the importance of explicitly acknowledging, supporting, and incorporating bilingual students' linguistic resources in both Spanish and English in order to optimize participation and facilitate understanding.

While the three studies above examined classes where both the teacher and students spoke the same language (Spanish), Unsal, Jakobson, Molander, and Wickman (2016) examined how bilingual students aged 13-14 years construed relations between everyday language and the language of science in a class in Sweden where the teacher and the students did not share the same minority language. The teacher was fluent in Swedish and Bosnian while the students were fluent in Turkish. Results showed how the students' everyday language repertoire may have limited their possibilities to make meaning of science content. Such struggles were exacerbated by the teacher's use of words that were not part of the students' language repertoire. Students also tended to use their minority language as a resource to translate words from Swedish to Turkish in order to participate in the planned activities. However, translating scientific concepts was problematic and led to the students' descriptions of the concepts not being in line with how they are viewed in science. Despite the struggles experienced by students in a classroom where the teacher did not speak the same minority language, researchers argued in favor of a translanguaging pedagogy, "an approach to teaching and learning in which students' whole language repertoires are used as valuable resources for constructing meaning and for developing academic competences in the language of instruction" (Moore, Evnitskaya, & Ramos-de Robles, 2017, p. 2).

Indeed, as all of the studies reviewed above have emphasized, a focus on what emergent bilinguals can do marks a shift away from sheltered models of teaching science by providing learners both access to content as well as situations that demand active use of language to communicate scientific understanding (Lee et al., 2013). By capitalizing on emergent bilinguals' resources and by providing the necessary supports, Lee and Llosa (2015) pointed out that the science teacher can recognize that these students can indeed engage in complex scientific practices no matter their level of language proficiency. Aligned with this view, Castro (2015) argued that language development standards, such as the Bilingual Common Core Progressions developed in New York State (New York State Education Department [NYSED], 2014), can

be used by science educators to guide instruction and assessment for emergent bilinguals. These language development standards focus on what language learners can do regarding different academic practices, instead of assessing emerging bilinguals for what they lack or cannot do. Focusing on what emergent bilinguals can do helps science teachers identify and build upon strengths and determine needs, particularly in light of engaging students in the language-intensive practices of argumentation and explanation so inherent within the NGSS (NGSS Lead States, 2013).

Research design and methods

Classroom Context

The context for this study was a 7th grade bilingual science classroom located in an underserved suburban school district in New York State. Students were at varying levels of English proficiency. The class functioned as a *transitional bilingual program*, whose main objective was to transition students to an English-only mainstream classes; home language was used as a bridge to learn English and content (Shin, 2013). As such, students had access to grade-level science standards and content objectives in their home language (Spanish).

The 7th grade classroom was comprised of 16 students (ages 12-14); students' English language proficiency levels ranged from Entering to Expanding (New York State Department of Education [NYSDOE], 2012). All students had been in the U.S. for less than two years, with a majority from El Salvador. At the time of data collection, three students had lived in the U.S. for only a few months, mainly speaking and understanding Spanish. Two out of the 16 students spoke and wrote in English and had expressed a desire to be placed out of the transitional bilingual program for the following academic year. The remainder of students could understand oral directions provided in English but felt more comfortable responding in Spanish.

The classroom teacher, Ms. B., was a native Spanish speaker with 20 years of experience teaching science that spanned both middle and high school; the majority of her teaching occurred in bilingual programs. As a native Spanish speaker, she translated all curricular materials and facilitated all classroom discussions that occurred in Spanish. As part of ongoing professional development with the first author, Ms. B. expressed the desire to implement a unit that focused on the science and engineering practices of explanation and argumentation. Thus, the authors provided support to Ms. B in both the creation and implementation of the curriculum. The unit on plate tectonics was the first time Ms. B., and correspondingly her students, engaged in such a curriculum during the 2014-2015 academic year. This unit occurred at the end of the school year, just prior to final examinations.

Researchers

The first and second authors were former science teachers in middle and high schools, respectively. The third author worked as an English as a Second and Foreign Language instructor with children, adolescents, and adults. Throughout this project, we embraced our varied perspectives stemming from our own teaching experiences, as well as our backgrounds in science and TESOL (Teaching English to Speakers of Other Languages) education to strengthen our methodological and pedagogical approach. All three authors co-planned the two-week unit with input from Ms. B. The second author was present during instruction on Days 8 and 9. The first author co-facilitated the two-week unit with Ms. B. The teachers' reflections about pedagogy and rationale(s) for modifying the curriculum during implementation are beyond the scope of this paper.

Curriculum

The two-week unit on plate tectonics explored in this study involved students in both the practice of explaining real-world phenomena and constructing arguments. This curriculum aimed at providing students opportunities to: (1) develop deep understanding of plate tectonics and (2) use oral and written academic language in English and/or their home language (Spanish). Inspiration for the planned curriculum came from two sources: the adopted state standards and textbook used by Ms. B., and the NSF funded textbook *Integrated Coordinated Science for the 21st Century* (It's About Time, 2004). The latter textbook emphasized an inquiry-based approach to science instruction. The two-week unit was comprised of ten 43-minute lessons that involved the students in four tasks (see Table 1).

Table 1

Tasks Focused on Scientific Argumentation and Explanation

Task 1:	Days 1-4 Argumentation	Students evaluated a claim of whether or not their own school should practice earthquake drills and argued whether there was sufficient evidence to support the claim. Students plotted earthquake data on a world map to infer the location of plate boundaries. Students then analyzed GPS tracking data to explore the ways in which those plates moved.
Task 2:	Days 5-6 Argumentation	Students practiced evaluating sample claims and argued whether there was sufficient evidence to support the claims. Students watched a video on the discovery of seafloor spreading. Students then read and discussed types of plate boundaries. Students describe the three types of plate boundaries and relate plate boundaries to the claim that the Earth's crust moves.
Task 3:	Days 7-9 Explanation	Students completed a lab on mixing hot and cold water to explain why waters of two different densities do not mix; they then used their understanding from this lab to explain how this phenomenon relates to convection currents in the Earth's mantle. Students observed a glitter lamp works and explain how it works. Students also applied their understanding to explain the mechanism for how tectonic plates move. Students completed posters that describe each boundary type and how subduction resulted from specific boundary collisions.
Task 4:	Day 10 Argumentation	The culminating task asked students to re-evaluate the claim from day 1 considering the location of a set of schools to determine whether each site should practice earthquake safety drills. Students worked in pairs and wrote a letter developing a logical argument based on whether there was sufficient evidence to support the claim. Students connected their argument with a description of how tectonic plates move via convection.

Supports. We drew from the work of Tolbert et al. (2014), Gibbons (2015), and recommendations made by members of the NGSS Diversity and Equity Team (2015) to inform the kinds of supports and scaffolds to engage students, particularly emergent bilinguals, in the practices of scientific argumentation and explanation. We incorporated practices such as: 1) intentional scaffolding of language, 2) authentic contexts building on home culture connections, and 3) multiple opportunities to verbally discuss ideas with peers in home language (Spanish) and new language (English). Supports included the use of: discourse frames; modeling of science conversations; translation of materials and instructions into home language; opportunities to work in pairs; students' prior experiences and home cultures; freedom to speak and write in home and new languages; and opportunities to revise the culminating letter. For more details regarding specific activities included in this unit, see Swanson, Kang and Bauler (2016).

Home culture connections. Throughout the unit, students were engaged in activities that actively tapped into their prior knowledge and cultural experiences by involving them in familiar situations. This is evident in the culminating task which asked students to work in pairs to write a letter justifying the need for earthquake drills at certain schools located around the world, including El Salvador, where many of the students were from. Students were asked to include their reasons why the selected school should practice earthquake drills (i.e., based on its proximity to a tectonic plate boundary) and a description of what causes earthquakes. Students were required to include the term *convection* and details about the different ways tectonic plates move in their description.

Data collection and analysis

In order to explore our research question, we assessed the extent to which students could construct scientific arguments and explanations in written and oral forms. Analysis of video and written work occurred concurrently. During this analysis, we were cognizant of what emergent bilinguals at varying levels of language proficiency are able to do with respect to producing the language functions of explain and argue.

Written work. Student written work was generated during each of the ten days of instruction. Written assignments associated with Days 1, and 5 through 9 were completed individually by the 16 students. In contrast, assignments completed on days 2 through 4 were completed in pairs. With respect to the culminating task (Day 10), 12 students completed it in pairs, generating six letters. Three students completed their letters individually; one student did not complete the culminating task. This resulted in a set of nine letters for analysis.

We first analyzed student written work associated with the unit's culminating task as evidence of the students' developing or emerging proficiency with science ideas as well as academic language. Eight of the nine letters were written in Spanish. To facilitate analysis, prior to coding, all Spanish writing was translated into English. To understand the translanguaging resources students tapped into, Spanish language was translated verbatim into English by a graduate research assistant, who was a native speaker of the variety of Spanish shared with the students. Two of the researchers can read and understand Spanish. The translation included maintaining words that students used or created or did not have an apparent English equivalent. For example, some students referred to convection as "conveccionnan." We analyzed the English versions of the letters first, and then cross-checked the original Spanish versions to ensure that our findings accurately represented students' scientific thinking in both languages.

We then drew from Halliday (1994), Gibbons (2015), and McNeill and Krajcik (2008) to design a rubric that attended to both content and academic language. We began with the three criteria (claim, evidence and reasoning) that McNeill and Krajcik (2008) included in their rubric for analyzing student written scientific explanations and drew from their definition of reasoning: “the justification for why their data count as evidence to support their claim, which often requires the use of scientific principles” (p. 103). We viewed this rubric as appropriate for assessing the culminating task - an opportunity for students to develop an argument regarding the need for earthquake drills - because we viewed the structures of “claim,” “evidence,” and “reasoning” as components of a scientific argument.

We included two criteria to analyze students' academic language based on a systemic functional approach (Halliday, 1994) that focused on the use of both scientific vocabulary and discourse for specific purposes. The design of the academic language criteria directly drew from Gibbon's speaking to writing mode continuum (Gibbons, 2015), illustrating how certain features of language might change as students transition from speaking to each other using language in conversational, face-to-face contexts to writing for an unseen audience using language in academic contexts. We also borrowed from the Bilingual Common Core Progressions (NYSED, 2014), which provided a framework for assessing students' language structures and practices associated with the discourse of the content-area being taught.

As we discussed the culminating task letters, we revised the rubric until we could assess student work along a continuum (*does not meet, approaches, and meets*) for each of the five criteria. Using the finalized rubric, all authors participated in coding the translated letters; all disagreements were discussed until resolved. See Appendix A for rubric.

Classroom discourse. The two-week unit also generated 7.5 hours of video and accompanying fieldnotes. To analyze classroom discourse, students were assigned numbers which were consistently used across transcripts and work samples (i.e. student 9 is always the same person). We adopted a qualitative approach to coding activities and classroom discourse (Saldaña, 2009). This analysis occurred in two passes. In the first pass, we watched the videos for all ten days in conjunction with reviewing fieldnotes and created event maps (Green & Wallat, 1981). An event map is an ethnographic archiving system that permits search and retrieval of relevant records such as record of events, activity, and actors. The purpose of the first pass was to identify instances when students engaged in learning content and practicing discourse most closely aligned to culminating task assessment criteria. Using the event maps, we developed a set of emergent codes (see Table 2): *scientific argumentation*, *scientific explanation*, *scientific vocabulary* and *academic scientific discourse* with subcodes generated for the first and last codes. Though the code *scientific explanation* was not included in the culminating task assessment criteria, we looked for opportunities for students to engage in this discursive practice because students practiced generating explanations which connected to their developing understanding of convection.

Table 2

Event Map Codes Relating Instances Students Practiced Argumentation and Explanation

Code	Sub-Code	Task 1				Task 2		Task 3			Task 4	
		1	2	3	4	5	6	7	8	9	10	
Scientific Argumentation	Evaluate validity of claims	X		X	X	X						X
	Practice developing a claim		X	X	X							X
	Practice identifying evidence to support a claim		X	X	X				X			X
	Analyze data from chart (evidence)	X	X	X	X	X					X	X
	What counts as evidence				X	X						X
	Connect claims with evidence using scientific concepts (reasoning)		X	X								
Scientific Explanation	Explain specific observations (or phenomena) through use of scientific concepts		X	X					X	X	X	
Scientific Vocabulary	Develop familiarity with scientific terms in home and new language				X	X	X	X	X	X	X	X
Scientific Discourse	Engage in oral discourse in home and new language to construct argument & explanation				X				X	X		
	Engage in written discourse in home and new language to construct argument & explanation	X	X	X	X				X	X		X

We coded the data according to patterns of frequency and correspondence, taking into consideration our own filters as well as variation and irregularities in the data. Possible filters we considered were our roles as designers of the curriculum as well as our personal level of involvement in its implementation (Spradley, 1980). The final column represents the elements students needed to successfully complete the culminating task (Task 4). For example, developing and evaluating claims was

practiced during the first five days of the unit. Analyzing data and identifying appropriate evidence for a given claim appeared throughout the four tasks.

In our second pass, we focused on the following days of instruction: days 2, 3, 7, and 8. We found these days highlighted classroom interaction directly associated with the scientific knowledge, language and skills needed to successfully complete the culminating task. It was our assumption that in looking more closely at the kinds of conversations happening on these days, we could shed light on the relationship between classroom instruction and the writing reflected in the letters (Bloome et al., 2004). Therefore, we selected these days to zoom in on and identify key moments (see Table 3).

Table 3

Key moments of Opportunities for Constructing Scientific Explanations and Arguments during Classroom Instruction

Day of Unit	Broader Event	Moment Description	Moment Duration	Teachers' Actions	Students' Actions
2	Connecting EQ Mapping Activity to Family/Principal Conversation	teacher explains dots represent earthquakes; students attempt to write two pieces of evidence to support principal's claim.	4m21s; 4m17s	explains and draw attention to principal's rationale; relates dots to earthquake activity	find two pieces of evidence
3	Comparing maps	students share opinions in pairs and write their responses	24s; 1m32s	gets students to write; prompt for thinking	try to explain the differences orally using both Spanish and English; try to write their answers based on teacher prompts and what they say
3	Return to Conversation with Principal	making connections to maps and the probability of	4m45s	gets students to think back on reasons why the principal might be right; get	talk with each other about plates being far away from Long Island

			an earthquake to happen on LI		students to use evidence from maps	
7	Hot/Cold Water Investigation	Water	developing causal mechanism for phenomenon	1m20s	explains cause of observation	share observations from first part of investigation
7	Hot/Cold Water Investigation Debrief: Connection to Density	Water	Connecting observation of hot/cold water to the term "density"	7m40s	connects observations of hot/cold water to concept of density to explain how convection causes tectonic plates to move	answer brief questions (right/wrong format - one word); repeat vocabulary after teacher's use of vocabulary in explanation
8	Revisiting Hot/Cold Water Investigation: Focus on Vocabulary	Water	clarifying concept of density and how it relates to hot & cold water - specifically revisiting explanations written during previous class investigation	1m25s; 57s	probes student thinking and have them rewrite their explanations from the previous investigation	verbalize why colors sometimes mixed and sometimes did not
8	Glitter Investigation	Lamp	describing how the glitter lamp works	5m 45s	prompts students as they are writing their explanations	verbalize and record their explanations

Following the traditions of studies in microethnography and classroom discourse (Bloome et al., 2004), we analyzed these key moments asking the following questions: What was the purpose of the moment? What were the students' actions from moment-to-moment? What were the students saying and doing? We then cross-referenced findings with general trends in classroom interaction as well as the culminating task letters and written classwork to ascertain how and to what extent academic language was used to connect science concepts to students' argument and explanations.

Findings

Our findings highlight the extent to which emergent bilinguals were able to construct arguments and explanations in both home language (Spanish) and new language (English) within the two-week unit on plate tectonics. As mentioned earlier, we focused on what emergent bilinguals *could do* based on their emerging language and science understandings. We present two sets of findings: the first set comes from classroom instruction. To capture students' bilingual abilities concerning the construction of arguments and explanations during the two-week unit, we present selected key moments, represented in transcripts, and their associated student written work. Within each example, we present both the Spanish and English translation when Spanish was used. Ms. B and the first author used both languages to engage students in science practices. Then, in our second set of findings, we present student work from the culminating task (Task 4) as it represented what emergent bilinguals were able to do by the end of the unit.

Examining Emergent Bilinguals' Written and Oral Discourse that Occurred During Instruction

We present findings on select days (key moments) during the unit in which students had explicitly engaged in scientific argumentation or explanation. While students had opportunities to practice argumentation and explanation throughout the unit, we highlight several representative moments that connect to the culminating task. Findings are associated with key moments on days 2, 3, 7, and 8 are explored using transcripts, descriptions of classroom activity, and student classwork.

Developing evidence-based arguments on Day 3. For two days (Days 2 and 3), students made claims relating a school's proximity to a tectonic plate boundary to the need for practicing earthquake drills. Teachers utilized both students' home language (Spanish) and new language (English) to engage them in the activities. Pairs of students first plotted dots representing past earthquakes onto transparent film placed on top of a world map. All students' transparencies were then stacked so that all dots were visible. Students drew lines to connect the dots and approximate the locations of plate boundaries. Next, teachers attempted to engage students in data analysis by having them infer the likelihood of experiencing an earthquake if one were near the drawn lines. Students were then asked to draw two pieces of evidence from this discussion to support the principal's claim that their school (located on Long Island, a land mass far removed from a tectonic plate boundary) should not practice earthquake drills. Students had a choice to use either English or Spanish. Because it was the beginning of the unit, students were in the initial stages of developing arguments as illustrated by the following example of classroom discourse between Student 1 and 6:

- | | | |
|---|---|---------------------------------|
| 1 | Student 1: Okay, dos, dos evidencias. Esta | Okay, two, two evidence. It's |
| 2 | por la agua un poquito. Tu estas de acuerdo | near the water a little bit. Do |
| 3 | o no de acuerdo? No porque yo... | you agree or disagree? No |
| | | because I... |
| 4 | Student 6: Dice: (reading from paper) | It says: |
| 5 | <i>“Write a sentence that the principal can use</i> | |
| 6 | <i>to explain his opinion to the family. The</i> | |
| 7 | <i>chance of having an earthquake on Long</i> | |
| 8 | <i>Island is small because...”</i> the tectonic | |
| | plates are far away from Long Island. | |

In this conversation, students used both home and new language to engage in the task. Through the use of home and new language, we were able to see ways in which students practiced the language demands connected with argumentation as well as their understanding of plate boundaries. Using Spanish, Student 1 began a conversation identifying and connecting evidence to a given claim. In lines 1-3, Student 1 engaged Student 6 in an exchange using expressions of argumentation such as “Tu estas de acuerdo o no de acuerdo?” and “No porque...” In line 2, Student 1 uses Spanish to say that Long Island’s proximity to water is evidence for earthquakes not occurring there. In lines 7-8, Student 6 offered justification for the given claim in the prompt by saying “the tectonic plates are far away from Long Island” in English. This student was successfully able to apply the term “tectonic plate” in justifying why Long Island is unlikely to experience earthquakes. Although it is unclear at this moment whether she completely understands that tectonic plates have boundaries and that boundaries are important to consider when discussing earthquake activity, the use of both home and new language makes visible students’ thinking at this time, which, in turn, provides good insight into their developing ideas in science.

Concerning the written work done for that day, of the seven other pairs of student responses, six were able to accurately provide one piece of evidence to support the principal’s claim, with the most common response being: “*en el mapa no muestra evidencia de terremotos en Long Island (on the map does not show evidence of earthquakes on Long Island).*” Most students chose to write in their home language. As with Students 1 and 6, all pairs demonstrated emerging understanding related to the second piece of evidence, either in terms of scientific accuracy or more sophisticated use of language. This was evident regardless of whether the students spoke or wrote in English or Spanish. Even though many were still reaching to provide sufficient evidence, all students were able to provide some type of evidence to support their claim.

Developing explanations on Day 7. On Day 7, students explored the concept of density (as a precursor to convection) by engaging in an investigation of hot and cold water. They found that when they placed a flask a cold water (dyed blue) on top of a flask of hot water (dyed red), the two colors mixed as the more dense cold water sank to the bottom flask and the less dense hot water rose to the top flask. However, when placed hot water on top of the cold water, the colors did not mix.

We provide two classroom excerpts from this day. The first excerpt is from a conversation conducted in English only between Dr. A and the whole class after the students had observed the waters mixing (or not mixing):

What’s happening to the atoms? *Time Stamp: 9:55-11:15; 20:45-28.15*

- 1 Dr. A: What happened?
- 2 Students: Me, me, me! (raising their hands)
- 3 Dr. A: Okay let’s say in English. I put cold water on top...tell me in English. Go ahead.
- 4 Student 3: The color is mix and creates purple.
- 5 Dr. A: Okay did you put the cold on top?
- 6 Student 3: Yeah

7 Dr. A: When the cold is on top the colors mixed. Who wants to say the other?

8 Student 2, can you add to that? Say more.

9 Student 2: When you put the cold water on top it transforms purple.

10 Dr. A: Yeah do you see the blue going down?

11 Students: Yeah

9 minutes later...

12 Dr. A: So now we have hot water and cold water. One is more dense than the other
13 one. Now watch carefully. This is me as water when I'm hot. Crazy. This is hot
14 water [moving hands rapidly].

15 Ms. B: Rapido.

16 Dr. A: Cold water. How does it work?

17 Students: Slow!

18 Dr. A: Now think about it. They are not moving very much.

19 Female student: A little

20 Dr. A: So if it's not moving... can I have him [a student] come with me? Can we
21 sit them all into one space? Let's say this is the bottle right here. If they are not
22 moving... we can fit many many people into one space.

23 Students: Yes

24 Dr. A: But if I'm going crazy. Can I fit crazy people in this space?

25 Students: No

26 Dr. A: So cold water is more dense. Repete.

27 Students: Cold water is more dense.

28 Dr. A: Who can tell me why? What's happening to the atoms? What's happening
to the water?

29 Student 9: I think because the hot water ... the molec...

30 Dr. A: Molecules?

31 Student 9: The molecules get... no ... it spreads

32 Dr. A: It's spreading yes

33 Female student: It's not moving that way

This discussion took place in students' new language (English). Students were supported in making observations prior to explaining so that they would have some of the new language expressions (e.g. purple, mixed, top, bottom) and hands-on experience to inform their thinking. Students were then introduced to the term *density* and asked to relate density with water temperature and molecular movement. In lines 1-3, Dr. A started by posing a question in English "What happened?" following by requiring that students try to respond "in English." In lines 4-11 students made observations about what happened to the hot and cold waters when one was placed on top of the other. With intentional support from Dr. A students were initially able to respond with single word responses (e.g. yes, no, slow). Eventually, by eliciting and supporting students' development of explanations in English, Dr. A helped Student 9 to describe how the water molecules spread when heated (lines 29 and 31). Students' responses in English demonstrate an emerging scientific understanding of the connections between why some things or phenomena happen.

Next, students were asked to develop a causal mechanism for the above phenomenon based on their ideas about density through an additional example of temperature variances within a swimming pool. Below is an excerpt of their discussion, which included both Spanish and English.

¿Cuál es más densa? - Time stamp: 13:33-15:30

- | | | |
|----|--|---|
| 9 | Dr. A: Why is cold water at the bottom of | |
| 10 | the swimming pool? | |
| 11 | Student 2: Because...oh I know! ¿Cómo | Because... I know! How do you say... |
| 12 | se dice?... cuando está soleado... el... el | when it's sunny and the sun... goes up |
| 13 | sol... le dá arriba entonces no...no... le da | so it does not go down because the |
| 14 | para abajo porque el agua está muy fría y | water is too cold and never goes through |
| | nunca se pasa de allí | there |
| 15 | Ms. B: ¿Pero qué tú sabes de cuál es más | But what do you know about which one |
| | pesada? | is heavier? |
| 16 | Student 2: La... la... la... no se mueve... | The... the... the... they don't move |
| 17 | no se mueve la... cuando está caliente no | there... when it is hot they don't move |
| 18 | se mueve la de abajo porque está muy fría | down because it is too cold so they don't |
| 19 | entonces no se (undecipherable) arriba | (undecipherable) up |
| 20 | Students: Me! (<i>two girls raise their hands</i>) | |
| 21 | Ms. B: ¿Pero cuál es más pesada? ¿Cuál | But which one is heavier? Which one is |
| 22 | es más densa? | denser? |
| 23 | Student 2: La fría | The cold |
| 24 | Student 4: The cold | |
| 25 | Ms. B: Okay, he got it (<i>speaking to Dr. A</i>) | |

- 26 Dr. A: Okay, so cold water heavy. How
27 do you say heavy? (*looks at Ms. B*)
- 28 Ms. B: Heavy...Pesada Heavy
- 29 Dr. A: Okay, cold water HEAVY. Hot
30 water... (*using hand motions*) LIGHT
- 31 Ms. B: LIGHT... Menos pesada Less heavy
- 32 Dr. A: Yes?
- 33 Student 5: Uh-huh
- 34 Dr. A: Okay, so why now? Let's go back
35 to our experiment. Why when you put hot
36 water on top... did the colors not mix?
37 Why when cold down here, hot up here?
38 How come colors stay separate?
(*showing with hand gestures*)
- 39 Ms. B: ¿Por qué no se mezclaron cuando Why didn't they mix when the hot one
40 la caliente estaba arriba y el frío estaba was on top and the cold one was at the
abajo? bottom?
- 41 Student 6: Porque tiene... Because it has...
- 42 Dr. A: Think about which one is light and
43 which one is heavy
- 44 Student 2: Porque una es más pesada que Because one is heavier than the other
la otra

The interaction started with Dr. A asking the question: “*Why is cold water at the bottom of the swimming pool?*” in lines 9-10. Through the use of both home and new language, Student 2 provided two explanations to the “*why*” question posed by Dr. A in lines 11-14 and then in lines 16-19. Tapping into his linguistic and experiential resources, Student 2’s first explanation in lines 11-14 connects scientific phenomenon to his prior knowledge and experiences. The registers of Spanish and English used to convey ideas is typical of everyday conversations, not including features of academic scientific discourse. For example, Student 2’s response seemed to show uncertainty of which scientific terms to use, such as “*how do you say?*” while also referring to his prior knowledge of how the sun usually heats the water that is on top of the swimming pool in Spanish. In the second attempt in lines 16-19, Student 2’s language included academic features, using language modeled by the teachers during class, such as “*no se mueve la de abajo porque está muy fría.*” Tapping into his expanded linguistic repertoire in his home language, Student 2 demonstrated an enhanced ability to explain by describing relationships between details and supporting ideas while still learning to articulate the scientific principle behind his explanation (why the hot water does not move down).

At the end of the interaction, in lines 34-38 and in lines 39-40, Dr. A and Ms. B asked questions, such as “*Why when you put hot water on top did the colors not mix?*” and “*¿Por qué no se mezclaron cuando el agua caliente estaba arriba y el frío estaba abajo?*” This prompting led to two students’ attempts to provide a more detailed explanation. Student 6 started saying “*porque tiene...*” in line 41 and Student 2 began to give a reason in line 44 - “*Porque una es más pesada que la otra,*” using the academic language “*más pesada*” to convey his thinking. The interaction above suggests that students were able to successfully describe the molecular movement of hot and cold water using an academic register of Spanish. With teacher support and questioning in students’ home language, their explanations also grew more detailed. Note the difference between this interaction and the previous interaction that took place in English only. Although students’ responses were still emerging when articulating the relationship between thermal energy and density regarding a real life phenomenon, it was evident that the use of home language allowed for the transition between an explanation that relied solely on prior knowledge and experiences to a more scientific explanation that connected the idea of density to hot and cold water.

We next turned to student work to see if students’ written explanations aligned or extended their oral explanations. To conclude their investigation of hot/cold water, students were asked to provide an explanation for the observed phenomenon (Prompt: “*Why did the colors not mix when then warm water was on top of the cold water?*” Use words like ‘less dense’ and ‘more dense’ in your explanation”). As a language support, they were reminded to use scientific academic vocabulary “*less dense*” and “*more dense*” in either Spanish or English.

Concerning language choice, of the 14 total responses, 11 were written in Spanish and three in English, showing students’ preference in expressing their scientific understanding in their home language. Below are four representative examples.

Student 7	porque el agua fría es mas denso y eso no los dejó mezclarse	because the cold water is more dense and that that did not let them mix (misspelled)
Student 10	que el rojo es menos denso y el azul es más denso.	that the red is less dense and the blue is more dense.
Student 13	por que el agua caliente es menos denso por eso se mantiene arriba y el agua fria no por que es más densa	because the hot water is less dense that is by the stayed above and the cold water not because it is more dense
Student 12	porque la elada es mas densa y la caliente menos densa, entonses la mas densa se queda abajo.	because the cold (misspelled) is more dense and the hot is less dense, so (misspelled) the more dense one stays down.

These responses demonstrated that students could correctly identify the cold water as more dense than hot water in Spanish. Student 13 noted that the hot water was less dense than the cold water and that it

“*mantiene arriba (stays above).*” Similarly, Student 12 wrote “*la mas densa se queda abajo (the more dense one stays down).*” Student 7 referred to the lack of mixing and linked it with the cold water being more dense. Even though students could have benefitted from additional supports in order to articulate how the information they provided could explain the observed phenomenon, most students' answers showed a burgeoning understanding of density. Their responses also demonstrated an emerging ability to develop an explanation supported by evidence. Tapping into students' existing linguistic repertoires allied with the use academic language supports in Spanish allowed students to apply scientific concepts and language to explain a scientific phenomenon in writing.

Developing explanations on Day 8. During the last few minutes of the period on Day 7, teachers connected the concept of density to convection currents, specifically convection within the Earth's mantle. Because this conversation was very brief and abruptly ended by the bell ringing, the majority of the conversation about convection currents occurred on Day 8 when students observed convection of glitter within a heated lamp and the class discussed what they saw in relation to what they had observed during the hot/cold water experiment. Day 8 was also an opportunity for students to synthesize their understanding of the relationship between temperature, density, and convection to explain the reason for tectonic plate movement. Just prior to the excerpt below, students observed the glitter lamp and recorded observations. They then tracked the motion of one piece of glitter and were asked to describe in writing what they saw using words like *up, down, left, right*. Students orally shared these responses with a partner. Students were then asked to describe how the motion of the glitter was similar to what they saw in the water investigation from Day 7. Lastly, students described how they thought the glitter lamp worked. Following is an excerpt from Day 8 when three students each provided explanations for how the glitter moved in the lamp. Dr. A and Dr. C (first and second authors, respectively) were present on this day to facilitate the discussion.

¿Cómo se llama? - *Time Stamp: 36:45-39:00*

- | | | |
|----|--|--|
| 45 | Dr. A: Can you explain, Student 7, for me?
Explicame | Explain to me |
| 46 | Student 7: Um... ¿En Español? Yo digo que | Um... In Spanish? I say that it has a |
| 47 | tiene un bombillo de luz y necesita electricidad | light bulb and it needs electricity so it |
| 48 | para que pueda trabajar y la cosita que tiene | can work and the thing that it has |
| 49 | adentro se caliente y los diamantes se puedan
mover | inside gets hot and so that the
diamonds can move |
| 50 | Dr. A: Okay, gracias (<i>moves away from Student</i> | Okay, thank you... |
| 51 | 7)... (<i>to Dr. C</i>) You want to take explanations? | |
| 52 | Okay, let's get going. Ms. B! Ms. B, let's move
on! | |
| 53 | Ms. B: Okay... vamos...(overlap) | Let's go... |
| 54 | (undecipherable) Student 5...Student 5...can we | |
| 55 | hear what you said? Shh... Student 4...She is | |
| 56 | going to let us know what she said... Student 5? | |
| 57 | Student 5: That... | |

58	Student: ¿Qué pasó?	What happened?
59	Student 5: ¿En Español?...¿En Español?	In Spanish?...In Spanish?
60	Student: Sí, en Español...	Yes, in Spanish...
61	Student 5: Okay (<i>starts reading what she wrote</i>)	
62	porque se mueve hacia arriba y hacia abajo y	because it moves up and down and it
63	hace como un...	forms like a...
64	Student 6: Círculo	Circle
65	Student 5: Círculo... círculo (<i>drawing circle in</i>	Circle...circle
66	<i>air</i>) pero cuando el agua está caliente va para	but when the water is hot it goes up or
67	arriba o frío va para abajo	cold goes down
68	Student 2: It's go down...	
69	Student 7: Miss! (<i>to Ms. B</i>) (<i>student is raising</i>	
70	<i>her hand waiting to be called</i>)	
71	Ms. B: Sí... pero... ¿El aire?	Yes... but... the air?
72	Student 7: Yeah	
73	Ms. B: The air is hot? They go up to the top?	
74	(<i>students continue to raise their hands</i>)	
75	Student 7: Yeah	
76	Ms. B: And when it's cold... (<i>showing with</i>	
77	<i>hand gesture going down</i>)	
78	Student 7: No eso es un círculo	No that's a circle
79	(<i>moves hands in circles</i>)	
80	Ms. B: They make a circle... Okay, Student 6	
81	Student 7: Miss!	
82	Student 6: Porque yo pe... Yo puse porque la	I wrote because the lamp is at the
83	lamparita está abajo...	bottom...
84	Ms. B: Excuse me (<i>asking students to quiet</i>	
	<i>down</i>)...	
85	Student: Shh	
86	Ms. B: Ella está le[yendo]... hablando	She is re[ading]...speaking

87	Student 6: Porque la cosita... la luz está abajo	Because the thing... the light is at the
88	cuando toca la agua se hace caliente entonces la	bottom when it touches the water it
89	cosita se mueve...	turns hot the things move...
90	Student 7: Student 6! Lo mismo estas diciendo	Student 6! You are saying the same
		thing
91	Student 6: Cuando está arriba se enfría porque	When it is at the top it gets cold
92	está muy lejos de la cosita entonces se vuelven	because they are very far from the
93	abajo luego arriba luego abajo	thing so they return to the bottom then
		to the top then to the bottom
94	Ms. B (asking all): ¿Cómo se llama?	What is it called?
95	Student 8: corrientes de convección	convection currents
96	Ms. B: convection currents	

This interaction captured a discussion involving a description of the science concepts of thermal energy and convection. With respect to teacher-student interaction, Dr. A began by asking the question: “*Explicame*” in Spanish in line 45. Note that this time Dr. A asked the question in Spanish establishing a change of code from new language - English, in prior interactions, to home language - Spanish. This change set the tone for a different conversation, now actively promoting the use of home language as a medium for scientific sense making. Dr. A’s elicitation of an explanation in Spanish promoted a series of more detailed student responses, which all attempted at explaining what made the glitter lamp work tapping into all their linguistic repertoires. Students kept reiterating the choice of code by asking “¿en español?” in lines 46, 59, and 60. What was immediately apparent from this excerpt was that students shared their thinking or commented on another’s response. Students seemed to be listening to one another as they shared their responses with multiple turn-taking. For example, Student 6 completed what Student 5 was saying in line 64. Student 7 stated that someone repeated the same thing she just said in line 90.

Concerning scientific explanations, Student 7 accurately identified the lightbulb and electricity as important components to make the lamp work in Spanish in lines 46-49. The student talked about thermal energy transfer: “*Yo digo que tiene un bombillo de luz y necesita electricidad para que pueda trabajar y la cosita que tiene adentro se caliente y los diamantes se puedan mover.*” Then, Student 7 linked this to the movement of the glitter using the coordinating conjunction “y” (and). After Student 7 attempted an explanation in lines 46-49, Ms. B continued prompting another student to answer the question: “*Can we hear what you said?*” in line 54. Ms. B kept switching codes from English to Spanish, allowing all students and teachers Dr. A and Dr. C to tap into their linguistic repertoires in new and home languages. Similar to Student 7, Student 5 attempted to explain the same phenomenon in lines 61-63, 65-67. Student 5 described the motion of “*it*” as a circle, with prompting support from Student 6. She also described the motion of the water in the lamp as a function of thermal energy transfer: “*cuando el agua está caliente va para arriba o frío va para abajo.*” In lines 87-89 and 91-93, Student 6 accurately explained the action and cause of the convecting movement of the glitter within the lamp in which the “*Porque la cosita... la luz está abajo cuando toca la agua se hace caliente entonces la cosita se mueve...*” and “*Cuando está arriba se enfría porque está muy lejos de la cosita entonces se vuelven abajo luego arriba luego abajo.*” Student 6 identified the light source as the means for the heating the solution within the lamp and how the

“thing” (glitter) moves up when heated and back down when cooled - effectively explaining the mechanism for convection.

When Ms. B asked the class what this process was called in line 94, Student 8 responded in Spanish “*corrientes de convección*” in line 95. Note that Ms. B asked a question about vocabulary, “¿Cómo se llama?,” after students had attempted to provide several explanations to the phenomenon. Ms. B purposefully postponed asking about specific terms until students had formulated some sort of explanation articulating their initial thinking about the scientific phenomena. This specific prompting might have helped the teachers bridge students’ explanations to the scientific term *convection currents*, better supporting the development of academic language in both new and home language (Gibbons, 2015).

Through this process, the students were in the initial stages of moving from using language that is immediately tied to the environment to attempting the use of scientific discourse. For example, Student 6 tried to explain the phenomenon of convection currents using language that is typical of face-to-face interactions where the speaker can see what is being talked about, such as “*la luz está abajo,*” in lines 82-83 and “*Cuando está arriba se enfría porque está muy lejos de la cosita,*” in lines 91-92. Note also the frequent use of the more general term “*cosita*” (thing) and the absence of an explicit subject in omitting it in Spanish, “*Cuando está arriba se enfría,*” or in using “*it*” or “*they*” in our translation, in lines 91-92. It is not clear what is going up, getting cold, or being far. The teacher bridged their use of academic language by inserting the scientific term “*convection currents,*” when asking the question “*what’s it called?*” in line 94 and by restating the term in line 96. This cue was taken up by students. Students 5, 6, and 7 engaged in a key first step in developing a causal explanation in that conceptual understanding was demonstrated. Although Student 7’s response did not include the causal mechanism by which energy transfers from the lightbulb to the water molecules and how this results in glitter movement and Student 6’s response did not include the term thermal energy, Students 6’s and 7’s are developing ideas about the concept of convection, demonstrating an initial understanding of this scientific phenomenon.

It is evident from this interaction how much the use of home language allowed the students to interject, build on each other’s responses, and produce explanations that connect why scientific phenomena happen to comparing content-related concepts, demonstrating with step by step details. With the support of Ms. B’s translanguaging practices, the students were able to make connections between their explanations and the scientific concept of convection in Spanish.

To continue with the investigation of ways students were developing explanations on Day 8, we selected and highlighted student written responses to the question: *How is the movement of the Earth’s mantle like the movement of the glitter lamp?*, as it asked students to synthesize what they learned from Day 7’s experiment on density and Day 8’s glitter lamp observations to infer how the Earth’s mantle moved. Of the 15 papers collected, five responses to this question were left blank, one incorrectly stated that the two phenomenon were different, and nine accurately stated that the two phenomenon were similar and proceeded to describe similarities. Several students’ writing included identical responses and were grouped together below; students completed the handout in table groups and were encouraged to talk with one another during the lesson. Students 1, 2, 6, 8, and 12 mentioned the circular movement of hot and cold within the lamp and mantle, thus describing in their own words the concept of *convection* in Spanish. Note that students’ use of academic language in Spanish was also emerging, needing support for spelling and for successful employment of certain academic forms. Student 3 also described the concept of *convection* in their own words.

Students 1, 6, 8 (papers contained identical responses)	En una forma es case lo mismo por que forman un circulo y abajo es caliente y arriba es frío	It's a form it's almost (misspelled) the same because they form a circle and down it's hot and up it's cold
Student 10	Que es igual solo que una es en una lampara y la otra es en la capa de la tierra	That it is the except "that one" is in one lamp and the other is in the layer of the earth
Students 2, 12 (papers contained identical responses)	porque las cositas van para arriba y otras para abajo y igual en el video que el manto de la tierra se va pa arriba y abajo	Because the little things go (misspelled) up (misspelled) and the others go down the same as (misspelled) in the video that the mantle of the earth go up (misspelled) "up" and down
Student 3		In the lamp goes up and down in the earth goes side to side forming a circle.

Culminating Task: An Example of Students' Written Arguments

The culminating task (Task 4) asked students to pick one school that was likely to have earthquakes and write a letter to the school arguing the need for earthquake safety drills. Eight of the nine letters were written in Spanish which is consistent with the students' choice for using Spanish in their written work during the unit. One letter was written in English. Table 4 includes a summary of the findings from the analysis of the nine letters using the rubric criteria. Overall, we found a marked consistency between how students performed in oral and written work throughout the unit and the unit's final assessment (culminating task).

Table 4

Student Performance on Culminating Task

Criteria	Meets	Approaches	Does not meet
Claim	100%	0%	0%
Evidence	0%	89%	11%
Scientific Reasoning	0%	33%	67%
Scientific Vocabulary	22%	45%	33%
Scientific Discourse	0%	89%	11%

Claim and evidence. Eight letters generated claims regarding the need for particular schools to practice earthquake drills in Spanish, and one letter was able to do the same in English; thus, all letters

met expectations on the rubric for this category. For example, Letter 1 included the following statement: “*Nuestro grupo ah decido decirles que es necesario que tomen medidas de prevencion ante los terremotos (Our group has decided to tell you that it is necessary that you take preventative action against earthquakes).*” Letter 6 begins with the statement: “*Nuestro grupo hemos decidido escojer la escuela La Paz Technical academi El Salvador (Our team has decided to choose the school La Paz Technical academi El Salvador).*” These findings align with what we saw during class interaction throughout the unit. Students were able to successfully generate claims as early as Days 2 and 3.

Students then worked to support their claim by providing evidence connected to the school’s location and/or the mapping activity that they completed during Task 1. All letters were able to provide some type of evidence to support their claim in either English or Spanish. Although many letters were still reaching to provide sufficient evidence, all letters included at least one piece of evidence. For example, in letter 8, a student wrote: “*encontramos evidencias en el mapa que pueda que pasen terremotos por ese lugar (we found evidence on the map that earthquakes can happen for that place).*” This student referred to a map as evidence to support their claim. Letter 1 referred back to work done in class to support their claim: “*...en la zone de San Miguel hay peligro de que ayan terremotos la zona de San Miguel se encuentra en una zona donde estan las placas tectonicas y muchos puntos que probablemente sean terremotos. (...in the San Miguel area, there is danger of earthquakes the area of San Miguel is located in a zone where there are tectonic plates and a lot of points where there can probably be earthquakes).*”

In other cases, students included non-scientific evidence to support their claims. For example, in letter 9, a student wrote “*I have these evidence because in what I have learn these days.*” To be able to relate to the data identified during the map activity, students need further support. These findings are consistent with findings from classroom discourse. Although some students were reaching to provide sufficient and precise evidence, most students were able to make claims, especially when they tapped into their home language resources.

Scientific reasoning. The scientific reasoning aspect of the culminating task was the most complex in that students not only had to understand the content but also be able to fluently communicate this understanding with clear and cohesive scientific language. As such, students struggled the most with incorporating scientific reasoning into their letters. This happened independent of the choice of language used - Spanish or English. Based on our rubric, successful incorporation of scientific reasoning needed to include appropriately defining *convection* and using this concept to connect the students claim (i.e. whether a school should practice earthquake drills) with evidence (e.g., location near earthquake dots on map activity). Letter 7 exemplifies students’ still emerging understanding of convection as a process in Spanish. In this letter, students wrote, “*un terremoto ocurre cuando el material se calienta sube y se conjela se buelbe a desconjelar y de todo eso se ase un ejercicio que se llama conveccion (an earthquake occurs when the material heats up rise and freeze goes back to unfreezing and all of that becomes an exercise which is called convection).*” Students correctly identified convection as a process that involves heating and cooling. Their understanding of convection is emerging because they are conflating this idea with freezing and unfreezing. Further, this understanding of convection is not linked with plate movement.

In another example, Letter 2, students wrote in Spanish:

- 1 *Los terremotos pasan porque el Earthquakes happen because the mantle*
- 2 *manto se calienta mucho y la corteza gets very hot and the crust is very cold that*
- 3 *es fria eso cuasa el movimiento de las causes the movement of the plates this*

4 *placas esta movimiento se llama* movement is called convection when two
 5 *conveccion cuando dos convergentes* convergent plates (“convergentes”) crash
 6 *se chocan forman montanas porque* against each other they form mountains
 7 *van a la misma direccion* because they move in the same direction

Students in this example were close to meeting expectations as they provided an explanation of how convection occurs (lines 1-4, Spanish and English translation) than those in Letter 7. They were able to situate convection within the Earth’s mantle and provide a more accurate description of hot or cold parts of Earth that lead to convection. However, the cyclical process of a convection current was still missing. In all, these findings are consistent with findings from classroom discourse during the Day 7 water investigation. Although students were reaching to provide precise explanations of convection and its role in the Earth’s mantle, most students were able to begin articulating their ideas about convection, especially when they tapped into their experience conducting the hot and cold water investigation using their home language as a resource.

Scientific vocabulary. In all letters, students could use terminology that was discussed during the unit with the aid of prompts as well as the scaffolds provided through sentence frames. Most letters were able to include and apply some scientific terms, such as *tectonic plates* and *earthquakes*, particularly in Spanish. For example, in Letter 3, students wrote: “*hay muchas posibilidades de terremotos en esa zona por la conveccion y movimiento constante do las placas tectonicas (there are many possibilities of earthquakes in that zone due to the convection and constant movement of the tectonic plates).*” At the same time, students’ use of other terms demonstrated the need for further support. For example, the use of *convergent* as a noun instead of an adjective might sound ambiguous or imprecise in student letter 2 “*cuando dos convergentes se chocan forman montañas porque van a la misma direccion (when two convergents (sic) crash against each other they form mountains because they move in the same direction).*” This initial attempt at using academic vocabulary demonstrates an emerging understanding of convergent boundaries.

Scientific discourse. With respect to scientific discourse, or the ability to “produce clear and coherent writing in which the development, organization and style are appropriate to task, purpose and audience” (New York State Department of Education, 2014, n.p.), the writing in the letters highlight how students worked to organize logical arguments that could be followed by an outside reader, and included several elements characteristic of letter writing. For example, in most letters, students could successfully include a salutation in Spanish (letter 4 “*Queridos estudiantes (Dear students)*”) and/or closing remark (letter 5, “*Sinceramente con mucho carino (Sincerely with much affection)*”), indicating students’ understanding of key aspects of writing a letter. It is interesting to note that all students chose to address a school in a Spanish-speaking country - in El Salvador or Chile. Some went so far as to tap into personal feelings to persuade their readers (letter 1 “*Yo pienso que tienen que tener alarmas de prevencion porque me preocupa que pueda pasarles algo les digo esto con mucho carino y atentamente. (I think that there needs to be prevention alarms because it worries me that something can happen to you. I tell you this with a lot of love and consideration).*”) The use of persuasive language in Spanish seemed to indicate students’ personal investment in the purpose of the task by using expressions such as “*me preocupa (I’m worried)*” and “*les digo esto con mucho carino (I tell you this with a lot of love).*” Without prompting, students were able to tap into their prior knowledge, experiences, and linguistic repertoires to address their readers.

With respect to related scientific understandings, most writing contained in the letters relied on the immediate environment, presenting some typical features of conversational discourse. This feature illustrates that students' skills were still emerging concerning academic writing for a more formal or outside audience. For instance, letter 1 included, "*San Miguel se encuentra en una zona donde están las placas tectónicas y muchos puntos que probablemente sean terremotos (San Miguel is located in a zone where there are tectonic plates and a lot of points where there can probably be earthquakes).*" The points the student refers to would likely only be understood by someone who was physically present in the classroom for the activity that included the actual map. As students' academic writing skills are still emerging, there is an ongoing need to support them to communicate their ideas such that an audience unfamiliar with the specific activities they engaged in would be able to understand all aspects of the students' arguments. On the other hand, their prior knowledge of the genre of letter writing in Spanish can be used and maximized as leverage. This shows how academic language and writing is a complex skill that needs to be developed in both home and new language.

Discussion

Our analysis revealed what emergent bilingual students could do with respect to their developing language and scientific understandings (Lee & Llosa, 2015). Findings demonstrated that, given the opportunity and adequate supports, students successfully engaged in initial attempts at practicing scientific argumentation and explanation. As emergent bilinguals, students tapped into their existing language resources as well as prior knowledge and experiences (García, Johnson, & Seltzer, 2017). Similar to Poza (2016), the students in our study used both new language (English) and their home language (Spanish) to make sense of their science learning. Our analysis revealed a marked consistency of initial attempts to engage in argumentation and explanation across the oral and written tasks. What students discussed during classroom interaction appeared consistently in their writings, especially in constructing claims throughout the unit and on the culminating task. Further, most students were able to provide some type of evidence to support their claim. These findings align to what Gibbons (2015) suggests concerning the need to develop students' oral language before engaging them in academic writing.

Moreover, this study also made visible what emergent bilinguals could do in light of the language-intensive practices of argumentation and explanation so inherent within the NGSS. In particular, the analysis of emergent bilinguals' oral and written discourse revealed the crucial interplay of students' home and new language use. Engagement in translanguaging practices, where all participants, including teachers and students, could tap into all of their linguistic repertoires seemed to have yielded the best contexts for the development of scientific arguments and explanations.

Concerning emergent bilinguals' oral discourse, the intentional use of home language allowed emergent bilinguals to produce more extended arguments and explanations. Especially when teachers purposefully leveraged all linguistic resources students brought by communicating with them in both new and home language, students' responses became more sophisticated, using more scientific language to argue for and explain scientific phenomena. This became even more evident on Day 8 when students built on each other's responses. There was a marked change among the two discussions on Day 7 and the discussion on Day 8. In contrast to the first discussion on Day 7, when students mostly used English to try to make sense and explain scientific phenomena, the second discussion in Spanish on Day 7 and the discussion on Day 8 promoted more extended explanations as students were able to tap into all their

linguistic repertoires. This happened with the intentional help of the teachers who also used Spanish and English purposefully during instruction on those two days.

Concerning emergent bilinguals' written discourse, most students' letters included a claim, some evidence, and features of scientific academic discourse. In addition, because students were able to tap into all their linguistic resources, they were also able to tap into their prior knowledge and experiences. This is visible through the writing in the culminating letters, where students used their knowledge of letter writing to construct compelling arguments about the need for earthquake drills. Although students were still developing to provide sufficient evidence and incorporate scientific reasoning in their letters, most were able to articulate initial understanding of convection in writing. The fact that students struggled the most with reasoning is not surprising as the ability to determine two or more central ideas and trace their development is achieved at the advanced levels of academic language proficiency (Wida Consortium 2004). Students' academic writing skills were still emerging with respect to including features of scientific academic discourse, such as the use of specific terms and syntax to refer to classroom events and experiments to an outside audience. This finding demonstrates that there is a pressing need to support emergent bilinguals in communicating their arguments and explanations to an academic audience. Even though most letters presented typical features of everyday conversations, and since this was students' first attempt at writing a scientific argument, we celebrate and acknowledge their ability to substantiate their claims with examples and evidence from classroom experiments and activities.

Above all, the simultaneous use of students' home and new language throughout the unit provided a window into student thinking. Content and language went hand in hand: without the use of home language, it would have been difficult to know what students were thinking at the time. By having access to students' thinking, teachers were able to build on their responses and bridge the use of academic language for scientific sense making. An example of this happened on Day 8 when Dr. A and Ms. B helped students to explain scientific phenomena connecting the movement of hot and cold water to the concept of convection currents.

Similar to findings and recommendations in Stevenson (2013), teachers must value emergent bilingual students' successes by acknowledging and celebrating emerging skills, building on the rich linguistic and experiential resources students bring in both in home and new language in order to optimize participation and facilitate understanding. These emerging skills and first attempts at using academic language should not be treated as wrong or simply disregarded. They should be considered part of the typical process of language development. Regardless of what language students are learning in, home or new language, use of academic language is a complex skill for most students to develop (Mercer, Dawes, Wegerif & Sams, 2004). The scientific NGSS practices of argumentation and explanation are language intense (Lee et al., 2013). Not acknowledging the demands of these practices or setting expectations misaligned to students' emergent language abilities can set them and their teachers up for failure. As the NGSS require that middle school students construct arguments and explanations of real-world phenomena, we recommend that science teachers start by encouraging emergent bilinguals to tap into their prior knowledge and use all their linguistic repertoires to observe and describe scientific phenomena. In doing so, teachers and students can challenge common assumptions, inquiring and finding scientific evidence to substantiate claims and explanations.

Conclusion

This study represented collaboration between researchers in science education and language acquisition and embodied our collective belief that all students have the right to rigorous and engaging science education. We saw our project as aligned to calls for further examination of students' language use during science learning (National Science Teachers Association, 2009). Communicating one's understandings about science concepts and the scientific endeavor, especially in written form, is a complex process that takes time to learn. Science teachers must become comfortable with recognizing and capitalizing upon emergent bilingual students' existing linguistic resources. By using only emergent bilingual students' new language, teachers can limit their ability to communicate at all. Moreover, one loses the capacity to accurately assess and monitor and further develop student thinking. We therefore recommend the development of realistic checkpoints and benchmarks that not only identify what emergent bilingual students are able to do, but also help them progress in their skills with argumentation and explanation as advocated by the NGSS.

References

- August, D., & Shanahan, T., eds. (2006). *Developing literacy in second-language learners: Report of the National Literacy Panel on Language-Minority Children and Youth*. Mahwah, NJ: Lawrence Erlbaum.
- Berland, L., & McNeill, K. (2011). For whom is argument and explanation a necessary distinction? A response to Osborne and Patterson. *Science Education*, 96(5), 808-813.
- Berland, L., & Reiser, B. (2009). Making sense of argumentation and explanation. *Science Education*, 93(1), 26-55.
- Block, D. (2003). *The social turn in second language acquisition*. Washington, DC: Georgetown University Press.
- Bloome, D., Carter, S.P., Christian, B.M., Otto, S., & Shuart-Faris, N. (2004). *Discourse analysis and the study of classroom language and literacy events: A microethnographic perspective*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Brown, B.A., & Ryoo, K. (2008). Teaching science as a language: A "content-first" approach to science teaching. *Journal of Research in Science Teaching*, 45(5), 529-553.
- Bybee, R. (2011). Scientific and engineering practices in K-12 classrooms. *The Science Teacher*, 78(9), 34-39.
- Canagarajah, S. (2013). *Translingual Practice: Global Englishes and Cosmopolitan Relations*. London: Routledge.
- Castro, M. (2015). How can teachers use English and Spanish language development standards to scaffold and support English language learners/emergent bilinguals in content and language development classes? In G. Valdés, K. Menken, & M. Castro (Eds.), *Common core bilingual and English language learners: a resource for educators* (pp. 196-203). Philadelphia, PA: Caslon.
- Ciechanowski, K.M. (2014). Weaving together science and English: An interconnected model of language development for emergent bilinguals. *Bilingual Research Journal*, 37(3), 237-262. DOI: 10.1080/15235882.2014.963737
- Cummins, J. (2005). A proposal for action: Strategies for recognizing heritage language competence as a learning resource within the mainstream classroom. *The Modern Language Journal*, 89, 585-592.
- Duran, B.J., Dugan, T. and Weffer, R. (1998). Language minority students in high school: The role of language in learning biology concepts. *Science Education*, 82, 311-341.

- Fradd, S.H. & Lee, O. (1999). Teachers' roles in promoting science inquiry with students from diverse language backgrounds. *Educational Researcher*, 28(6), 14-20.
- García, O. (2015). How should we refer to students who are acquiring English as an additional language? In G. Valdés, K. Menken, & M. Castro (Eds.), *Common core bilingual and English language learners: a resource for educators* (pp. 23-24). Philadelphia, PA: Caslon.
- García, O., Johnson, S. I., & Seltzer, K. (2017). *The translanguaging classroom: Leveraging student bilingualism for learning*. Philadelphia, PA: Caslon.
- García, O., Sylvan, C. E., & Witt, D. (2011). Pedagogies and practices in multilingual classrooms: Singularities in pluralities, *The Modern Language Journal*, 95(3), 385-400.
- Gee, J. P. (2008). What is academic language? In A.S. Rosebery & B. Warren (Eds.), *Teaching science to English language learners: Building on strengths* (pp. 57-70). Arlington, VA: NSTA Press.
- Gibbons, P. (2015). *Scaffolding language scaffolding learning* (2nd ed.). Portsmouth, NH: Heinemann Press.
- González-Howard, M. & McNeill, K.L. (2016). Learning in a community of practice: factors impacting English-learning students' engagement in scientific argumentation. *Journal of Research in Science Teaching* 53(4), 527-553. doi: 10.1002/tea.21310
- Green, J. L., & Wallat, C. (1981). Mapping instructional conversations: a sociolinguistic ethnography. In J. L. Green & C. Wallat (Eds.), *Ethnography and language in educational settings* (pp. 161-205). Norwood, NJ: Ablex.
- Halliday, M.A.K. (1994). *An introduction to functional grammar* (2nd ed.). UK: Edward Arnold.
- Halliday, M.A.K. & Matthiessen, C. (2004). *An introduction to functional grammar* (3rd ed.). UK: Edward Arnold.
- Halliday, M.A.K., & Martin, J. (1993). *Writing science: literacy and discursive power*. Pittsburgh, PA: University of Pittsburgh Press.
- Hogan, K., & Maglienti, M. (2001) Comparing the epistemological underpinnings of students' and scientists' reasoning about conclusions. *Journal of Research in Science Teaching*, 38(6), 633-687.
- It's About Time (2004). *Integrated coordinated science for the 21st century*. Armonk, NY: Author.
- Lee, O. (2003). Equity for linguistically and culturally diverse students in science education: a research agenda. *Teachers College Record*, 105, 465-489.
- Lee, O. (2005). Science education with English language learners: synthesis and research agenda. *Review of Educational Research*, 75, 491-530.
- Lee, O. & Llosa, L. (2015). What are the language demands for science in the Next Generation Science Standards? How do they relate to the literacy standards for science in the Common Core State Standards? In G. Valdés, K. Menken, & M. Castro (Eds.), *Common core, bilingual and English language learners: a resource for educators* (pp. 164-165). Philadelphia, PA: Caslon.
- Lee, O., Miller, E., & Januszyk, R. (2015). *NGSS for all students*. Arlington, VA: NSTA Press.
- Lee, O., Quinn, H., & Valdés, G. (2012). *Language Demands and Opportunities in Relation to Next Generation Science Standards for English Language Learners: What Teachers Need to Know*. Understanding Language Stanford University. Retrieved from <http://ell.stanford.edu/sites/default/files/pdf/academic-papers/03-Quinn%20Lee%20Valdes%20Language%20and%20Opportunities%20in%20Science%20FINAL.pdf>
- Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to next generation science standards and with implications for common core state standards for English language arts and mathematics. *Educational Researcher*, 42(4), 223-233.

- McNeill, K., & Krajeck, J. (2008). Assessing middle school students' content knowledge and reasoning through written scientific explanations. In J. Coffey, Douglas, R., & C. Stearns (Eds.), *Assessing science learning: Perspectives from research and practice* (pp. 101-116). Arlington, VA: NSTA Press.
- Members of the NGSS Diversity and Equity Team (2015). English language learners and the Next Generation Science Standards. In O. Lee, E. Miller, & R. Januszyk (Eds.), *NGSS for all students* (pp. 101-117). Arlington, VA: NSTA Press.
- Mercer, N. Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: ways of helping children to use language to learn science. *British Educational Research Journal*, 30(3), 359-377.
- Moore, E., Evnitskaya, N., & Ramos-de Robles, S.L. (2017). Teaching and learning science in linguistically diverse classrooms. *Cultural Studies of Science Education*. DOI 10.1007/s11422-016-9783-z
- National Research Council. (2000). *Inquiry and the national science education standards*. Washington, DC: National Academy Press.
- National Science Teachers Association. (2009). *NSTA position statement: Science for English language learners*. Retrieved from: <http://www.nsta.org/about/positions/ell.aspx>
- NGSS Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.
- New York State Department of Education. (2014). *NYS bilingual common core language arts progressions*. Accessed from <https://www.engageny.org/resource/new-york-state-bilingual-common-core-initiative>
- Osborne, J., & Patterson, A. (2011). Scientific argument and explanation: a necessary distinction? *Science Education*, 95(4), 627 – 638.
- Poza, L.E. (2016). The language of ciencia: translanguaging and learning in a bilingual science classroom, *International Journal of Bilingual Education and Bilingualism*, DOI: 10.1080/13670050.2015.1125849
- Quinn, H. (2015). Science and engineering practices for equity: creating opportunities for diverse students to learn science and develop foundational capacities. In O. Lee, E. Miller, & R. Januszyk (Eds.), *NGSS for all students* (pp. 7-19). Arlington, VA: NSTA Press.
- Saldaña, J. (2009). *The coding manual for qualitative researchers*. London: SAGE Publications.
- Schweingruber, H., Keller, T., & Quinn, H. (Eds.). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.
- Shin, S. J. (2013). *Bilingualism in schools and in society: Language, identity, and policy*. London: Routledge.
- Spradley, J. P. (1980). *Participant observation*. Belmont, CA: Wadsworth.
- Slavin, R. & Cheung, A. (2005). A synthesis of research on language of reading instruction for English language learners. *Review of Educational Research*, 75, 247-281.
- Stevenson, A.R. (2013). How fifth grade Latino/a bilingual students use their linguistic resources in the classroom and laboratory during science instruction. *Cultural Studies of Science Education*, 8, 973–989.
- Swanson, L., Bianchini, J., & Lee, J.S. (2014). Engaging in Argument from Evidence: A Case Study of English Language Learners and Their Science Teacher in an Urban High School. *Journal of Research in Science Teaching*, 51(1), 31-64. DOI 10.1002/tea.21124
- Swanson, L., Kang, E., & Vaz Bauler, C. (2016). Making science real: Supporting English learners in argumentation and explanation through authentic tasks. *Science Scope*, 39(8), 27-34. Washington, DC: National Science Teachers Association Press.

- Tolbert, S., Stoddart, T., Lyon, E., & Solis, J. (2014). The next generation science standards, common core state standards, and English learners: using the STELLA framework to prepare secondary science teachers. *Issues in Teacher Education*, 23(1), 65-90.
- Unsal, Z., Jakobson, B., Molander, B.O., & Wickman, P.O. (2016). Science education in a bilingual class: problematising a translational practice. *Cultural Studies of Science Education*. doi:10.1007/s11422-016-9747-3.
- Valdes, G. (2001). *Learning and not learning English: Latino students in American schools*. New York: Teachers College Press.
- Valdés, G. Menken, K., & Castro, M. (Eds.). (2015). *Common core bilingual and English language learners: A resource for educators*. Philadelphia, PA: Caslon.
- Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A.S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: the logic of everyday sense-making. *Journal of Research in Science Teaching*, 38(5): 529-552.
- Wida Consortium. (2004). WIDA English language proficiency standards. *Madison, WI: State of Wisconsin*.
- Zhang, Y. (2016), Multimodal teacher input and science learning in a middle school sheltered classroom. *Journal of Research in Science Teaching*, 53, 7–30.

Appendix A

Rubric for Plate Tectonics Culminating Task

Criteria	Meets (2)	Approaches (1)	Does not meet (0)
Claim (<i>Identify which school needs to practice earthquake safety drills</i>)	makes an accurate and complete claim	makes an accurate but incomplete claim	does not make a claim or makes an inaccurate claim
Evidence (<i>Present data that supports the claim, this includes map data</i>)	provides appropriate and sufficient to support claim.	provides appropriate but insufficient evidence to support claim. may include some inappropriate evidence.	does not provide evidence, or only provides inappropriate evidence (i.e. evidence that does not support claim)
Scientific Reasoning (<i>Justify why evidence connects to claim - this includes description of what causes earthquakes highlighting process of convection</i>)	provides reasoning that completely links evidence to claim. includes appropriate and sufficient scientific principles	attempts to provide reasoning that links the claim and evidence. Reasoning is scientific in nature; however it is incomplete in that the reasoning does not fully link claims to evidence or does not incorporate	does not provide reasoning, provides faulty reasoning (illogical), or provides reasoning that is not scientific in nature

		sufficient principles	scientific
Scientific Vocabulary (e.g., <i>Tectonic plates, plate boundaries, convection, divergent, convergent</i>)	uses precise scientific terms accurately and unambiguously	attempts to use some scientific terms, but they are used ambiguously or inaccurately	does not attempt to use any scientific terms
Scientific Discourse (Bilingual Common Core Anchor Standard W.4: Produce clear and coherent writing in which the development, organization and style are appropriate to task, purpose and audience.)	text does not rely on the immediate environment, providing an orientation to the reader through use of scientific discourse and accurate punctuation.	text sometimes relies on the immediate environment, presenting some typical features of conversational discourse; however, there is still some orientation to the reader	text completely relies on the immediate environment, presenting many typical features of conversational discourse and thus providing little or no orientation to the reader; inaccuracies in punctuation interfere with meaning.

Note: Verbiage for the first three components (claim, evidence, scientific reasoning) taken from rubric originally described in McNeil & Krajcik, 2008.