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Engaging in Argument and Communicating Information: A Case Study of English Language Learners and Their Science Teacher in an Urban High School

Abstract

This study documents how an urban high school science teacher engaged her English Language Learners (ELLs) in the discourse-intensive science and engineering practices of (1) arguing from evidence and (2) obtaining, evaluating, and communicating information. The teacher taught an introductory integrated science course to classes with a large percentage (44%) of students who spoke Spanish as their first language. We investigated the instructional strategies this teacher used to support her ELLs in the practices of argumentation and communication, and the ways ELLs constructed and communicated claims, evidence, and reasons in whole class and small group settings as a result. From qualitative analyses of teacher interviews, classroom interactions, and student products, we found that the teacher routinely implemented three types of instructional supports to help ELL students argue from evidence and communicate information: primary language support (although she herself was not fluent in Spanish), deliberate scaffolds, and small group instruction. Further, given these multiple opportunities for engagement, we found that ELLs experienced both successes and challenges participating in class, crafting arguments from evidence, and reading and producing written texts: While ELL students 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, our findings emphasize the need to more closely attend to the teaching and learning of discourse in science. We end with ways to strengthen both research on and teaching of science for ELLs.

Keywords: English Language Learners, argumentation, urban education, equity, high school

Introduction

In the United States, the number of K-12 students who speak a language other than English at home has dramatically increased over the past 30 years (Aud et al., 2010). In California, where this study was conducted, almost 1.5 million students (roughly 24% of the student population) attending public schools in 2009 were designated as English Language Learners (ELLs). Unfortunately, a gap in science learning persists between ELLs and their English-proficient peers at both the national (National Center for Education Statistics, 2009) and state (California Department of Education, 2011) levels.

In the midst of these changing K-12 student demographics, the vision for the scope, purpose, and substance of an exemplary science education has changed as well: Discourse is now central (Achieve, Inc., 2013; National Research Council [NRC], 2007, 2012). Four of the eight science and engineering practices described in *A Framework for K-12 Science Education* (NRC, 2012) can be considered discourse-intensive (Quinn, Lee, & Valdés, 2012): developing and using models; constructing explanations (for science) and designing solutions (for engineering); engaging in argument from evidence; and obtaining, evaluating, and communicating information. For example, in the practice of arguing from evidence, students learn that "what counts [in science] as evidence is data and observations. Hence argumentation in science is not a purely verbal exercise. It is an exercise in the coordination of language and experience and thus another rich language learning opportunity" (pp. 4-5). For ELLs trying to master both the English language and the specialized language of science in English, engaging in discourse-intensive science practices like arguing from evidence is a challenging yet crucial task.

Our study lies at the intersection of these two pressing needs: to better understand how teachers and their ELL students productively engage in discourse-intensive science practices. We investigated one urban high school science teacher, Ms. H, and her ELL students' efforts to construct arguments from evidence and to communicate these arguments to others. Our research questions examine both the opportunities for learning these practices and the students' take up of such opportunities. We asked: (1) How did Ms. H engage and support ELLs in the discourse-intensive science practices of argumentation and communication? (2) Given these opportunities for learning, how did ELLs construct and communicate arguments from evidence across instructional contexts?

Literature Review: ELLs' Engagement in Discourse-Intensive Science Practices

We reviewed existing studies conducted in similar contexts: urban classrooms. Specifically, we examined research that investigated ELLs and their teachers' talk and actions to better understand how ELLs develop and communicate science understandings. We first identified studies that investigated ELLs' use of both their home, or primary, language and the English language. At the elementary school level, Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001) described how ELL students successfully used their home languages and everyday experiences as resources to construct explanations of natural phenomena. At the middle school level, Moje, Collazo, Carrillo, and Marx (2001) documented how multiple discourses can conflict with one another in the science classroom across oral and written modes of representation, and argued for the construction of a hybrid space where such discourses could be productively integrated. Spanning middle and high school levels, Rosebery, Warren, and Conant (1992) examined how participation in collaborative science inquiry shaped ELL students' conceptual knowledge and use of hypotheses, experiments, and explanations to organize their reasoning. These researchers used ELLs' primary language of Haitian Creole to assess their understanding. Taken together, this body of work highlights the importance of affording ELL students the opportunity to use their primary language during science instruction.

We then reviewed research that described ELL students' successes and challenges in learning discourse-intensive, sense-making practices. For example, Buxton and Lee (2010) found that 3rd and 4th grade students, including ELLs, engaged more readily in lower levels of scientific reasoning (amount and types of assertions, and supporting details) than in higher levels (how well ideas are warranted with evidence and inference, and how underlying causal mechanisms are used to explain assertions). Varelas et al. (2008) carefully documented how 1st through 3rd grade students, again, including ELLs, started from "ambiguous" objects (objects where the feature structures are unspecified and many potential relationships exist) to participate in four types of reasoning about states of matter and to generate scientific arguments as a result. Varelas and colleagues included in their examination instances where members of small groups failed to reach consensus on the classification of an everyday object.

With this present study, we extend research focused on ELLs' successes and challenges in learning discourse-intensive science practices in urban classrooms in three ways. First, with few exceptions (e.g., Rosebery et al., 1992), much of the work on ELL students learning science is situated at the elementary or middle school level. We contend that extending this research to include the high school level is important, as the science ideas explored and the expectations for arguments generated are more complex than in elementary or middle school. Second, our study is influenced by the work described above indicating the importance of allowing ELL students to use their primary language when constructing science understandings. Because the teacher we investigated validated her students' use of Spanish, we examined how she and her students used both Spanish and English as they constructed and communicated arguments from evidence. Finally, our study explores mis/matches among participation patterns and modes of discourse ELL students employ to craft and communicate their understanding. Moje et al. (2001) examined both students' oral discourse and their written products, but did not compare the kinds or substance of ideas generated across them. Varelas et al. (2008) noted instances where oral arguments made during small group discussions matched information written on individual datasheets. However, researchers neither examined such mis/matches between group discussions and writing through the lens of language nor considered their potential to inform recommendations for instruction. In a third study, Pappas, Varelas, Ciesla, and Tucker-Raymond (2009) analyzed urban elementary students' scientific writing, but did not examine connections between such texts and classroom conversations. Our study differs in that we investigated dis/connects between ELLs' whole class and small group discussions, as well as their oral conversations and written products. In short, the purpose of our study is two-fold: to better understand how high school ELLs engage in discourse-intensive science practices and to identify ways teachers can effectively support their students in doing so.

Conceptual Framework: The Centrality of Language

We examined ELL students and their teacher's talk and actions using a sociocultural lens (Vygotsky, 1978). Sociocultural theory foregrounds the interdependence of collective and individual processes in learning and teaching. Students are understood to learn science through shared talk and co-participation in activities (Driver, Asoko, Leach, Mortimer, & Scott, 1994). They are scaffolded in the co-construction of more complex scientific ideas by their teacher and/or more able others (Brown, 1994). A sociocultural perspective also emphasizes the importance of learning environments that expand the agency and understanding of both students and teachers. Further, sociocultural theory makes visible the centrality of language in the teaching and learning process. Below, we discuss the importance of language in both the learning of science, in general, and the instruction of ELLs in science, in particular.

Language in Science

Learning science involves learning the language unique to science disciplines and how to use that language to express ideas and build understanding (Brown, Collins, & Duguid, 1989; Lemke, 1990). The view that language is central to learning science emerges from studies of scientists as communities: Scientists interact with one another in particular ways using specific oral and written discourse styles (Bazerman, 1988; Latour & Woolgar, 1979; Yore, Florence, Pearson, & Weaver, 2006). This understanding of language as central to science learning is also found in descriptions of current reform-based science practices (Achieve, Inc., 2013; NRC, 2012). The new standards in science explicitly call for the development of language and literacy in and through engagement in disciplinary core concepts, texts, and practices (Bunch, 2013).

As stated in the introduction, we focused our investigation on two of four discourse-intensive science and engineering practices (Quinn et al., 2012): argumentation and communication. *A Framework for K-12 Science Education* (NRC, 2012) defines scientific argumentation as "a process of reasoning that requires a scientist [or a science student] to make a justified claim about the world" (p. 71). An argument consists of a claim, data, and reasons (see Toulmin, 1958, for the origins of this definition). An argument's first component, a claim to knowledge, is a tentative statement about how the world works. An argument's second component is data, or evidence, including observations, measurements, or findings from previous studies. Reasoning, the third component, includes "statements that explain *how* the evidence supports the claim and *why* the evidence should count as support for the claim" (Sampson & Blanchard, 2012, p. 1124, italics in the original). Through the writing and revising of arguments, scientists further refine and strengthen their understandings (Yore et al., 2006).

A Framework for K-12 Science Education (NRC, 2012) identifies obtaining, evaluating, and communicating information as another practice central to science and engineering. Like scientists, students should engage in "the communication of ideas and the results of inquiry—orally, in writing, with the use of tables, diagrams, graphs, and equations, and by engaging in extended discussions with scientific peers" (p. 53). They should also read different types of science texts and critically evaluate the information provided. Quinn, Lee, and Valdés (2012) described how this discourse-intensive practice intersects with language learning: Obtaining, evaluating, and communicating information, "more than any other [practice], points to reading and writing as well as to listening and speaking. . . . The point of this work [oral presentations and written reports] is science understanding and science communication" (p. 5). Students and teachers should focus on making sense of the science ideas communicated, they emphasized, rather than on correcting the mechanics of the oral or written language produced.

Instructing ELLs in the Language of Science

The practices of engaging in argument and obtaining, evaluating, and communicating information require understanding both the nature of the activity itself and the complexity that is inherent in spoken and written language. The language of science differs from conversational English in multiple ways: It has different discipline-specific vocabulary, grammar, language functions and related discourse structures, and text types (Cummins, 2000). For example, the language of science not only contains a vast number of discipline-specific vocabulary terms (e.g., sub-atomic particle), it uses such terms frequently. Martin (1993) argued that the use of discipline-specific vocabulary facilitates the organization of scientific information. He elaborated: "It is easier to refer to mixtures than to substances that can be easily separated without making any new chemicals" (p. 172). As a second example, while the lexical density (a measure of the density of information determined by counting the number of lexical items, or content words, per clause) of everyday talk is about two, the lexical density of science textbooks averages around five (Schleppegrell, 2001), and of scientific articles, between 10 and 13 (Halliday, 1993). As a third example, scientific writing is replete with nominalized forms of expression where extended explanations are condensed into complex noun phrases (Halliday, 1993; Schleppegrell, 2001). As a final example, the authoritative language found in science textbooks is quite different than the language(s) used in everyday contexts: Authoritativeness is conveyed through the use of science-specific vocabulary, declarative sentences, and passive voice (Fang, 2005; Schleppegrell, 2001, 2004). Some science textbooks do integrate language that is more informal and interactive in nature. However, if these informal linguistic features are not explicitly contrasted with the authoritativeness of science, textbooks can both poorly model scientific discourse and decrease the likelihood that readers will comprehend their contents.

Students, particularly ELLs, find it difficult to master science discourse because it requires understanding and having fluency in both the forms of the language (its phonemic, morphemic, syntactic, and semantic components) and the functions that that language can perform (what the language of science can do) (Dutro & Moran, 2003). Halliday (1993) identified multiple characteristics of science writing that can pose difficulties for learners: These include lexical density, syntactic ambiguity, and grammatical metaphor (the latter two are related to nominalization discussed above), as well as interlocking definitions, technical taxonomies, special expressions, and semantic discontinuity (p. 71). "[These characteristics] evolved to meet the needs of scientific method, and of scientific argument and theory. They suit the expert; and by the same token they cause difficulty to the novice" (p. 84). Students need to understand the many linguistic features specific to science writing, Schleppegrell (2001) added, if they are to read science textbooks and to write coherent scientific arguments.

As such, science teachers must move away from viewing the teaching of academic language in science as a discrete curricular target or as simply the means to communicate the content one has learned (Bunch, 2013). In the former instance, Bruna, Vann, and Escudero (2007) found that a teacher's understanding of academic language development as vocabulary led to watered-down science discourse in an ELL classroom. Halliday (1993) asserted that a teacher's focus on vocabulary alone will not assist students in learning to understand and use the language of science: "Vocabulary is much more obvious, and easier to talk about, than grammar . . . . [However,] the problems with technical terminology usually arise not from the technical terms themselves but from the complex relationships they have with one another" (p. 71). Further, Rowe (1974), and more recently, Michaels, Shouse, and Schweingruber (2008) encouraged science teachers to more closely attend to the language of science by replacing the rapid-fire exchange of questions and answers with conversations about natural phenomena – where students share their own ideas, respond to others, and collectively engage in scientific reasoning. In sum, rather than equate vocabulary with academic language, science instruction must present language as a mediator of the teaching and learning process. Teachers must encourage and support students' development of sense-making talk across both everyday and scientific languages, their construction of arguments grounded in evidence, and their ability to effectively communicate their understanding of science concepts and practices orally and in writing.

Research Design and Methods

Our study was conducted at Orchard, an urban high school in southern California. In 2009-2010, the year of this study, Orchard's students represented three main ethnic groups: Latino/a (87%), European American (6%), and African American (4%). Over 80% of students qualified for free or reduced lunch. Approximately 33% were designated ELLs; Spanish was the most common primary language spoken other than English.

All content courses at Orchard High School followed block scheduling: Students attended one 30-minute advisory period at the beginning of the day followed by four 80-minute periods. With this schedule, students completed an entire course in one semester. Block scheduling was implemented so that students took eight courses during the academic year, two more than if the school followed a traditional schedule. Ms. H preferred the longer periods because students had more time to engage in sustained investigations and conversations about science concepts. Ms. H noted that students had the opportunity to share their initial understandings of data collected during an investigation before the period ended. However, she cautioned that the total number of instructional minutes for a given course was reduced (compared to a traditional schedule).

Integrated Coordinated Science

During the 2009-2010 academic year, all freshmen at Orchard enrolled in a 20-week Integrated Coordinated Science (ICS) course. ICS served as an introduction to high school science. It consisted of four units, spanning selected topics in earth science, physics, chemistry, and biology. Each unit lasted approximately five weeks. Further, since all freshmen were enrolled in ICS, the course did not contribute to student tracking into or out of science. After completing ICS, students took at least two additional science courses.

The ICS textbook (Smith et al., 2004) was based on the *National Science Education Standards* (NRC, 1996) and developed with support from the National Science Foundation. The text emphasizes the teaching of science as inquiry. Ms. H also used an ICS instructional guide developed by her school district. This guide describes the main concepts covered by the curriculum; provides a list of state science standards; offers suggestions for activities in the textbook and additional sources; and outlines district policies, programs, and instructional goals. Ms. H helped develop this guide and facilitated ICS district-sponsored trainings.

Both the textbook and guide view argumentation and communication as central to the discipline of science and therefore necessary components of science instruction. Students are expected to "reason" as scientists do and to "think like scientists." The textbook activities include questions that ask students to support their ideas with evidence collected during their investigations. The textbook's introduction suggests that the activities will assist students in learning how science works. The guide recommends use of additional "immersion units" that allow students to investigate a phenomenon, gather data, confront conflicting evidence, and draw conclusions. Elsewhere, the guide describes "accountable talk" whereby students justify their ideas using evidence. However, such information, suggestions, and questions are limited in providing guidance to classroom teachers, who must determine exactly how to scaffold such practices in their own local instructional contexts, in particular, as they work with ELLs.

The Physics and Chemistry units of the ICS curriculum were selected for investigation. They occurred mid-course and fell under the umbrella of the physical sciences. With the teacher's assistance, we then identified one lesson sequence within each of these two large units (sound waves from Physics and atomic structure from Chemistry) for data collection. The two selected lesson sequences met five criteria. (1) Each spanned approximately one week and thus represented a large portion of a given unit's activities. (2) Each focused on student use of argumentation and communication. (3) Each contained a definitive "beginning" (where ideas were introduced and students' prior understandings were elicited), "middle" (where students deepened their understandings of core ideas through investigation and discussion), and "end" (where students completed an assessment). (4) Each represented a conceptual challenge for students. Mrs. H explained how students often struggled with the concepts of energy and energy transfer when studying sound waves. She also noted students' difficulty in understanding the structure of atoms they could not "see" and the ways scientists investigated objects invisible to the naked eye. (5) Each exemplified the types of planning and activities Ms. H routinely used.

Teacher, Student Participants, and Researchers

The teacher. Ms. H was purposefully selected to construct an exemplary case (Patton, 1990). At the time of this study, Ms. H had taught ICS for seven years at two different high schools. As previously noted, she helped write the district's instructional guide for the ICS course and facilitated its professional development for ICS teachers. She was recognized as a model teacher by her school colleagues and district personnel. She also was department chair at her school. Most importantly, Ms. H implemented reform-based teaching strategies purposefully designed to support ELLs in learning science (see National Science Teachers Association, 2009).

Ms. H was of Puerto Rican and European American descent and spoke English as her first language. She did not consider herself to be bilingual in English and Spanish; she referred to herself as a "limited Spanish speaker" and described her Spanish speaking skills as "conversational" with a "basic level" of science vocabulary for the topics covered in the curriculum. Ms. H had completed teacher education courses and professional development experiences on how to teach science to ELLs; she did not, however, hold a Bilingual, Crosscultural, Language, and Academic Development (BCLAD) credential.

The students. Fifty-four students (20 female and 34 male) from two of Ms. H's class periods – Periods 2 and 3 – participated in this study. Ninety-three percent (93%) of student participants were Latino/a and 44% were designated as ELLs. Two student participants' language proficiency was not yet identified, likely the result of having just enrolled in the district. We grouped students with designations of Reclassified Fluent English Proficient (RFEP, 18 students), Initially Fluent English Proficient (IFEP, four students), and English Only (EO, six students) as "fluent English speakers." However, the number of students designated as RFEP and IFEP remains noteworthy because these students spoke Spanish as well as English. Because of the high number of ELLs in Period 3, Ms. H was assisted by a bilingual aide, a college student who received course credit for her work in a high school setting. The bilingual aide, however, was neither pursuing an undergraduate major in science nor taking courses in science education.

At the time of data collection, Ms. H and her students had already completed the first unit of the ICS curriculum: Earth Science. All 54 student participants were video recorded during whole class instruction of the Physics' sound waves lesson sequence and the Chemistry's atomic structure lesson sequence. As part of her regular instruction, Ms. H constructed heterogeneous groups with respect to gender and language proficiency, ranging from two to four students in Period 2 and from five to six students in Period 3. (There was one exception. During the first half of the course, Ms. H assigned all newly arrived ELL students in Period 3 to their own small groups so that they could more easily work with the bilingual aide.) Period 3 had larger groups because of its larger class size. Groups were reconstituted approximately every four weeks. During the filming of each lesson sequence, then, two video cameras, one to capture whole class instruction and one to record small group work, were placed at the back of the classroom so that they would interfere as little as possible with instruction. The student group for each lesson sequence who was assigned to the table closest to the "small group" camera was selected as the focus group. In Period 2, one group of four was filmed for the physics lesson sequence and a different group of four, for the chemistry lesson sequence. Because two students were in both groups, there was a total of six focus students in Period 2. Similarly, in Period 3, one group of six was filmed for the first lesson sequence and a different group of five, for the second lesson sequence. Because two students were in both of these groups, there was a total of nine focus students in Period 3. Of the 15 focus students across the two periods, six were female and nine, male. Eight were designated as ELLs and seven, fluent English speakers.

The researchers. The first and second authors are former high school science teachers; the third author is a former ESL teacher. The first author worked with Ms. H at a previous school for four years and collected the data presented here. She also mapped the instructional sequences (Green & Wallat, 1981) and generated all interview and classroom transcripts. All three authors participated in the analysis of data and the write up of findings.

Data Collected

Four types of data were collected. One data type was video records. Two physical science lesson sequences were filmed to capture small group and whole class interactions. A total of 11 days of class (five for the physics lesson sequence and six for the chemistry lesson sequence) were filmed for both periods. Given that most class periods were 80 minutes in length, this translated to approximately 15 hours of instruction filmed for each period (29 hours total).

Our second type of data was fieldnotes. The first author took fieldnotes of class activities, focusing on descriptions of the context, conversations among students, and group dynamics.

Teacher interviews were our third type of data. Five semi-structured (Spradley, 1979) interviews were conducted, ranging in length from 35 to 80 minutes. Two interviews occurred before the sound waves lesson sequence. These initial interviews (a) documented Ms. H's intended instruction in argumentation and communication so as to later compare to her enacted practice; and (b) obtained background information about her teacher training and teaching experiences. Ms. H discussed her goals for the ICS course, her views regarding the importance of argumentation and communication in science, and how she met the needs of her ELL students. In particular, she explained her decision to provide primary language support for ELLs.

Two additional interviews were conducted, one after each lesson sequence. During these interviews, Ms. H reflected on the activities and assignments implemented. She also described the opportunities she provided her students to engage in science practices and to develop their science discourse and English language skills. Further, Ms. H examined student work samples and explained students' progress mastering science discourse and English language skills.

The final interview occurred after the semester had ended and students had received their course grades. During this interview, Ms. H provided an overview of the ICS course. She also discussed students' learning of concepts, their engagement in argumentation and communication, and ELLs' developing science discourse and English language skills across units. As with the lesson sequence interviews, Ms. H provided evidence to support her conclusions regarding enduring student understandings; such evidence included student work samples, quizzes, and grades. We viewed this final interview as a valuable means to understand how Ms. H made sense of her own and her students' successes and challenges in teaching and learning science.

A variety of student work from each lesson sequence, including quizzes, notebooks, and posters, made up the fourth data type. However, only students' group posters were analyzed for this study. Groups displayed findings from investigations and/or key ideas from discussions or readings on these posters and shared them with the whole class (e.g., in a gallery walk or a group presentation). Three sets of posters were analyzed, two from sound waves and one from atomic structure. Ms. H also referenced these posters in interviews when reflecting on student learning.

Data Analysis

As our study investigated the teaching and learning of discourse-intensive science practices, we began our analytic process by reviewing the work of Green and colleagues (Green & Dixon, 1993; Kelly, Crawford, & Green, 2001) on language use and collective activity in classrooms. We sought to understand how the practices of argumentation and communication were proposed, negotiated, and taken up by the teacher and her students, in particular, the ways Ms. H afforded opportunities for all students, including her ELLs, to generate, present, and evaluate science arguments, and how ELLs constructed and communicated arguments as a result. Our analysis was guided by our research questions posed in the introduction to this article and by Emerson, Fretz, and Shaw's (1995) recommendations for qualitative research. Further, the first author conducted member checking (Lincoln & Guba, 1985) with the teacher after each of our two analytic stages, as well as during the initial write-up of findings.

Construction of transcripts and event maps. We constructed a detailed transcript of each teacher interview. We then mapped the instructional events (Green & Wallat, 1981) that occurred during each filmed lesson sequence (see Reveles, Cordova, & Kelly, 2004, for a detailed example). For every five minutes of class, an overview of Ms. H's instructions to the class, small group conversations, and whole class lectures and discussions was provided. Next, using these maps, relevant excerpts of classroom interactions were identified and verbatim transcripts, constructed. Relevancy was determined based on the substance and type of teacher and/or student discourse. Whole class and small group discussions of science content, in-class hands-on activities, small group presentations, and the asking or answering of procedural and content-related questions were deemed relevant. Instances in which students engaged in off task talk or individually completed work were not transcribed. Finally, three translators translated oral classroom interactions and student written work completed in Spanish. All three were native Spanish speakers fluent in English who taught high school, although only one had experience teaching science. Once completed, translators compared their transcripts to identify differences in translated passages. These differences were discussed until a consensus was reached.

Two stages of analysis. The first stage of analysis targeted research question one about Ms. H's instruction. Ms. H's interview transcripts and the two lesson sequences' instructional maps and transcripts served as primary sources of data. Teacher interview transcripts were first coded for Ms. H's views on (a) the teaching and learning of science, (b) the needs of her ELL students, and (c) the types of classroom practices she implemented. Within this last code, classroom practices Ms. H provided related to the teaching of argumentation and communication received a second sub-code separate from those that focused on meeting the needs of ELL students. Next, instructional maps and transcripts of the two lesson sequences were analyzed using these same three sets of codes so as to compare Ms. H's intended and actual classroom instruction. We then looked across this initial set of coded data to identify two salient themes: (a) science discourse and (a) instructional strategies to support ELLs in argumentation and communication. Additional rounds of focused coding yielded three dimensions in Ms. H's views of science discourse and three key strategies she implemented to support ELLs in the construction of arguments and the communication of information.

Our second stage of analysis, in response to our second research question, examined the instructional maps and transcripts of the two lesson sequences, students' small group posters, and transcripts of interviews with Ms. H. We used our review of literature on ELL students' discourse-intensive science practices in urban classrooms to guide our analytic decisions. We first documented the ways Ms. H and her ELL students used Spanish in addition to or instead of English to construct and communicate arguments. We then analyzed teacher-student and student-student conversations to identify patterns in ELLs' engagement in these discourse-intensive practices. In each setting, small group and whole class, we identified the ways in which students contributed to the ongoing conversation: *who* talked and what was the *substance* of that talk. As a third piece of this second analysis, we compared the *substance* of students' small group conversations to their written posters, looking for similarities and differences in their arguments grounded in evidence. We also examined their written posters for linguistic features of scientific writing. Findings from this three-part, second stage of analysis are presented in terms of ELL students' successes and challenges in (a) participating in class, (b) constructing arguments from evidence, and (c) using science texts to obtain and communicate information.

Findings

Our findings are organized by research question. To answer our first question on ways Ms. H scaffolded ELLs' argumentation and communication, we begin by describing her understanding of science discourse. We then focus on three key strategies she used to assist ELLs in developing and communicating arguments from evidence: primary language support, deliberate scaffolding, and small group work. Given these opportunities for learning afforded by Ms. H, to answer our second question, we discuss the ways in which her ELL students constructed arguments in small group and whole class contexts and communicated these arguments orally and in writing. We include examination of their successes and struggles in participation, argumentation, and the reading and producing of scientific writing.

Finding Set 1: Ms. H's Practices to Support ELLs' Construction and Communication of Arguments

Ms. H understood science to include a discipline-specific set of practices and style of discourse (Stanley & Brickhouse, 2001). She conceptualized science discourse as consisting of three dimensions: (a) generating and evaluating arguments from evidence; (b) sharing ideas and understandings with others in public forums; and (c) using precise language, including specialized academic and science-specific words (see Snow, 2008). Of central importance to Ms. H was the teaching and learning of argumentation, in particular, how evidence is used to support claims. Ms. H emphasized evidence, she elaborated, because "at the end of the day, claims, predictions, and hypotheses mean nothing unless you have evidence." Ms. H added that she and several science teacher colleagues agreed to focus on the relationship between claims and evidence during the year this study took place. Ms. H and her colleagues, however, did not adopt common teaching practices and activities designed to promote argumentation.

During both filmed lesson sequences, Ms. H provided her students with multiple, scaffolded opportunities to engage in the process of developing arguments from evidence. Sometimes, teacher and students focused solely on identifying claims that could be supported with evidence. Other instances involved students in determining what evidence (e.g., data collected from class activities, data collected by scientists in the past) supported or refuted a given claim. In still other instances, students discussed the relationship between a claim and evidence, and identified reasons why a particular piece of evidence counted as evidence for the claim. These opportunities spanned in-class student investigations, the interpretation of cartoon images from the ICS textbook, and classroom and homework assignments.

More specifically, during the five-day physics lesson sequence, students completed an interpretation of a cartoon depicting someone plucking a string, two warm-up activities in which students generated claims about phenomena they observed, two multiple-step investigations, two group posters summarizing those investigations, and a homework prompt ("Explain what evidence we have collected thus far that supports the claim 'vibrations can make sound'."). This was in addition to several whole class discussions conducted as a result of these activities. During the six-day chemistry lesson sequence, seven such opportunities to examine claims and evidence were provided to students. Indeed, there was only one day during each lesson sequence in which activities did not include an explicit focus on developing arguments; during these days, instruction focused on science vocabulary and academic language development.

The other two dimensions of Ms. H's view of science discourse, sharing ideas in a public forum and using precise language, were important to her because of their relationship to argumentation. With respect to her second dimension of science discourse focused on communication, Ms. H explained how sharing ideas publically was integral to evaluating claims:

> I want [students] to be able to ask for evidence – not just provide it – but to be able to ask for evidence when a piece of information is provided to them. . . . And to develop "asking for evidence" means being able to put your thoughts into the public and accept criticisms and questions and then revising your ideas.

Ms. H also thought students should be able to "explain their thinking in written format or verbal format, so that way it can be revised." In particular, Ms. H encouraged her students to articulate their initial ideas about a natural phenomenon in order to mark changes in conceptual understanding over time. Further, Ms. H included opportunities to read, interpret, and evaluate scientific information. She discussed with students how to discern when they were receiving "good information" from sources like the Internet or a science-related journal, as well as engaged them in reading and interpreting articles in *Scientific American*:

> The styles and formats that I focus on . . . would be [the journal] *Scientific American*. [In this type of article, one is] looking at. . . meta-studies or a compilation of scientific ideas that are written for . . . someone who's interested in the [scientific] community and is involved in the community. But [the article is] still written for, by and large, the lay person. That is as far as I have taken it in my classroom.

Through these latter types of activities, Ms. H hoped her students would be empowered to discuss socio-scientific issues and to ask questions about how and where ideas originated.

Examination of Ms. H's practices during the two filmed lesson sequences showed she focused on providing students opportunities to publicly communicate findings from their investigations during whole class discussions and group presentations. Students were asked to generate three posters to be shared with the class; these posters were similar to science texts in that they were "multimodal" (NRC, 2012, p. 74), involving both written explanations and drawings (see also Pappas el al., 2009). Students were expected to include science vocabulary terms as appropriate as well. However, Ms. H did not provide opportunities for students to evaluate scientific articles (although this may have occurred at other times).

For Ms. H, her final dimension of science discourse – the importance of using precise language – was fundamentally connected to her second and first dimensions. In relation to the sharing of ideas in a public forum, Ms. H explained that precise language included appropriate use of both individual scientific terms and language more broadly to construct meaning. However, use of appropriate terminology was a large focus of her instruction. Ms. H underscored the importance of utilizing appropriate terminology – what she called content vocabulary – when communicating an argument (her first dimension of science discourse):

> If you're communicating yourself in a meaningful way, where you could have an open discussion and people could go back and forth, [including statements like] "I agree," "I disagree," then you have to have the content vocabulary and the content language. Because that way you are all communicating about the same thing, because the same words mean the same things to everyone.

According to Ms. H, scientific terms were important in argumentation because they had agreed upon meanings. As such, students needed opportunities to learn how to use these terms.

During each filmed lesson sequence, Ms. H provided one day of instruction that explicitly focused on content vocabulary. For example, on the last day of the physics lesson sequence, students completed a worksheet in which they paired content vocabulary with corresponding images. Following this activity, students worked in pairs to construct sentences using whiteboards: Ms. H provided two or three terms and asked students to construct a sentence with them. Ms. H's emphasis on content vocabulary was also visible in some homework prompts. For example, after students finished one investigation, they were instructed to complete the following: "In a paragraph, summarize key ideas/findings from the activity. Use three vocabulary words: pitch, wavelength, tension." Indeed, student use of vocabulary was something Ms. H monitored during lessons as one way to identify whether students understood the material.

> The primary thing [I look for] is when I ask them to explain, students start to spontaneously use the new vocabulary. Instead of saying, "Oh it sounds," they say, "The pitch is higher, the pitch is low." They choose of their own accord, without me giving them directions [to use vocabulary]. …. Also students when they're explaining [their ideas] to each other, that they're choosing to use those words because they're more precise than the general words that they used before. . . . It starts in conversation first, and then as they become, in my observation, as they become more comfortable, it starts to transfer to their writing.

Finally, we emphasize that Ms. H viewed science discourse as closely tied to attending to the instructional needs of ELLs (see Quinn at al., 2012). In order to integrate her three dimensions of science discourse for the ELLs in her science classes, Ms. H routinely implemented primary language support, deliberate scaffolds, and small group activities. We discuss each of Ms. H's three key instructional strategies below.

Primary language support. Ms. H implemented primary language support as one of three key instructional strategies to help ELLs develop and communicate scientific arguments. She stated that her practice of providing primary language support in a content course as atypical at Orchard: It was neither routinely implemented by other teachers nor expected by her school administration. She also noted that her teacher education and professional development experiences did not include examination of primary language support. As such, Ms. H viewed primary language support as a personal decision derived from her teaching in urban classrooms.

Ms. H saw primary language support as central to her efforts to encourage *all* students, including ELLs, to participate in class activities and to promote their learning of science: "A lot of the students have to process verbally – they have to talk about it [a science idea or question] and they have to discuss it in whatever language they are most comfortable with." For Ms. H, being able to articulate one's ideas was essential to demonstrating understanding: "If you can't say it, you don't know it." Ms. H expressed this opinion both to the first author during her initial interviews and to her students during class time. When speaking specifically about the use of students' primary languages in class, Ms. H elaborated:

> If you can say it and it's in your natural tongue, it's easier for you to remember it and access it when you need it. So if you can say it, you are more likely to be able to use it.

Further, Ms. H explained, because the ICS course at Orchard preceded all other science courses, it was expected to help students learn foundational disciplinary concepts. If ELLs were unable to participate in her class because they were required to use English, they would not only fail to do well academically in ICS, but in future science courses as well.

Ms. H's decision to validate ELLs' use of Spanish, their primary language, shaped her instructional practice in three important ways. One way Ms. H enacted primary language support was to work with her in-class bilingual aide during Period 3, the school's other bilingual aides, and bilingual teacher colleagues to translate between English and Spanish. The bilingual aide in Period 3 worked with students individually or in small group settings during class time; however, the aide never addressed the entire class. Over the course of a lesson, Ms. H and the bilingual aide also communicated with one another to ensure that the aide understood the tasks that the students were asked to complete. Further, because Ms. H frequented all tables to monitor student learning, the aide and Ms. H sometimes worked together with the same group of students.

Ms. H also consulted with her bilingual teacher colleagues outside of regular classroom instruction. Because Ms. H only had access to a Spanish glossary of the English ICS textbook, she asked colleagues to translate textbook passages into Spanish for class use and to generate handouts, assessments, and other classroom materials in Spanish. The use of written translated materials was a central means by which Ms. H integrated Spanish into her instruction. At times, both the Spanish and English translations of the material were provided to all students. One example of this was seen with a homework assignment from the chemistry lesson sequence in which students completed an anticipation guide comparing their opinions to those expressed by the author of the textbook. At other times, Ms. H provided translations of activity directions or textbook selections to individual students or small groups. Occasionally, textbook passages used by students were not translated. Finally, Ms. H asked colleagues fluent in Spanish to assist her in working with individual students and to make phone calls home.

As second way, Ms. H used her own limited Spanish. For example, Ms. H used her Spanish when talking to students in their small groups, when she thought asking questions and clarifying ideas in Spanish helpful. However, she did not integrate Spanish into her lectures. It is important to underscore that Ms. H's primary means of providing instruction to students was in English and her ultimate goal was to help her ELLs acquire the language of science in English.

Most notably, as a third way to enact primary language support, Ms. H allowed all students to use either or both English and Spanish during class activities and discussions, as well as in written assignments. She encouraged students to begin discussing their science ideas in the language(s) of their choice; ELL students often wrote their initial ideas in Spanish. Ms. H then tried to transition ELLs from Spanish to English over the course of a series of lessons. After participating in the task and talking with their peers, the bilingual aide, and herself, Ms. H argued that ELLs were better able to use English in their discussions of natural phenomena. To clarify, Ms. H neither purposefully structured opportunities for students to write in one language as opposed to another nor required students to create posters that used one or both languages. Rather, Ms. H left decisions about which language(s) to use up to the students or small groups themselves. Ms. H simply encouraged students to use English when she thought they were able – to help move students from Spanish to English over the course of a lesson series or unit.

Examples of teacher and student use of Spanish and English can be found in activities focused on developing evidence-based arguments as part of the physics lesson sequence. During the first two days of the sequence, students completed a cartoon analysis, a warm-up activity, and an investigation of sound using string. They also were given a passage from the ICS textbook to read in English. Students were allowed to complete the cartoon analysis and warm-up in Spanish or English, record data from the investigation in either language, and communicate with their peers using both languages. An example of how Ms. H worked with one small group to translate ideas between Spanish and English with respect to the textbook – the final step in preparing a poster summarizing the two days – is provided in the third subsection of Finding Set 2 below.

As a result of enacting primary language support in these three ways, Ms. H expected ELLs not only to share their ideas, ask questions, and deepen their understanding of science, but to hone their abilities to talk and write in English as well. Ms. H also thought that ELLs themselves would reflect on their classroom conversations and recognize their own growth in science understanding, science discourse, and English proficiency.

> [ELLs] are also seeing, "Oh hey, look, I'm learning. I said three things about [a given science topic] and I was right but I could only say three things and now I can say ten things [about it]. . . . Now I can say four things in Spanish and I can use three English words." And that they are able to expand on their prior understanding or revise their prior understanding.

Ms. H understood that her decision to provide primary language support created some difficulties both for herself and for her students. For herself, the translations between English and Spanish needed as part of primary language support introduced unproductive ambiguity into the teaching and learning process. Ms. H identified two ways translations made it difficult for her to thoroughly monitor her students' understanding. First, translations sometimes obscured students' understanding of science terms and concepts. For example, Ms. H noted that a small group used the Spanish word "el sonido" which translates to the English word "sound" in their poster; they did not use the Spanish term "el tono" which translates to the English term "pitch." (See Figure 1. This also occurred in Maria's presentation under the first subsection of Finding 2 below.) However, it was pitch, not sound, that was the focus of the investigation and the textbook reading. As such, Ms. H questioned whether this group had used the term el sonido to describe the concept of pitch or a more general quality of a sound, such as volume. Indeed, several small groups had confused the concepts of pitch and volume during their investigations with string the day before. This confusion was addressed in English through a class discussion. We note that both the terms sound and pitch were discussed in the ICS textbook; that pitch and el tono but not sound and el sonido were listed in the English and Spanish glossaries at the end of the text; and that Ms. H only used the term pitch, and not its Spanish translation, during classroom instruction.

[INSERT FIGURE 1 HERE]

Although the students in this group used the term el sonido instead of el tono in Spanish, they used the term pitch correctly in English. The group wrote: "By adding more weight the pitch/tone is higher." Because pitch was used correctly in English but not in Spanish, Ms. H and we as researchers were left to wonder if all group members understood the concept of pitch.

A second way translations created unproductive ambiguity for Ms. H was in terms of their accuracy. Ms. H expressed concern about the accuracy of ideas translated orally in class. As she relied on her bilingual aide or a bilingual peer to provide most oral translations, Ms. H was unable to monitor the quality and substance of ideas communicated. She questioned to what extent ELLs had access to key ideas from lectures, activities, and discussions that were conducted primarily in English and then translated for them into Spanish. Ms. H also expressed concern about the accuracy of written translations. While Ms. H saw herself as proficient enough in Spanish to provide oral directions and some science explanations, to converse with students in small groups, and to informally assess students' oral science understandings and short pieces of writing, she often relied on other faculty members to translate longer written assignments students completed in Spanish into English. Ms. H elaborated:

> When it comes to like [written] reports? No. I have to ask a second opinion because my Spanish isn't accurate enough. If I'm going to be grading them and say, "This is the criteria that I'm grading you on," it would be unfair [to the student because] my Spanish isn't good enough.

The teacher colleague Ms. H most frequently consulted was not a science teacher; because of this, Ms. H did not rely on this colleague's content knowledge. Ms. H explained that she asked the colleague to provide a translation and then used that translation to assess the student's science understanding on her own. She added that she sometimes needed to ask her colleague follow-up questions regarding the translation. Therefore, it was not always clear whether a student's nuanced misunderstanding was an artifact of the ambiguity of the translation process.

With regard to her students, Ms. H thought primary language support might disadvantage them when taking the end-of-year state standardized tests. Ms. H recognized that if students only read texts and learned vocabulary terms in Spanish, this might put them at a disadvantage when completing the state-mandated, end-of-year science tests written in English. She stated, "I'm finding that words need to be translated – the content vocabulary – when possible into their primary language. . . . [But this] is problematic because students don't get to take the test in Spanish." Therefore, as stated above, while students were allowed to engage in conversations and complete assignment using both languages, they were encouraged to express their science ideas in English when possible. Ms. H thought this balance would assist students in acquiring the academic language and content knowledge they needed for tests and for future science courses.

Deliberate scaffolds. As a second key instructional strategy to support her ELL students in constructing and communicating arguments, Ms. H routinely and deliberately scaffolded students' science language development. First, Ms. H rephrased students' contributions to identify claims and evidence and to articulate relationships between them. This type of scaffolding was intended to help students better understand aspects of argumentation, such as (a) what distinguishes an observation from a claim and (b) how and why claims are supported by evidence. The latter component also included discussion of the quality and quantity of evidence one could use to support a claim. For example, Ms. H rephrased students' contributions and involved them in guided discourse to reinforce use of precise language when constructing a claim. In the excerpt below, Ms. H capitalized on Lucio's (a fluent English speaker) use of the word "pressure" and his making of the complex claim that adding pressure to a string results in a higher pitch when the string is plucked to introduce the term "tension."

Lucio: [...] if you like pluck it [the string], like it'll make like a noise and then if you put more pressure and then you pluck it, it'll make like a different noise.
Ms. H: When you mean pressure? Like, if I say, "I'm under pressure." What does that mean?
Roberto: They're pressuring you.
Student: You got stress.
Ms. H: Like, "Get your work done go, go, go!" What do you mean pressure?
Lucio: Like I don't know how it's called but like pulling [*moving his hands apart*].
Ms. H: Okay so how much it's being pulled upon [*moving her hands in the same was as Lucio*]?
Lucio: Like it's really tight.
Ms. H: Okay. Tightness, we're going to be talking about a measure of how much tightness or how much pull is on the string and that's actually a word called tension [*moving two fists apart*].

Because the word pressure both spans two parts of speech (a noun in line 1 and a verb in line 4) and has multiple definitions, it is not surprising that Ms. H asked Lucio to clarify what he meant (line 3). She did so by asking what pressure meant in a different sentence ("I'm under pressure"). Roberto (an ELL) and a third student responded to Ms. H's question by describing pressure in terms of how it can be applied to one's feelings (i.e., stress). These responses led Ms. H to provide a second example of pressure as stress -- "Get your work done go, go, go!" -- to further assist Lucio in explaining what he meant by the word (line 6). Lucio then introduced the word "pulling," using hand gestures to help him explain what he meant by pressure (line 7). Ms. H adopted the word "pulled" as well as the hand gestures to ask Lucio to elaborate. Lucio next introduced the word "tight" (line 9). Finally, Ms. H ended the exchange by introducing the term tension and by defining it using the words "tightness" and "pull," both versions of words that Lucio had used. In sum, Ms. H validated both Roberto and Lucio's responses when she rephrased them to help the class understand that there are different meanings of the word pressure and to help Lucio clarify the way he was using the word in articulating a claim. By acknowledging that the word pressure has more than one meaning, Ms. H built from the knowledge her students brought with them to the classroom to facilitate learning.

Second, in addition to rephrasing students' contributions, Ms. H provided students with explicit structures to use to present their arguments. As one example of deliberate structures, in the case of the cartoon analysis introduced above, students were asked to support each generated claim with two pieces of evidence. As a second example, with each of the three group posters assigned, Ms. H provided a template for students to use. A third example comes from Ms. H's initial interview. When talking about the Earth Science unit, Ms. H described an activity in which she scaffolded students' efforts to generate a claim supported by four pieces of evidence. For homework, students were asked to complete a graphic organizer: They wrote a claim and then, in each of four boxes, one piece of evidence for their claim. The next day in class, students used their graphic organizers to construct an interpretive paragraph. Ms. H elaborated:

> They [the students] are making a claim and they're collecting their evidence and [in] each box [of the graphic organizer students write] just one sentence. . . . And at home they are supposed to be combining that claim and evidence, interpreting, making an interpretive paragraph and I'm wanting them to struggle with that by themselves. But the intent is that [the next day during class] we cut those [pieces of] evidence – those strips – out and then actually physically manipulate the pieces of paper so that they can make paragraphs that make sense to them.

Ms. H argued that the use of a graphic organizer and the act of physically manipulating pieces of evidence was beneficial for ELLs. It encouraged them to "prioritize evidence" while creating their arguments: to identify the quality of the different pieces of evidence and to determine the optimal order in which to present that evidence so as to put forth a convincing argument.

During both the physics and chemistry lesson sequences, then, Ms. H deliberately scaffolded student learning in two ways: She integrated opportunities to construct and communicate arguments across content activities and assignments and included explicit structures to support students in their engagement in these practices. At the beginning of the course, Ms. H also included explicit lessons on what a claim is, as well as the difference between observation and inference. We emphasize that Ms. H intentionally wove her instruction on the practices of argumentation and communication together with instruction on science concepts.

Small group work. Ms. H assigned her students to small groups, organized to maximize opportunities for ELLs to interact. While in groups, each student adopted a specific role (e.g., team manager, supply master, procedure specialist, etc.). Ms. H structured her small group work so as to provide students at least two different contexts in which to discuss their ideas: (a) Ms. H would ask small groups to engage in an activity or respond to a given prompt so students could discuss their ideas with their group members, and (b) the groups would report back to the whole class. Often, Ms. H called on one member (e.g., supply master) from each group to share during the subsequent whole class conversation. On other occasions, Ms. H asked for a volunteer from each group to share out. It is important to note that this small group/whole class pattern was often repeated more than once during an individual 80-minute period.

Ms. H's purpose in implementing small group work was to provide a safe environment for students to share ideas, and to either come to consensus or describe their different viewpoints.

> [A] lot of people [students] are afraid that their ideas are wrong or that they're not going to articulate them in a smart enough way. . . . [So I] ask [the] team manager to share. . . . [The] team manager is going to share out whatever idea [the group] think[s] is best at the table. [This way, I am] giving [students] the freedom to communicate ideas to the whole group [class] but maybe not have the liability of admitting that it's their own or someone else's [idea].

Ms. H thought that it was imperative for ELLs to talk with their classmates, the bilingual aide, and herself in these small group settings. By providing students the opportunity to share their ideas in small groups first and then electing one individual to be the spokesperson for the entire group, Ms. H attempted to lower students' anxiety levels, and therefore, to increase the likelihood that students – including ELLs – would engage in class activities and conversations.

Across the two lesson sequences examined, we found that Ms. H consistently provided opportunities for students to engage in argument in their small groups. For example, during four of the five days of the physics lesson sequence, students had at least one opportunity to engage in some aspect of argumentation (e.g., the relationship between claims and evidence, a focus on reasoning, etc.) in small groups. During the first two days of this lesson sequence, students engaged in two separate group activities each day. The following excerpt is taken from the second day of the physics lesson sequence. Working in their small groups, students were asked to make a claim whether sound is a transverse or longitudinal wave. Students were to support their claim with evidence from their observations of the movement of a balloon tied to a string in front of a speaker playing music.

3 Lidia: Transverse.
//
7 Lucio: Oh, it's not transverse, it's not, it's a push and pull wave.
8 Marlen: No, it's not.
9 Lucio: Oh my God… the balloon is getting pushed and pulled, pushed and pulled.
10 Marlen: Oh yeah, yeah.
11 Lucio: That's a longitudinal. I'm supply master, I mean procedure specialist.
//
24 Lucio: [*speaking to Ms. H who is walking by the group's table*] I know.
25 M. H: Does your table have evidence? Everyone? Even if I ask Marlen, does she know what you know?
26 Carlos: [*speaking to Ms. H*] Hey, we all know.
27 Lucio: Look, look, look, look, look, watch, watch, look, shhh. A push and pull wave is pushed like forward
28 and comes back. [*speaking to a student from another table*] Hey turn around and cover your ears.
29 Lidia: Don't talk to him [*referring to the student seated at another table*].
30 Lucio: The balloon goes forward and back. Evidence.
31 Carlos: The evidence is it's going back and forth?
32 Marlen: That's our evidence?
33 Lucio: The balloon was going back and forth, that's our evidence.

In response to Lidia's (an ELL) claim that sound is a transverse wave, Lucio (a fluent English speaker) claimed it was a longitudinal wave (line 7). After Ms. H informed Lucio that everyone in his group needed to understand the evidence for sound being a longitudinal wave (line 25), Lucio referred to the balloon moving back and forth as evidence (lines 27-28 and 30). In response, Carlos (an ELL) and Marlen (a fluent English speaker) both clarified that the movement of the balloon was what Lucio used as evidence to support his claim (lines 31-33).

Finding Set 2: ELLs' Successes and Challenges in Argumentation and Communication

We identified both successes and challenges in Ms. H's ELL students' efforts to engage in argument and communicate information. We remind readers that Ms. H intentionally promoted student participation, provided opportunities to learn science concepts and practices, and engaged her students in the discourse of science; as such, we used these criteria in our identification of successes and challenges. More specifically, we examined if and how ELLs participated in small group activities and whole class discussions. Also, we looked at the form and substance of their oral talk and written work to determine if and how ELLs demonstrated their understanding of concepts, argumentation, and communication. Instances that met our criteria were considered to be successes. Careful review of those that fell short led us to identify challenges ELLs faced. We organized our discussion of ELL students' successes and challenges in three parts: student participation, argumentation, and scientific writing.

While ELLs used both English and Spanish to communicate their ideas, they participated in whole class discussions less frequently than their fluent English-speaking peers. We found mixed success in our examination of ELLs' participation in Ms. H's class. One success was that ELL students used both English and Spanish to communicate their ideas; primary language support afforded them this opportunity to use one or both languages. For example, as discussed in greater detail in subsections two and three below, a small group of four ELL students (their fifth member, a fluent English speaker, was absent on this day) attempted to construct arguments for the structure of the atom using primarily English – both in their conversations with their fellow group members and with Ms. H. In line 60 of the third transcript excerpt from this small group, one group member, Claudio, introduced the Spanish word bolitas (meaning little balls) to refer to the alpha particles in Rutherford's experiment.

As a second example, some ELLs conducted their small group presentations to the whole class in Spanish. Of the 26 group posters presented across two assignments during the physics lesson sequence, four included Spanish. (All 15 posters from the later chemistry lesson sequence were written in English.) In the following excerpt from a poster presentation during the physics lesson sequence, Maria, an ELL student, presented her group's findings from their investigation on the sounds made by straws of varying lengths in Spanish.

1	Ms. H:	So table six is in the back. So stand up with	
2		your poster [demonstrating how to hold	
3		poster]. So we've got a bilingual presentation.	
//			
11	Maria:	Cuando el popote es chico el sonido es más	*When the straw is small the sound is higher. When*
12		alto. Cuando el popote es largo el sonido es	*the straw is longer the sound is low. When the straw*
13		bajo. Cuando el popote esta tapado se escucha	*is covered it sounds low. When it's uncovered it*
14		bajo. Cuando esta destapado se escucha	*sounds high. If you want to calculate the . . . the size*
15		alto. Si quieres calcular el . . . el tamaño de	*of a wave, multiply by two.*
16		una ola, multiplicado por dos.	
17	Ms. H:	All right. So now, when the straw was short,	
18		what was the pitch?	
19	Class:	High.	

When Ms. H introduced this group, she highlighted for students that it was a "bilingual presentation," meaning that the speaker would present the information in Spanish (lines 1-3). Ms. H did not envision bilingual presentations as students repeating themselves or their ideas in both English and Spanish; rather, she facilitated tandem talk (Lee, Hill-Bonnet, & Gillespie, 2008). Tandem talk occurs when a speaker builds on or elaborates the ideas of a previous speaker in a different language. Once Maria finished her presentation in Spanish (line 16), Ms. H repeated one of the group's findings in English and introduced the science vocabulary term "pitch" (lines 17-18). While Ms. H did repeat a portion of Maria's group's findings, she did so for the instructional purpose of introducing the term pitch, which was not included in the presentation. Later, Ms. H signaled to the class that this group included information about pitch that many of the other small groups had forgotten. As such, Ms. H used English to assist the class in identifying and attending to important aspects of this group's presentation conducted in Spanish.

We remind readers that it was the group members' decision to present their poster in Spanish, not Ms. H's. Ms. H provided students with the opportunity to participate in class discussions and presentations using the language(s) that they were comfortable with; she was committed both to having students share their ideas in a pubic forum and to primary language support. However, because Ms. H herself always spoke to the whole class in English, English remained the dominant language of whole class instruction.

Despite ELLs' active participation in small group conversations and instances where ELLs publically shared their small groups' ideas to the whole class, overall, we found that ELLs participated less often in whole class discussions than their fluent English-speaking peers; this we identified as a challenge. Individual students' responses to whole class discussion prompts were tallied for each class period across the 11 days of instruction. Individual student response counts were organized by day and then by language proficiency level. Fluent English speakers were more likely to participate in whole class conversations following Ms. H's discussion prompts. Indeed, in more than 80% of whole class discussions observed, ELLs made up less than 33% of active participants. This finding is particularly important since almost half of the students (44%) in each class were designated as ELLs.

We returned to our analysis of recorded small group interactions to help explain this imbalance in whole class participation between ELLs and non-ELLs. We found that although ELL students participated in small group conversations, they rarely volunteered or were selected by their small group to present to the whole class. ELLs also switched group roles with other members so that they did not have to share out. Such a pattern could arise in Ms. H's class without notice because she allowed group members to select their own group roles and because she routinely called on only one student (by role) per group to share out.

ELLs successfully engaged in some aspects of argumentation and struggled with others during small group work. In our presentation of Finding Set 1, we argued that Ms. H worked diligently to provide classroom contexts that promoted student engagement in discourse-intensive science practices. We explore ELL students' successes and challenges with argumentation in this subsection; ELLs' successes and challenges in obtaining and communicating information are discussed in our third subsection.

As with classroom participation, we found that ELLs successfully engaged in some aspects of argumentation, in particular, the identification of claims and evidence during small group conversations. For example, during the closing activity in the chemistry lesson sequence, small groups were asked to create a summary poster. The poster was to include two parts. One part involved drawings: Each small group was to draw Bohr models of assigned atoms; to identify the number of protons, electrons, and neutrons in each; and to list what the atoms held in common. The second component consisted of a response to a writing prompt: *"What evidence do we have that the electrons are outside the nucleus and the protons are inside the nucleus? Hint Given: Cathode Ray, Spectrum Tubes (Friday), Rutherford's Alpha Particle*." Ms. H added that students should discuss the charges of protons and electrons in their responses as well.

The following excerpt is taken from one small group composed of four ELL students as they began to craft their response to Ms. H's writing prompt. (This small group, with Claudio as one member, was introduced in the first subsection of Finding Set 2 above.)

Josefina: So what is our evidence? Our evidence is
Felipa: Our evidence is all the experiments that we did. I don't know.
Alexis: Remember the little video we saw the other day?
Claudio: Remember, we saw the video [of an interaction between a cathode ray tube and a magnet].
Alexis: Yeah.
Claudio: The one I'm telling you about. The one where the green thing, you know?
Josefina: First we have to write like, um, electrons are around the nucleus, no, not the, yeah, the nucleus, right? Yeah, the nucleus because, nah not because

//
14 Felipa: Well, so like we could write the evidence that we have that
15 Claudio: [*raising his hand*] I'm going to ask her [Ms. H] about the [cathode] ray [video].
16 Alexis: The evidence that we have that, that, that electrons are outside the nucleus is
17 Josefina: Okay, that's why. Electrons are outside the nucleus.
18 Felipa: [*pointing to Alexis*] And what did you say?
19 Alexis: The evidence that we have that the electrons are outside the nucleus is etcetera.

The four students worked together to try to identify what evidence they had to support their ideas about the structure of an atom; all four contributed to this conversation. The group first attempted to recall the three activities listed as "hints" in the prompt written on the board (lines 3-6). Josefina then asked her other group members how they should write down their evidence on the poster (lines 7-8); she used the first half of the teacher's written prompt to specify that they should provide evidence that the electrons are outside the nucleus. Next, Felipa responded, "The evidence that we have that" (line 14). Alexis then added to Felipa's comment, "The evidence that we have, that, that, that electrons are outside the nucleus is" (line 16). Like Josefina, Alexis' sentence structure is clearly related to the first half of the prompt.

By the end of line 19 in the above excerpt, students in this small group had worked collectively to recall activities they had completed during this lesson sequence and Alexis had provided a useful sentence structure to frame the group's response. However, a closer analysis of this excerpt makes clear that this group had yet to determine which activities served as evidence for different parts of an atom. Claudio stated that the cathode ray video was evidence to be included on the poster (lines 4, 6, and 15); however, Claudio did not articulate what the cathode ray video served as evidence for (i.e., that electrons are negatively charged). Josefina offered that electrons were located outside the nucleus (lines 7-8), but did not link this idea to evidence (i.e., the class discussion following the computer animation of Rutherford's experiment when students were asked to draw an atom and/or the Bohr model assignment completed the day before). These connections between the activities and the type of evidence they provided are a critical part of developing a successful argument (as well as a successful response to Ms. H's prompt).

As group members continued to discuss ideas for their written argument, they focused on the video animation of Rutherford's experiment as evidence to support their claims. After Claudio called on Ms. H (line 15 in the previous excerpt), the students worked with their teacher to determine that the animation provided evidence for a positively charged nucleus (lines 43-46). Ms. H rephrased their ideas using the terms "nucleus" and "positive" (line 47).

37 Ms. H: The Rutherford is the
38 Claudio: The thing where [*moving both arms outward repeatedly*]
39 Ms. H: Where the alpha particles went through the gold foil [*demonstrating with hand gestures*].
40 Group: Oh, okay.
41 Alexis: And then it hit it, they bounce back?
42 Ms. H: Yes, describe that. That taught us the nucleus was what?
43 Alexis: [*holding both hands up making a circular shape*] The center
44 Ms. H: Was?
45 Claudio: Some of them have positive things.
46 Alexis: Yeah, positive.
47 Ms. H: The nucleus was positive.
48 Alexis: [*using hand gestures*] And when they would touch each other they will bounce back.

In short, by the end of this second excerpt, the group had determined that findings from Rutherford's experiment served as evidence for a positively charged nucleus.

Unfortunately, Alexis was unable to incorporate the language Ms. H modeled when he repeated his earlier comment regarding the interaction between the alpha particles and nuclei (lines 41 and 48). After Ms. H left the group, Alexis also announced to his peers that he forgot what he had just said. As such, Josephina did not record their oral ideas about evidence for a positively charged nucleus on the poster. Further, the small group had not yet articulated reasons for how or why this piece of evidence should count as support for a claim.

Although ELL students in Ms. H's class were able to articulate claims and identify evidence verbally, a challenge they faced was articulating reasons – how a piece of evidence supports a claim and why that evidence should count as support for a claim – in both their oral small group conversations and written group posters. We found this challenge just as important in helping to understand instructional practices needed to support ELLs in the construction and communication of arguments as their successes. Continuing with the small group introduced above, members returned to their discussion of Rutherford's experiment, taking up Alexis' initial efforts to talk about the interaction between nuclei and alpha particles (see again line 48 in the second transcript excerpt) to focus on how the experimental results counted as evidence.

Claudio: [*looking at Josefina who is writing*] Okay, she [Ms. H] said that. Remember, okay let's say, remember those little bolitas [Spanish word meaning "little balls," referring to the alpha particles] [move] that way [*making hand gestures representing the movement of the alpha particles*].
Josefina: [*laughing*] I remember the little bolitas.
Claudio: Okay the little blue bolitas like – okay they're positive right? They're positive. And then like the golden foil – you know how it was going like that [*wiggling fingers*] with little particles [*referring to the electrons depicted outside the nuclei in the animation*].
Josefina: Uh-huh.
Claudio: Those are negative so they [the alpha particles] just goes right through there [the area where the electrons are located]. No wait up.
Josefina: Yeah.
Claudio: And then it [the atom from the animation] had negative and then it had other little [*making two circles with his hands, referring to the nuclei*]
Josefina: No, no, no. They [the nuclei] were positive. Because the little balls [the alpha particles] were positive.
Claudio: They were positive.
Alexis: [*to Josefina*] Why don't you start writing it down.
Claudio: And the foil was negative. It [an atom] has negative and positive remember? You know how it [the animation] had like like little big balls [*making two circles with fingers, referring to the nuclei*] and then it had like little [*wiggling fingers, referring to the electrons*]
Josefina: [Inaudible] neutral.
Claudio: Yeah.
Alexis: The gold balls were the nucleus.
Claudio: [*making circles with each hand*] The blue balls [alpha particles] hit like one of those big golden balls [*makes right angle gesture with arm representing the alpha particle bouncing away*].
Alexis: It [alpha particles] reacts back.
Claudio: It [alpha particles] bounces away [*moves arms from extended position to bent/by armpit alternating*]. Yeah whatever it [alpha particles] just goes through it doesn't do nothing [*signals nothing with hand gestures*].
Josefina: Yeah cause.
Alexis: Yeah cause when it [alpha particles] gets too close it bounce back.
Josefina: I get it, but how are we going to write it [on the summary poster]?
Alexis: Okay, start like this, the evidence that we have that the electrons are outside the
Josefina: [*as she is writing*] A little slower please. The evidence

As the group discussed what they saw in the animation of the Rutherford experiment, they attempted to reason how the findings (in particular, the behavior of the alpha particles, or little blue balls/bolitas) from that experiment provided evidence for a positively charged nucleus. Claudio used multiple resources – English, Spanish, and hand gestures – to articulate to his group (in particular, Josefina) what the animation depicted (lines 60-62, 64-66, 68-69, 71-72, 75, 77-79, 81, 83-84, 86-88). He demonstrated how resourceful students can be in thinking about and communicating their ideas when given opportunities to use different modes of communication, such as Spanish and gestures, to convey meaning (see Givry & Roth, 2006). Yet, even as the group transitioned to writing their response, they did not fully express the reasoning component for their argument (see Sandoval & Millwood, 2005).

After line 92, the small group's conversation and activity focused almost exclusively on the writing process. The group ran out of time before finishing their summary paragraph. As her peers listened to Ms. H conclude the lesson, Josefina completed the response by herself.

In their completed written response, the group identified Rutherford's experiment as evidence for the structure of the atom and offered a brief description of the video animation of this experiment that they saw in class. They wrote:

> The evidence that we have that the electrons are outside the nucleus is when we saw the Alpha particle animation video. In that video we saw the Alpha particles ~~going through~~ that went around the "+" yellow nueclues. But some Alpha particles hit the nueclues and they repeled. When the Alpha particles went through the electrons it didn't repel.

(See Figure 2. We note that although the top half of the group's poster, their drawings of atoms and associated text, include some errors, we discuss only the bottom half of the poster here.)

[INSERT FIGURE 2 HERE]

More specifically, the first sentence of the group's written response again demonstrates how they focused on the first half of the prompt – the location of electrons. However, the findings from Rutherford's experiment provide evidence of a small, positively charged nucleus. The second, third, and fourth sentences were written by Josefina at the end of class. From these sentences, it is clear that Josefina tried to document what her group had discussed. For example, the second sentence alludes to the interaction between alpha particles and electrons. Josefina wrote that the alpha particles "went around" the nuclei; Claudio had used the words "goes right through" the area around the nuclei in the small group conversation. In the third sentence, Josefina introduced the term "repel" to describe what occurs when alpha particles hit a nucleus. No one had used this term in the small group conversation; perhaps Josefina remembered the term from the class discussion. The final sentence refers to the interaction between alpha particles and electrons; Josefina used these terms in reference to Claudio's description of how alpha particles did not interact with electrons in the same way that they interacted with nuclei.

This group's written response and, to a lesser extent, their small group discussion fell short of Ms. H's expectations for an argument. First, the group did not identify the locations of both electrons and protons in their written response. Second, in their written work, the group did not reference all three activities that were completed during the lesson sequence as evidence for the atom's structure (provided in the "hint"). Although their poster only referenced Rutherford's experiment, in their small group discussion, the group did talk about all three activities. (Both the Rutherford experiment and cathode ray videos were mentioned in the above excerpts; Claudio asked Ms. H about the spectrum tube experiment in a separate excerpt.) Third, the group's written summary did not address the charges of electrons and provides only a vague reference to "+" nuclei. Yet, in the excerpts above, the group did discuss the charge of the nucleus, as well as the area outside of the nucleus: Claudio stated that an atom has both negative and positive charges, to which Josefina added the term "neutral." The group's oral conversations, while incomplete in that they did not fully articulate their reasoning, were richer and demonstrated more understanding of the class activities and concepts than what was written on their poster.

We note that this group's summary poster was not unique. Groups across both periods struggled to articulate what and how class activities served as evidence for the location and charges of protons and electrons. Of the 15 posters collected for this assignment, three did not include any reference to class activities. Eight groups referenced the animation of Rutherford's experiment, yet its use as evidence in their descriptions varied. Some groups linked the animation to the idea that the nucleus of an atom is positively charged. Other groups focused specifically on protons – either that protons are positively charged or that they are located in the nucleus. One group used the animation to talk about the mass of an atom's nucleus. Finally, a few groups linked the animation to the location of electrons.

In the interview following the chemistry lesson sequence, Ms. H acknowledged how the summary poster activity made visible the ongoing challenges her students experienced with constructing arguments from evidence. Ms. H explained:

> A lot of the students tried to draw [an image of] the Rutherford experiment and tried to explain this idea that things [alpha particles] were going through. . . . They were collecting evidence and they were able to make decisions [about the structure of an atom]. But connecting all of the experimental evidence to draw a conclusion, that whole scientific process, they weren't able to [state], "Here's my evidence. Here's my rationale." Therefore, then they can make a claim. They weren't able to make all of those steps.

Ms. H did not indicate any perceived differences in the quality of students' oral discussions in comparison to their written work. She also did not note that constructing an argument verbally was more or less challenging than documenting the same argument in writing.

In light of her students' continuing difficulties identifying evidence and articulating reasons, Ms. H reflected on her own practice. She discussed how and why she had incorporated different approaches to help students understand the elements of a scientific argument in the lesson sequences we observed.

> And in hindsight, you know, our department is focusing on claims, evidence, rationale, and it's something that I just started to do in the last two years. And trying to discover what's the best way to roll out how to do that analytical thinking [with my instruction]. . . . Do you talk about evidence first? Do you talk about claim[s] first? So professionally right now, I'm trying different, different approaches and I haven't found one yet that I feel like really concretely rolls out this method of internal dialogue that scientists have.

In our examination of classroom transcripts, we found that Ms. H did use varied approaches to teaching argumentation. Ms. H asked students (a) to generate their own claim and then support it with evidence (e.g., cartoon activity); (b) to first consider evidence from their investigation and then make an appropriate claim (e.g., balloon activity); and (c) to construct an argument using claims, evidence, and reasons (e.g., the chemistry summary poster). There was a common focus on the relationship between claims and evidence throughout these varied kinds of activities.

While ELLs' written work included some features of scientific writing, they experienced challenges in reading and producing science texts. The summary poster of the small group of Claudio, Felipa, Alexis, and Josefina, discussed in subsection two above, even with its limitations, exhibits a number of linguistic features of scientific writing; we counted this as a strength. First, the group's final product exemplifies what the NRC (2012) referred to as the multimodal nature of science texts. The poster includes both images (two drawings of Bohr models of assigned atoms) and written text (a description of what the two atoms share in common and an argument for the structure of the atom).

Second, the small group's written response exhibits a high lexical density, another linguistic feature of scientific writing (Fang, 2005; Halliday, 1993). The group's response includes four clauses, or a total of 57 words. (We did not count the two words that were crossed out, considered the term "alpha particles" to be comprised of two words, and read "+" as an adjective.) Of these 57 words, 27 (47%) are lexical items. Although Halliday (1993) himself did not calculate percentages in his discussion of the lexical density of scientific articles, the three examples he included (p. 76) range from 59% to 71%.

Third, the group's response also contains some aspects of the authoritativeness commonly found in scientific writing (Fang, 2005). One way an authoritative tone is conveyed is through the use of science-specific, rather than commonsense, vocabulary. Science-specific vocabulary terms the group included in their written response are evidence (used once), electron (used twice), alpha (used four times), particle (used four times), repel (used twice), and nucleus (used three times). Interestingly, in comparing the group's oral conversation to their written response, we found both similarities and differences in the science-specific terms employed; this comparison was introduced in subsection two above in our initial examination of the group's writing. The group used the terms "electron" and "nucleus" in both contexts. In their small group conversation, the students spoke about "negative" and "positive;" on their poster, however, the group only included the sign "+" likely to indicate the term positive. The group wrote the term "alpha particle" on their poster, which only Ms. H used in their small group conversation. The fact that Josefina wrote three of the four sentences of this group's response on her own might help to explain this mismatch between oral conversation and written product. Another way authoritativeness is conveyed is by using declarative, rather than imperative or interrogative, sentences. All four sentences on the poster are declarative. Passive also voice helps to convey an authoritative tone. While the first two sentences indicate the group as an agent (e.g., "the evidence that we have…" and "in the video that we saw…"), the second two statements do not.

Despite producing texts that exhibit linguistic features of scientific writing, ELL students struggled with several other aspects of the practice of obtaining, evaluating, and communicating information; we discuss two of these challenges here. One challenge was in moving from oral discourse to the communication of information in writing. An aspect of this struggle involved the mechanics of writing. The third transcript presented above highlights how Josefina's group attended to the mechanics of writing the summary paragraph – not to including the ideas they had just discussed or to successfully answering the prompt. In the final lines of this excerpt (lines 91 and 93), Josefina asked Alexis if he could repeat his sentence about the location of the electrons so that she could write it down. In the fourth transcript excerpt below, Josefina continued to seek her peers' assistance in the mechanics of documenting the group's ideas.

94 Josefina: How do you spell nucleus again?
95 Alexis/Claudio: N…
96 Alexis: U… C… L
97 Josefina: N… U… N, U what? Oh never mind, I got it. Uh-huh.
98 Claudio: [*pointing to poster*] No, you aren't supposed to E.
99 Alexis: Yeah.
100 Josefina: No E?
101 Claudio: No [*laughs loudly at Josefina*].
102 Alexis: Leave it there.
103 Claudio: It's cause it sounds like "neu" I know but just put "nu'' N, U.
104 Alexis: Just put "is."
105 Felipa: Just leave it like that, leave it like that.

The group continued to work on the construction of their first sentence – how to spell science terms (e.g., “Alpha particle”) and what to call the animation of Rutherford’s experiment – until Ms. H asked all groups to stop.

Another aspect of this struggle in moving from oral to written language was visible in this small group’s preoccupation with identifying what to write in response to the teacher’s prompt; this preoccupation with writing worked against their efforts to successfully articulate reasoning for their argument. Multiple members expressed the need to attend to how to write down their answer to Ms. H’s prompt (e.g., Josefina, lines 7-8 and 91; Felipa, line 14; Alexis, lines 19, 76, and 92). Further, once the group moved to the writing process, they used only part of Ms. H’s prompt as a starting sentence frame (see Alexis in lines 19 and 92). Students are typically taught in school to use questions as starting sentence frames in their responses; however, Alexis repeated only the first part of the prompt, *“what evidence do we have that the electrons are outside the nucleus,”* without the second part, “*the protons are inside the nucleus*.” This contributed to an incomplete display of the group’s understanding of atomic structure.

Yet another aspect of this struggle to move from oral to written language can be found in examination of the written response itself: There exists a gap between group members’ oral conversation about evidence and reasons (even if they were unable to fully articulate how and why the experimental findings counted as evidence) and what they included in their written work. In the previous section, we noted that Josephina failed to record on the poster that Rutherford’s experiment served as evidence for a positively charged nucleus. We also noted that while all three in-class activities were discussed orally by group members, only one activity was recorded in the group’s written summary. Taken together, the four small group excerpts document this group’s challenges in identifying, reasoning about, and writing down evidence for the structure of the atom. Failure to fully capture in writing ideas expressed orally, then, also contributed to an incomplete display of the group’s understanding of atomic structure.

A second challenge ELLs experienced with regards to written texts was obtaining information from their science textbook to inform conversation and activity in small groups. Groups completed a poster during the second day of the physics lesson sequence; recall that during the first two days of this lesson sequence, students had completed an analysis of a cartoon from the ICS textbook, engaged in an investigation, observed a phenomenon during a warm-up activity, and read a selected passage written in English from their ICS textbook. Groups were asked to summarize their understanding of changes in a sound’s pitch produced by (1) strings of varying lengths and (2) strings that had more or less tension on them. Each of the “boxes” on the poster was required to have a drawing and a caption.

Students in one small group completed two of the five boxes on their poster in English and two in Spanish; they left one box blank (see again Figure 1). In the interview excerpt below, Ms. H discussed how the group members worked to construct their poster, as well as identified strengths and limitations of the final poster itself.

1	*Speaking*	Ms. H:	Yes, because the reading [a section of the ICS textbook] was in English,
2			[this group’s] team members [worked with the bilingual aide to] read
3			each section out loud and then summarized the key idea in Spanish. And
4			I worked with them, helping them find the key sentence [from the
5			reading]. We translated the key sentence for that paragraph and then they
6			had to try to put that into their own words, so [this group’s poster is] not
7			complete in part because of the translation issue. So,
9	*Reading top left box*		Vibration is what causes sound.
10	*Speaking*		So that’s appropriate, it summarized the paragraph, they had a picture,

	they have a summary and they used a vocabulary word. And this is
Translating top right box	When you put -- when you add more tension to the string, it makes a higher noise, or a higher sound.
Speaking	[The students] didn't use the word pitch. Now this becomes difficult. I allow students to write in Spanish. Some of the vocabulary words, it's very [inaudible] to find an analog for the science word in Spanish. But some of them, it's more difficult. So this is an example where the word pitch – [students have] been using the [Spanish] word that translates directly [to] sound [in English] for the word pitch. So you don't get -- it's harder to compare [this group's poster] to other students' [posters].

Ms. H detailed the long and complex process this small group used to make sense of their science textbook written in English in creating their poster. The process included the group members, the bilingual aide, and herself. It also included moving across oral and written modes of English and Spanish. Because this small group needed to read, translate, digest, and summarize the ideas in the text, Ms. H continued, group members ran out of time and were unable to finish their poster. Instead of including five pictures with corresponding captions, the group was only able to draw one picture and write four statements.

Discussion and Implications

From our investigation, we found that Ms. H supported her urban high school ELL students in constructing arguments from evidence and in communicating information in three substantive ways. She (1) provided primary language support, most notably by allowing her students to use Spanish as well as English when participating in class discussions and completing assignments; (2) deliberately scaffolded students' efforts to develop arguments grounded in evidence; and (3) implemented small group work. These pedagogical choices, strategies recommended by researchers as effective in teaching ELL students science concepts and practices (Quinn et al., 2012; Rosebery & Warren, 2008), provided more and richer opportunities for ELLs to engage in discourse-intensive, sense-making practices of science.

Our analysis also revealed that high school ELLs experienced both successes and challenges in constructing and communicating arguments. For example, ELLs were able to state claims and identify evidence in their small group conversations, but experienced difficulties in articulating the reasons a piece of evidence should be connected to a claim. As such, this study underscores the immense complexity in meeting the needs of ELLs in learning discourse-intensive science practices. Even when a teacher believed in the importance of integrating content instruction and academic language development, and implemented multiple reform-based instructional strategies to teach discourse-intensive science practices, gaps between instructional goals and student learning outcomes persisted.

Our three sets of implications below are targeted at researchers and teachers working in classrooms similar to the one investigated here – where the teacher and most of her or his students share some proficiency in both English and Spanish. We argue that opportunities to learn the discourse-intensive practices of argumentation and communication should be both varied and carefully structured to facilitate ELL students' mastery of the languages of English and Spanish across oral and written modes of science discourse.

Implication 1: The Importance of Varied and Explicit Instruction in Argumentation

Science education reform documents highlight the importance of understanding the nature and purpose of scientific argumentation for all learners (Achieve Inc., 2013; NRC, 2012).

Such documents not only include descriptions of how argumentation should grow in sophistication over the course of a learner's K-12 education, but link the learning of this disciplinary practice to academic language development as well. Many subject matter teachers assume English language development happens outside of their classroom – during instruction in ESL or in language arts (Nieto, 2009). However, given the language demands of science that are now clearly articulated in current reform documents, science teachers must explicitly present and support students in learning science in English as a third language – one different from students' primary language and from conversational English (DeLuca, 2010). In brief, science teachers must "purposefully enact opportunities for the development of language and literacy in and through teaching the core curricular content, understandings, and activities that teachers are responsible for (and, hopefully, excited about) teaching in the first place" (Bunch, 2013, p. 298).

Like Quinn, Lee, and Valdés (2012), for Ms. H, constructing a scientific argument grounded in evidence, sharing one's ideas with others, and using precise language (her three dimensions of science discourse) were closely tied to her views regarding the importance of attending to the instructional needs of ELLs in her science classes. Ms. H provided her ELL students with multiple opportunities to develop claims, identify supporting evidence, and provide reasons across individual, small group, and whole class contexts. She encouraged students to talk with and listen to arguments or components of arguments offered by her or by their peers during small group and whole class discussions. Ms. H also explicitly defined and helped students to identify claims and evidence. She both modeled the language needed to discuss them and structured students in their own efforts to do so. Such deliberate scaffolds sit within Quinn, Lee, and Valdés' (2012) set of "discourse strategies" teachers should implement to support ELLs in learning discourse-intensive science practices (p. 8). Ms. H's deliberate scaffolds also resonate with Dutro and Moran's (2003) recommendations to foreground language forms (using specialized academic words) and language fluency (sharing science ideas with others), in addition to language functions (what a language can do).

From our findings, we argue that Ms. H engaged her ELL students in the discourse-intensive practice of argumentation by providing (1) variation in opportunities to learn coupled with (2) explicit instruction. We encourage other classroom teachers to do the same: to couple an explicit focus on argumentation with multiple kinds of learning opportunities so as to support ELL students in understanding what constitutes an argument and in articulating their own claims, evidence, and reasons. Teachers' instruction should include ongoing conversations about the nature of claims and evidence and how they are related, as well as modeling the academic language needed to discuss the two. Further, teachers must provide ELL students with carefully structured opportunities to both talk with and listen to their peers as they work to construct arguments and communicate ideas. Finally, explicit instruction must extend to when students are working to share their arguments verbally and in writing, as these two modes of representation present unique and distinct challenges for ELLs.

We caution, however, that even with varied learning opportunities coupled with explicit instruction, ELL students in our study experienced challenges as well as successes in arguing from evidence. In some cases, challenges we identified did not clearly resonate with existing research conducted with non-ELL students. For example, while previous studies have shown that the structure and complexity of non-ELL students' scientific arguments improve after explicit instruction in argumentation (Zohar & Nemet, 2002), even after a short period of time (i.e., three lessons, Venville & Dawson, 2010), we did not find explicit instruction sufficient to address the potentially unique needs of ELL students. Part of the mismatch between our findings and those of Zohar and Nemet (2002) and Venville and Dawson (2010) might be the result of different research designs: The latter two sets of researchers looked for improvement in the practice of argumentation pre to post instruction while we examined student construction of arguments primarily in the moment. As such, more research is needed to better understand outcomes for ELLs versus non-ELLs when science teachers provide explicit instruction in argumentation.

In other cases, challenges ELL students in our study experienced in learning the practice of argumentation match those identified by other researchers. As an example, in the extended small group discussion about their chemistry summary poster, group members were not always able to connect claims with evidence or to articulate how evidence supported a particular claim. Indeed, Ms. H herself noted such challenges experienced by her ELL students in her interviews. These findings are consistent with other studies documenting the challenges middle and high school students who are fluent in English experience when constructing or evaluating scientific arguments. Hogan and Maglienti (2001) found that middle school students assigned a higher ranking to claims consistent with their prior knowledge and with their own interpretations of the evidence, whereas scientists focused more on whether the claims were appropriately supported by data provided. Sandoval and Millwood (2005) found that high school students struggled with supporting claims with an appropriate amount of evidence and reasoning (what the authors referred to as warrants). Again, more research on the teaching and learning of argumentation, on ways to refine and enhance multiple opportunities for learning and explicit instruction in argumentation, particularly in classrooms where ELL students are present, is needed.

Implication 2: **The Importance of Primary Language Support in Science Classrooms**

Primary language support is housed under the umbrella of sheltered instruction. From a sociocultural frame that values interaction and collaboration (Palincsar, Brown, & Campione, 1993), as well as students' funds of knowledge (Moll, Amanti, Neff, & Gonzalez, 1992), the role of ELLs' primary language in instruction is considered significant. Primary language support can not only help ELLs better comprehend material, but can serve as a means for mediating learning by enabling students to seek further clarification and to convey their understanding. It can also facilitate the learning process, reduce psychological frustration, increase comprehension, and strengthen concept understanding (Cline & Necochea, 2003; Cummins, 1981). In a climate where English-only is favored in educational and societal settings, allowing students to use their primary language affirms language as a valuable resource rather than as a problem to be overcome (Ruiz, 1994). Indeed, *A Framework for K-12 Science Education* (NRC, 2012) recognizes "the importance of accepting, even encouraging, students' classroom use of informal or native [primary] language and familiar modes of interaction" (p. 285).

Our findings underscore the importance of implementing primary language support in science classrooms. Ms. H's instructional practices allowed students to use their primary language (in this case, Spanish) as a tool towards understanding and gaining fluency in academic English. The integration of Spanish as a resource for learning created possible spaces (Moll et al., 1992; Moje et al., 2001; Ruiz, 1994) where ELLs could engage with, talk about, and present on the content material. This is not to say that the implementation of primary language support in Ms. H's classes was dilemma-free. For example, Ms. H perceived a tension between encouraging students to use their primary language of Spanish to express science understanding and preparing them for the end-of-year statewide tests administered in English. As a result, she encouraged students to use English when they were able to do so. Still, Ms. H's commitment to and facilitation of speaking and writing in Spanish made clear that even when a teacher is not a fluent speaker of her students' primary language, providing primary language support is still possible.

Despite Ms. H's use of sheltered instructional strategies, particularly primary language support, there existed an imbalance in participation between ELLs and non-ELLs during whole class discussions. Part of this imbalance emerged from the way Ms. H implemented and her students took up group roles in activities; this was discussed in our findings above. This imbalance in whole class versus small group participation may also have been due, in part, to a perception of a power differential between English and Spanish in the classroom, as has been noted in the literature (Cummins, 2000; Moll et al., 1992; Nieto, 2009; Ruiz, 1994). That is, if ELL students in Ms. H's class indeed perceived English to be the language of power and the language of instruction, one would expect them to be less willing to share their ideas – in either English or Spanish – in whole class settings orchestrated by Ms. H.

A promising way to address this imbalance in whole class participation between ELL and fluent English-speaking students is to make movement across conversational Spanish, conversational English, and the academic discourse of science in both languages more explicit and transparent for students (Cummins, 2000; Lindholm-Leary, 2001). In order to do so, teachers must refine the pedagogical strategies that they use. Ms. H, for example, might have more carefully orchestrated small group presentations to the whole class by asking an ELL student to co-present with a fluent English-speaking group member. This type of student pairing, in turn, might have influenced which languages students used and how they used them both during small group conversations and presentations to the whole class. Ms. H might also have made more explicit her practice of tandem talk (Lee et al., 2008), where she used English to build from students' ideas expressed in Spanish. The use of tandem talk would not only strengthen the implementation of primary language support, but reduce the need for others (peers, the bilingual aide, or bilingual teacher colleagues) to translate between Spanish and English, and thus, lessen the ambiguities associated with such translations. Further, Ms. H might have required students who were bilingual to speak and write arguments and captions for illustrations in both languages. This would have allowed her to routinely discuss the importance of language in science, and to better ascertain what students knew and could do by looking across arguments, illustrations, and illustration captions in two languages. Again, such a regular practice would not only enhance primary language support, but reduce the need for others to translate English into Spanish for ELLs, and thus, lessen the ambiguities associated with such translations as well.

Implication 3: Attending to Kinds of Communicative Opportunities and Modes of Representation in Small Group Work

In Ms. H's classes, students sat in assigned groups, strategically formed to maximize opportunities for ELLs to interact. Research makes clear that the more students talk in small groups, the more they learn (Cohen & Lotan, 1997; Bianchini, 1997). Research also suggests that increased student participation and peer interaction facilitate English language and academic English acquisition better than teacher-directed initiatives (Mohr & Mohr, 2007). The findings from our study further highlight the importance of implementing small group work as a way to meet the needs of ELLs (with activities that enable teachers to formatively assess students' understanding). Ms. H utilized small groups to encourage ELLs to talk science and to provide ELLs opportunities beyond whole class discussions and lectures to engage in learning science concepts and practices. Her movement between whole class instruction and small group work aligns with recommendations made by Quinn et al. (2012). As with primary language support, we found small group work provided a fruitful context for ELLs to construct scientific arguments with their peers: Transcripts revealed the richness of their conversations – both in terms of the resources they used (i.e., Spanish, English, and gestures) and their desire to accurately communicate their understanding of natural phenomena.

However, again, as with primary language support, our findings also raise important questions as to what small group work should look like when teaching ELL students discourse-intensive science practices. We recommend more careful attention to the kinds of communicative opportunities provided and modes of representation encouraged. Our recommendation to attend to kinds of communicative opportunities is grounded in our finding that ELL students' participation in small groups did not necessarily translate to their participation in the whole class. To better facilitate the transition between small group and whole class participation, we suggest that teachers monitor not only which students participate during the class period, but in which context(s) (whole class discussions, questions during lectures, small group work, pair activities, etc.) they do so -- to better understand in which kinds of communicative opportunities individual ELL students participate. Our suggestion above to pair an ELL student with one fluent in English during presentations to the whole class is another step toward easing this transition.

Our recommendation to more closely attend to the modes of representation students employ during group work emerged from our finding that small group discussions were not necessarily captured in writing on posters. To help ELL students more easily move between oral and written discourse, we suggest teachers intersperse short writing prompts within small group tasks. The purpose of these prompts would not be to disrupt small group conversations (Cohen & Lotan, 1997), but to provide students small, frequent opportunities to record their ideas in writing and to prompt deeper conversations by allowing time for reflection. For example, at the beginning of a small group activity, a teacher could ask individual group members to (1) identify a key sentence (a central science idea) in the group task, (2) rewrite the sentence in her or his own words, and (3) then share her or his sentence with each other.

Concluding Thoughts

This study contributes new insights into the teaching and learning of discourse-intensive science practices for ELLs in urban high school classrooms. It suggests important refinements to our understanding of the ways teachers and students can use language to construct and communicate arguments from evidence orally and in writing, as well as the roles of primary language support and small group work in the teaching and learning of these practices. As stated in our implications, more research on how teachers and their ELL students engage in discourse-intensive science practices, particularly at the secondary school level, is needed; we offer two additional directions for future work here. One avenue of needed research relates to ways to support ELLs in engaging in argument and communicating information across different instructional contexts and using different modes of representation. For example, as presented in our findings and discussed in our implications, our study suggests the need to better understand how to encourage ELLs to present posters and to share out ideas during whole class discussions. Another avenue in need of additional research is how to provide primary language support in classrooms where teachers attempt to engage their students in constructing and communicating arguments but cannot speak the primary language(s) of their students and/or have students who speak multiple primary languages. Certainly, some of our recommendations would not be relevant or viable in classrooms where the teacher and many of his or her students did not share two common languages. Such additional research, conducted in the context of developing language and literacy in and through teaching disciplinary concepts and practices, should help the field move closer toward a science education for *all* students, including the ever increasing number of ELL students who are learning the languages of English and science at the same time.

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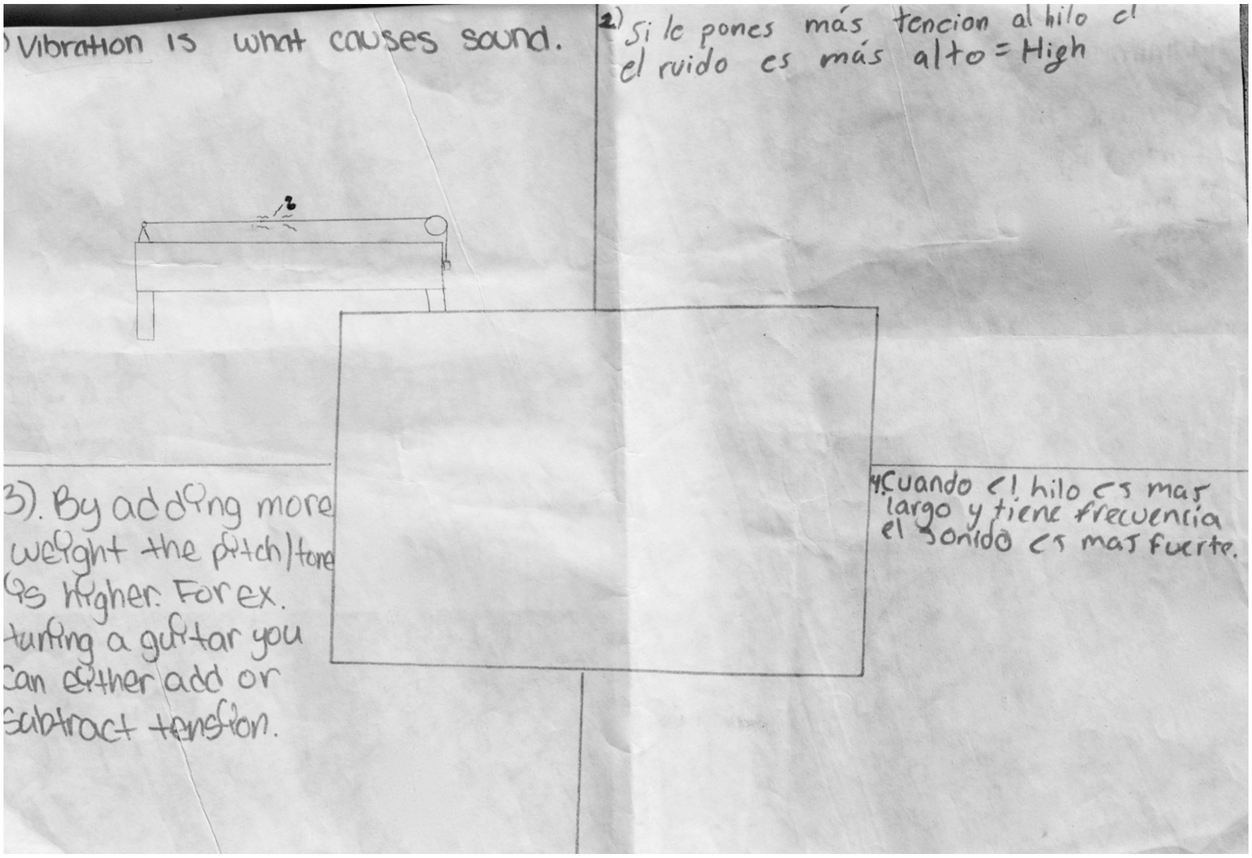

Figure 1. Group poster depicting the relationships among string length, tension, and pitch

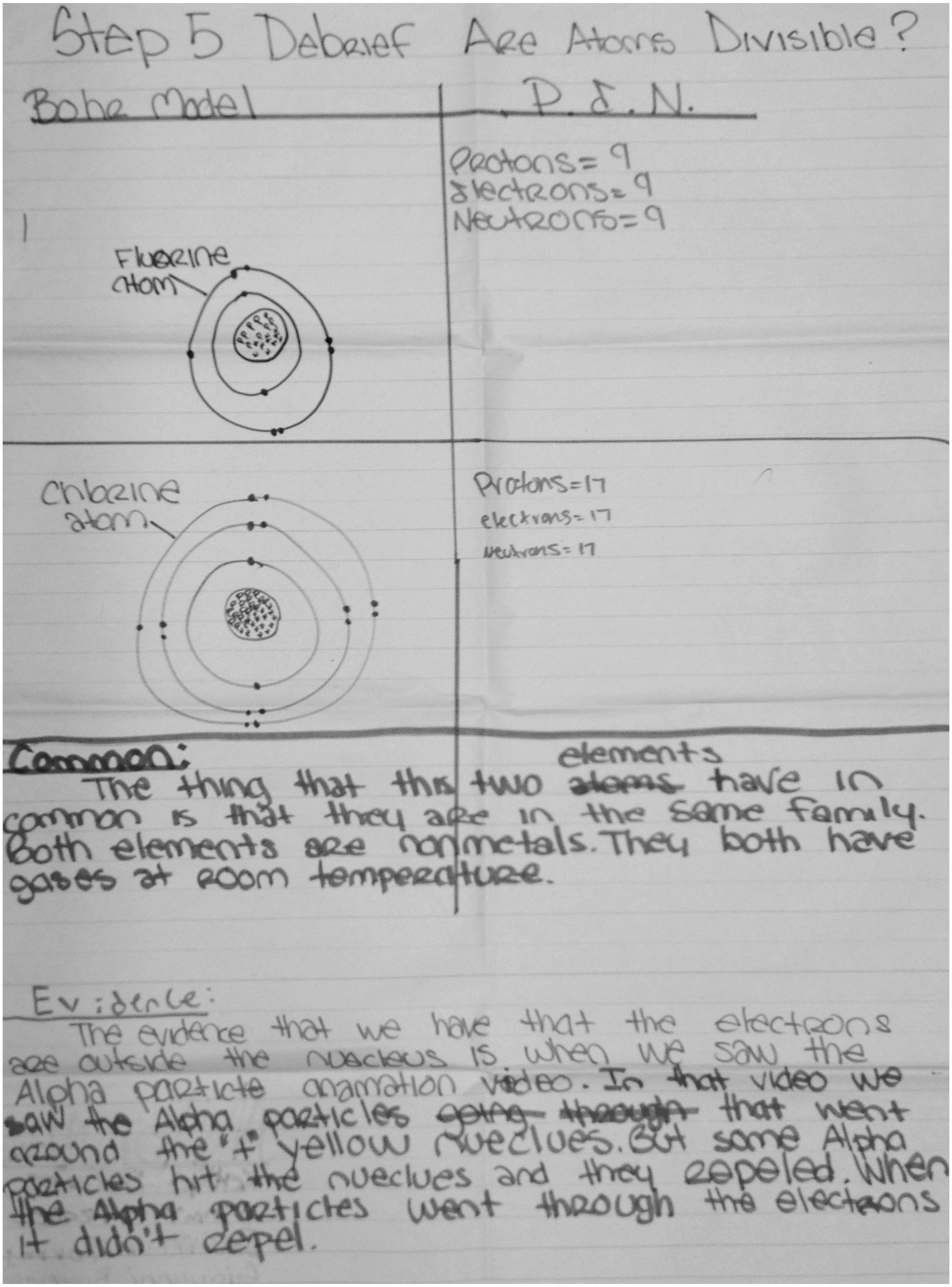

Figure 2. Group poster depicting drawings of and argument for structure of atoms