International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

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To cite this article: María González-Howard, Katherine L. McNeill, Lisa M. Marco-Bujosa & C. Patrick Proctor (2017): 'Does it answer the question or is it French fries?': an exploration of language supports for scientific argumentation, International Journal of Science Education, DOI: 10.1080/09500693.2017.1294785

To link to this article: http://dx.doi.org/10.1080/09500693.2017.1294785

Published online: 19 Mar 2017.

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INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2017
http://dx.doi.org/10.1080/09500693.2017.1294785

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'Does it answer the question or is it French fries?': an exploration of language supports for scientific argumentation

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ABSTRACT

Reform initiatives around the world are reconceptualising science education by stressing student engagement in science practices. Yet, science practices are language-intensive, requiring students to have strong receptive and productive language proficiencies. It is critical to address these rigorous language demands to ensure equitable learning opportunities for all students, including English language learners (ELLs). Little research has examined how to specifically support ELL students' engagement in science practices, such as argumentation. Using case-study methodology, we examined one middle school science teacher's instructional strategies as she taught an argumentation-focused curriculum in a self-contained ELL classroom. Findings revealed that three trends characterized the teacher's language supports for the structural and dialogic components of argumentation: (1) more language supports focused on argument structure, (2) dialogic interactions were most often facilitated by productive language supports, and (3) some language supports offered a rationale for argumentation. Findings suggest a need to identify and develop supports for the dialogic aspects of argumentation. Furthermore, engaging students in argumentation through productive language functions could be leveraged to support dialogic interactions. Lastly, our work points to the need for language supports that make the rationale for argumentation explicit since such transparency could further increase access for all students.

ARTICLE HISTORY
Received 4 August 2016
Accepted 10 February 2017

KEYWORDS
Argumentation; English as a second/additional language; language supports

Science education traditionally comes across as students memorising a series of uncontested facts, with the idea that scientists engage in a singular scientific method (Osborne, 2010). Because this perception is far from how the discipline is carried out in real life, many countries have taken initiatives to reconceptualise how science is taught and learnt. A central feature of these reform initiatives is for students to engage in authentic practices of the scientific community. One of these practices, scientific argumentation, is stressed in new standards, reports, and curricula of many European countries (Science Teacher Education Advanced Methods [S-TEAM], 2010), Australia (ACARA, 2012), and the United States (NGSS Lead States, 2013). Educational researchers across the world have advocated for integrating argumentation into classroom instruction,

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arguing for its significant role in the development of scientific competence (Erduran, Ozdem, & Park, 2015). Specifically, argumentation allows students to take a more active role in their learning as they interact dialogically with peers to construct, critique, and refine understandings of scientific phenomena (Ford, 2012).

Engagement in science practices, including argumentation, requires students to use language in complex ways (Lee, Quinn, & Valdés, 2013). To partake in argumentation, for instance, students need to employ language skills across different functions (i.e. reading, writing, speaking, and listening) in order to take in new information, make sense of it in light of their existing understandings, and express learning. These rigorous language demands are important to consider with respect to the rapid changes that are occurring in student demographics worldwide. As a global educational phenomenon, immigration has resulted in immigrant children entering schools who do not speak the societal language of the receiving country (Suárez-Orozco, Suárez-Orozco, & Todorova, 2008). Language and literacy research has documented this occurrence in many countries, such as Canada (Geva & Farnia, 2012), Germany (Limbird, Maluch, Rjosk, Stanat, & Merkens, 2014), and Norway (Lervag & Aukrust, 2010).

In the United States, national reports indicate that about 20% of current students speak languages other than English at home (U.S. Census Bureau, 2012). Moreover, English language learners (ELLs) constitute the fastest growing student population in the United States (National Center for Education Statistics, 2012). To ensure successful implementation of science reforms, teachers will need to make instructional shifts and have strong understandings of not only science practices, but also of strategies for supporting all students, regardless of English proficiency levels. However, the reality is that ELL students 'frequently confront the demands of academic learning through a yet unmastered language without the instructional support they need' (Lee & Buxton, 2013, p. 37). Thus, it is critical that research bridging science and second language learning explore and identify pedagogical approaches for supporting ELL students in language-intensive science practices. Findings from such work could help science teachers better attend to the linguistic demands their ELL students face in the classroom, all the while maintaining the rigour of students' science learning. Towards this end, our study investigates language supports that teachers could use to engage ELL students in argumentation.

Theoretical framework

To contextualise this study within the larger field of science education, we review two areas of research. The first area focuses on argumentation in science education. In this section, we define argumentation, distinguishing between its structural and dialogic components, both of which are necessary to consider when exploring the ways in which teachers instruct and support their students in this science practice. In this section, we also describe challenges students commonly experience engaging in argumentation. Secondly, we review the limited research that exists on argumentation and ELL students, concentrating on the language demands inherent to this science practice, as well as highlighting factors that have been shown to influence ELL students' argumentation experiences.

Scientific argumentation in education

Similar to Jiménez-Aleixandre and Erduran (2008), we conceptualise argumentation as a complex practice that encompasses two interrelated components: the structure of an argument, and the dialogic interactions that take place as individuals form and make sense of arguments. The structure of an argument includes a claim that is justified by evidence and reasoning (McNeill, Lizotte, Krajcik, & Marx, 2006). Within this structural framework, a claim is an answer to a question; evidence includes relevant measurements or observations that support a particular claim; and reasoning, which often incorporates scientific principles and ideas, functions as the connection between the claim and evidence. Research has found that focusing on the structure of an argument and the epistemological role each piece plays is an important and useful entry point for teaching students about this science practice (McNeill et al., 2006; Von Aufschnaiter, Erduran, Osborne, & Simon, 2008). However, these structural pieces are not constructed in isolation. Students build and revise potential arguments to explain natural phenomena in coordination with other classroom members (Andriessen, 2007); these social interactions are what make up the dialogic component of argumentation. Supporting students' sensemaking of scientific phenomenon, these social interactions encompass students engaging in the processes of construction and critique (Ford, 2012). Consideration of the dialogic component of this science practice is crucial in order for students to develop an understanding of *how* and *why* to construct, critique, and revise arguments (Henderson, MacPherson, Osborne, & Wild, 2015). Thus, equal attention ought to be placed on both components when examining argumentation in science classrooms.

Moreover, research has demonstrated the myriad ways in which teachers influence if, when, and how students engage in both the structural and dialogic components of argumentation. The teacher plays a critical role in establishing a classroom environment in which this science practice is carried out (Simon, Erduran, & Osborne, 2006). The role of the teacher includes the types of questions they ask to prompt students to justify their ideas with evidence (Evagorou, Jiménez-Aleixandre, & Osborne, 2012; McNeill & Pimentel, 2010), as well as the manner by which tasks are framed so that students attend to their peers' ideas (Berland & Hammer, 2012). However, supporting students in argumentation also necessitates teachers being cognisant of the linguistic demands inherent to this science practice. Both the structural and dialogic components of argumentation are particularly language-rich, as they require students to use language in various ways to perform complex analytic tasks (González-Howard & McNeill, 2016). For instance, for a student to question another person's argument, they need to not only take in and make sense of their peer's idea, but then also communicate their question in a comprehensible fashion.

Research in argumentation, which has been conducted in a variety of classrooms with differing student populations, has found the language functions required by this science practice to be challenging for students. For example, when writing arguments, students might struggle with providing adequate evidence (Sandoval & Millwood, 2005), and may be unable to explain why they chose particular evidence in support of a claim (i.e. their reasoning) (Bell & Linn, 2000). Additionally, when engaged in this science practice through talk, dialogic interactions between peers can be challenging for students during both small group (Evagorou & Osborne, 2013; Sampson & Clark, 2009) and whole-class discussions (Erduran, Simon, & Osborne, 2004). As evidenced by this work, rich language processes are foundational to argumentation, and research has documented all students struggling with aspects of this science practice. However, most studies on argumentation have been conducted in mainstream classrooms, not explicitly examining the experiences of ELL students. This is problematic given the integral relationship between science and language; language is the means by which to engage in the types of analytic tasks that result in science learning (Lee et al., 2013; Rosebery & Warren, 2008). And although all students encounter challenges when partaking in argumentation across writing and talk, the difficulties for ELL students might be augmented because they are conducting them in a language in which they are not fully proficient (Lee et al., 2013). Consequently, exploring the instructional moves that teachers employ when supporting these language demands is critical to making argumentation accessible for *all* students.

Argumentation and ELLs

Science practices encompass increased rigour of what students need to be able to do with language as they interact with peers during the learning process (Hakuta, Santos, & Fang, 2013). In terms of argumentation, students might partake in this practice using receptive (i.e. listening or reading) and/or productive (i.e. speaking or writing) language functions. For instance, they might read arguments in a science text describing different explanatory claims for why dinosaurs became extinct, and then be prompted to argue orally with peers about which claim they believe is strongest. While all students experience difficulties with these language demands, these challenges are amplified for ELL students (Lee et al., 2013). Yet, despite changing student demographics, and the push for science educators to integrate language-intensive science practices in their instruction, little existing literature addresses the argumentation experiences of ELL students and their teachers. However, reform efforts have begun to stimulate new research agendas focused on supporting all students – including those who have been historically marginalised from the discipline – in meeting the academic rigour set forth by new visions of science proficiency (Lee, Miller, & Januszyk, 2014).

For instance, Lee et al. (2016) recently explored how teachers' knowledge and instruction were impacted by a curricular and professional development intervention focused on promoting science for ELL students. They found positive effects from the intervention on teachers' instruction, particularly in terms of their use of inquiry-based activities and language development strategies. However, although appropriate given the large-scale nature of the intervention, this work relied on teachers' self-reported instructional practices. Classroom observations would more accurately depict how teachers attend to their ELL students' needs during science instruction. Additionally, the curriculum in Lee and colleagues' study included guidance and scaffolding for students' English language development as it pertained to their science learning (e.g. translated key science terms, science content represented through multiple modes such as text and graphics). While an important feature, we argue that it is also necessary to provide language supports that are specific to the science practices, such as argumentation. Not only is student engagement in these science practices a learning goal in itself, but it is also a means through which to support students' development of scientific knowledge (Osborne, 2014).

On a much smaller scale, Swanson, Bianchini, and Lee (2014) conducted a case study documenting the instructional strategies a high school teacher used to engage her ELL students in argumentation. Their analysis revealed that the teacher deliberately used language supports to make argumentation more accessible for her students, including translating materials, and providing students with explicit structures, like graphic organisers, for presenting arguments. While insightful, this study did not explore how the instructional strategies aligned with the quality of students' argumentation, nor did it tease apart which argumentation component – structure or dialogic interactions – the strategies addressed. Because such information is important to fully support student engagement in this science practice, we set out to extend this prior research by more deeply exploring the argumentation experiences of ELL students and their teacher. Specifically, our work was guided by the following research question –*What is the nature of language supports that a teacher employs to support her ELL students' engagement in the structural and dialogic components of argumentation?*

Methodology

In the following sections, we describe the qualitative research methods that were utilised to develop a single case study of our focal teacher's classroom. Case-study methodology (Yin, 1994) provided an appropriate means for the exploratory nature of this work. Although a single case study does not enable broad generalisations, the descriptions of this teacher and her students shed light on the strategies that might be employed to engage ELLs in this science practice. Thus, this approach aims to provide insight into a largely unexplored area of research with regard to understanding how to instruct and support ELL students in language-intensive science practices. Moreover, a case study enables us to richly illustrate the instructional strategies this teacher enacted that fostered her students' argumentation experiences.

Curricular context

This study occurred in the context of teachers piloting a middle school life science curriculum that integrated science and literacy instruction in order to support student engagement in science concepts across reading, writing, and speaking (Pearson, Moje, & Greenleaf, 2010). Furthermore, lessons in this curriculum were written to elicit student engagement in argumentation. The curriculum was made up of two life science units titled *Microbiome* and *Metabolism* (Regents of the University of California, 2013a; 2013b). During the first unit, *Microbiome*, students explored the idea that changes in a person's microbiome result in alterations to that person's health, for better and for worse. Students also learned about faecal transplants, a medical treatment that involves using one person's healthy microbiome to cure another person who is suffering from life-threatening bacteria called *C. difficile.* During the second unit, *Metabolism*, students learned how the human body systems work together to produce energy by getting matter to and from cells. Throughout this unit, students often used a metabolism simulation run through a tablet computer to investigate body systems that were and were not working properly (e.g. a person training to become an athlete, or a person with diabetes).

Six target lessons were purposefully selected for analysis, with three lessons chosen from each unit, all with an emphasis on either the structural or the dialogic components of argumentation. For instance, while Lesson 1 focused on argument structure, encouraging students to decipher irrelevant information from relevant evidence in support of a particular claim, Lesson 6 stressed dialogic interactions, as students evaluated and debated competing claims. Furthermore, lessons were chosen with consideration of the manner by which students were expected to use language to engage in argumentation. Specifically, across the target lessons, students participated in argumentation using both receptive (e.g. reading) and productive (e.g. speaking) language functions. For example, in Lesson 2 students read model arguments to develop an understanding of characteristics that make arguments persuasive (such as articulating reasoning), while in Lesson 5, they orally debated which of two claims was best supported by evidence. It was important that the target lessons elicit student engagement in both the structural and dialogic components of argumentation across language functions in order to explore how the teacher's argumentation instruction attended to the full span of her ELL students' linguistic needs.

Participants

One of the teachers who piloted this curriculum was intentionally selected from part of a larger project (Marco-Bujosa, McNeill, González-Howard, & Loper, 2017). This teacher, Ms. Newbury (a pseudonym), taught in a sheltered English instruction (SEI) setting, a learning environment where content and language development objectives are simultaneously taught (Echevarria, Vogt, & Short, 2008). In this case, the content was science. Ms. Newbury was a White, native English speaker in her mid-30s who had been teaching for almost 10 years. She possessed a master's degree in education, was certified to teach middle school science, and had completed a series of professional development workshops around planning and delivering lessons in support of ELL students acquiring academic knowledge while developing English proficiency. In terms of argumentation, Ms. Newbury had attended a few workshops about this science practice before piloting this curriculum, and self-reported incorporating argumentation in her classroom instruction many times. Thus, given our interests in exploring language supports for argumentation, the combination of Ms. Newbury's background and her instructional context made her an excellent subject for this case study.

As the only SEI middle school science teacher in her school, Ms. Newbury was responsible for teaching many classes of students across grades and English proficiency levels. The students in the class we observed were a mixture of 6th and 7th graders (i.e. students ages 11–13) with beginning levels of English proficiency. All of the students in this class were native Spanish speakers who had recently immigrated to the United States from countries in Central and South America. These students' backgrounds were not unique to the school in which Ms. Newbury taught. Ms. Newbury's classroom was located in a public school in the Northeast United States that served nearly 800 students in kindergarten through 8th grade (i.e. students ages 5–14). Mirroring the nearby community's population, student demographics of the school was approximately 73% Hispanic, 15% White, 9% African-American/Black, 2% Asian, and 1% Other. Furthermore, 79% of the students in the school were eligible for free and reduced lunch, and 50% were identified by the school district as ELLs.

Data collection and analysis

The data source collected for this study consisted of video recordings of the six target lessons. Most of the lessons took place over multiple class periods, resulting in approximately 7½ hours of video footage. In examining these videos, we were interested in how students engaged in argumentation, as well as how the teacher supported students in this science practice. We explored these experiences in two different ways: student engagement in argumentation, and teacher language supports. First, we focused on the quality of students' argumentation across the target lessons. We developed a coding scheme for this analysis using the theoretical framework, as well as an iterative analysis of the data (Miles, Huberman, & Saldaña, 2013). Table 1 provides a synthesised version of this coding scheme.

This coding scheme focused on key characteristics of both the structural and dialogic components of argumentation as identified in recent literature (e.g. Jiménez-Aleixandre & Erduran, 2008; McNeill, González-Howard, Katsh-Singer, & Loper, 2016). Specifically, in terms of the structural component of this science practice, these key characteristics included students' justifying claims with evidence and reasoning; while for the dialogic component, key characteristics entailed students questioning, critiquing and building off peers' ideas, as well as critiquing competing claims. For every lesson, students' argumentation for each key characteristic was coded in terms of presence and quality, where the unit of analysis was the entire class of students (not an individual student). Specifically, students' argumentation for each key characteristic received a score where: present and of high quality = 2, present and of low quality = 1, and not present = 0.

Table 1. Synthesised video coding scheme of students' argumentation.

Argumentation component	Presence and quality		
	High	Low	Absent
Argument structure	Numerous students : • Support their claims with high-quality evidence. • Explain the link between their evidence and the claim using scientific ideas (i.e. reasoning). High-quality evidence and reasoning are a part of the classroom norms.	The use of high-quality evidence and reasoning is part of some students' contributions, but not of a large percentage of the students in class.	No students use high-quality evidence or explain their reasoning.
Dialogic interactions	Numerous students: • Question and critique arguments produced by peers, and listen and build off of others' ideas. • Consider and critique competing claims. This type of interaction is a part of the classroom norms.	These types of interactions are part of some students' contributions, not of a large percentage of the students in class. Most students present ideas or talk directly to the teacher, but do not substantially interact with peers. Also, most students consider competing claims, but do not critique them.	Students do not interact with peers, as the teacher tends to direct the conversation. Also, students do not consider or critique competing claims.

Thus, the highest score students could receive in a lesson across the key characteristics of both the structural and dialogic components was 8 (i.e. evidence = 2, reasoning = 2, questioning, critiquing and building on other's ideas = 2, and critiquing competing claims = 2). Two independent raters coded each target lesson's video recording using this coding scheme, and obtained 82% reliability. Any disagreements about coding were resolved through discussion.

Secondly, descriptive coding (Saldaña, 2013) was used to identify and inventory the language supports Ms. Newbury employed to attend to her students' learning of and engagement in argumentation during the target lessons. Using this analytical technique, two independent raters re-watched each video and coded it with regard to the teacher's language supports. Table 2 includes the name and a description of each language support for argumentation that emerged from this analysis.

Afterwards, these raters met to discuss and categorise their inventoried accounts of these codes. Specifically, when synthesising these language supports, we took note of which area(s) of argumentation they supported (i.e. argument structure, dialogic interactions or both). When conducting this analysis, it became apparent that Ms. Newbury's language supports actually took on two forms. Some supports generally helped her students to attend to one of these argumentation components (e.g. sentence starters that reminded students to include reasoning in their written arguments). Meanwhile, other language supports focused on providing a rationale that would help her students understand *why* these argumentation components are important (e.g. explaining to students how particular phrases related to reasoning, such as 'this means that _____', make

Table 2. Language support codes and descriptions.

Code	Description
1. Check for understanding	Monitoring student comprehension, which can take place as students read written arguments or listen to others speak (e.g. stopping a video argument to ask students 'what was that person's claim?').
2. Concept wall of argumentation terms	Including a visual representation of key terms and ideas that students ought to know to engage in argumentation tasks (e.g. what counts as scientific evidence).
3. Simplification of claim	Modifying the language of a claim to make it more comprehensible for students.
4. Allowing native language use	Enabling students to use their first language to engage in an argumentation task. Students might choose to use only their first language or work across multiple languages.
5. Vocabulary instruction of argumentation related words	Defining words that are important for students to know and understand to better engage in argumentation tasks (e.g. the meaning of 'relevant').
6. Modelling language expectations for an activity	Making explicit how students ought to use language to engage in an argumentation activity (e.g. highlighting how a written argument is structurally organised).
7. Peer modelling	Having students demonstrate to peers how to carry out an argumentation task (e.g. a pair of students verbally critiquing each other's written arguments).
8. Providing extended time	Giving students additional time in class to construct ideas and/or complete an argumentation activity.
9. Writing scaffolds	Providing students with instructional supports for writing arguments, such as a template that highlights an argument's structure.
10. Working with peers	Allowing students to interact with other students to complete argumentation tasks, which can give them opportunities to jointly develop language and engage in sensemaking.
11. Conversational sentence starters	Providing students with phrases around the structural and dialogic components of argumentation that help them enter discussions (e.g. 'I disagree with _____ because_____').

an argument more persuasive). Thus, the language supports identified across the six target lessons were not only categorised by the argumentation component they aligned to (e.g. argument structure), but also to whether they were a general language support, or one that offered a rationale. Moreover, language supports were classified as supporting either receptive (reading and listening) or productive (speaking and writing) language skills, as they related to students' argumentation engagement. Depending on its use during a lesson, a language support could align with both types of language functions.

After coding the videos in both of the ways just described, we summarised the analyses through visual representations (see Figure 1 and Table 3) to find trends in the data (Miles et al., 2013). We examined these displays, searching for patterns between and across the students' argumentation and the teacher's instruction. This resulted in the identification of three trends that describe the nature of Ms. Newbury's language supports for argumentation.

Findings

As previously mentioned, the purpose of this study was to identify and characterise the nature of the language supports that Ms. Newbury utilised to engage her ELL students in the structural and dialogic components of argumentation. Our findings are presented in two sections. The first section provides an overview of the students' argumentation across target lessons, which serves as a context for examining Ms. Newbury's language supports. The second section, which is organised around the three trends that characterised the language supports, discusses the instructional strategies that Ms. Newbury employed in more depth.

Overview of students' argumentation

Overall, the presence and quality of students' argumentation varied throughout the six target lessons. Figure 1 includes an overview of students' argumentation across both the structural and dialogic components of this science practice.

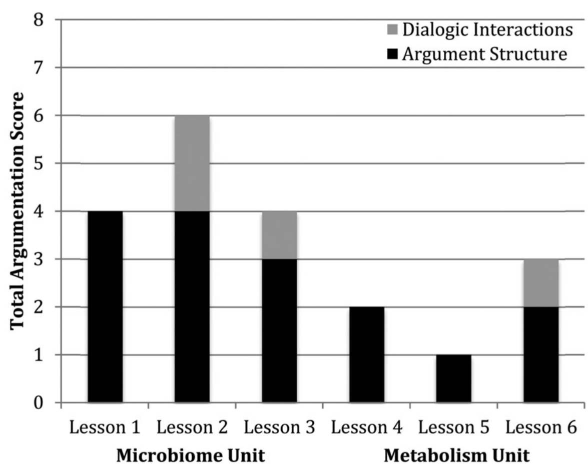

Figure 1. Presence and quality of students' argumentation.

Table 3. Presence and focus of language supports across target lessons.

Language function supported	Language support	Target lesson: *Microbiome* unit, Lesson 1	Lesson 2	Lesson 3	*Metabolism* unit, Lesson 4	Lesson 5	Lesson 6
Receptive	1. Check for understanding	S, $\boldsymbol{S_R}$		S	S		S
Receptive and productive	2. Concept wall of argumentation terms	S	S				
	3. Simplification of claim	S	S	S			
	4. Allowing native language use			S	S	S	
	5. Vocabulary instruction of argumentation related words	$\boldsymbol{S_R}$, $\boldsymbol{D_R}$	$\boldsymbol{D_R}$				
	6. Modelling language expectations for an activity	S, $\boldsymbol{S_R}$	S, $\boldsymbol{S_R}$, $\boldsymbol{D_R}$				
Productive	7. Peer modelling	S, $\boldsymbol{S_R}$		S			
	8. Providing extended time	S, D	S, D	S			
	9. Writing scaffolds		S, $\boldsymbol{S_R}$, D		S, $\boldsymbol{S_R}$		
	10. Working with peers				S, D	S, D	
	11. Conversational sentence starters						S, D

Argumentation component supported: S = Structure, $\boldsymbol{S_R}$ = Rationale for Structure, D = Dialogic Interactions, $\boldsymbol{D_R}$ = Rationale for Dialogic Interactions.

As illustrated by Figure 1, students' argumentation was stronger in the *Microbiome* unit than in the *Metabolism* unit. Out of a possible score of 8 (which would be given if all of the key argumentation features were present and of high quality), students averaged a score of 4.7 across the three lessons in the *Microbiome* unit, and a score of 2 across the three lessons in the *Metabolism* unit. We would not expect any one lesson to offer opportunities for students to engage in all of the key characteristics of both the structural and dialogic components of argumentation, as each lesson was written to focus on a particular aspect of this science practice. Nonetheless, during the first unit, students more frequently justified their claims with evidence and reasoning, and interacted with peers as they constructed and evaluated arguments.

Furthermore, we observed some alignment between the argumentation component targeted in a particular lesson and how students' engagement in this science practice was scored during analysis. For instance, Lesson 1 focused on argument structure, which was the area students scored high in this lesson in terms of both presence and quality. Similarly, students were coded as engaging in dialogic interactions (albeit with low quality) in Lesson 3, which emphasised this argumentation component. However, we did notice that – regardless of each target lesson's argumentation focus – students were more often coded as using the structural pieces of an argument (i.e. justifying their claims with evidence and reasoning) than they were coded for interacting dialogically with other students as they engaged in argumentation. This was especially evident, in that students were coded as participating in the dialogic component of argumentation in only three target lessons (Lessons 2, 3, and 5), while they were coded as using the structural features of an argument to some degree in all target lessons.

The main takeaways from examining students' argumentation were that their engagement was more prevalent and stronger during the first unit than it was during the second unit; and across the target lessons, students attended to the structure of an argument more than they engaged in dialogic interactions with their peers. These insights subsequently provide a context to examine the language supports for argumentation that Ms. Newbury used, and to explore how these supports aligned with her students' argumentation.

Language supports for argumentation

This section is organised by the three major trends that characterised Ms. Newbury's language supports: (1) more language supports focused on the structure of an argument, (2) dialogic interactions were most often facilitated by productive language supports, and (3) some language supports offered a rationale for argumentation.

More language supports focused on the structure of an argument

Throughout the target lessons, Ms. Newbury implemented different language supports to help her ELL students learn about and engage in argumentation. As Table 3 shows, these language supports differed amongst the lessons in terms of both presence and focus, with Ms. Newbury employing more language supports in the *Microbiome* unit in comparison to the *Metabolism* unit.

Furthermore, most of Ms. Newbury's language supports pertained to the structural component of argumentation; fewer language supports helped her students to engage in the types of dialogic interactions inherent to this science practice (e.g. critiquing competing claims). This trend is evident in Table 3 with more language supports coded as attending to argument structure (31 of 40), than the dialogic component (9 of 40).

For example, during Lesson 2, students wrote scientific arguments answering the question: How did a faecal transplant cure the patient who was infected with *C. difficile*? In preparation for this task, Ms. Newbury examined an exemplar written argument with students. With this argument projected on the front board, students identified sentences that corresponded to the structural features of an argument (e.g. claim, evidence and reasoning). Ms. Newbury then made transparent the organisation of written arguments by clarifying, 'So what's the structure here? We have claim, evidence, reasoning, evidence, reasoning, evidence, reasoning, claim. Do you see it?' (*Support 6–Modelling language expectations for an activity*) While explaining, she pointed to the sentences that corresponded to these structural features. Moreover, Ms. Newbury used different coloured markers to highlight the different structural components on the projection. Later, the teacher referenced this order to students as they wrote their arguments.

Additionally, Ms. Newbury spent nearly half of the class facilitating a discussion about the various phrases one could use when discussing the structural components of an argument (*Support 9–Writing scaffolds*). The teacher projected her computer screen and took notes as students brainstormed different sentence starters that they could use when writing their arguments. Figure 2 shows an image of the projected screen where Ms. Newbury recorded students' ideas.

Ms. Newbury distinguished whether sentence starters aligned with the claim, evidence, reasoning, or conclusion. Both of these language supports were appropriate given the argumentation task students were working on.

However, it was apparent that most of Ms. Newbury's language supports focused on argument structure even when lessons were written to emphasise the dialogic component of this science practice. For example, Lesson 3 targeted dialogic interactions as it entailed students collaborating with peers to construct and present a persuasive argument. Yet, as

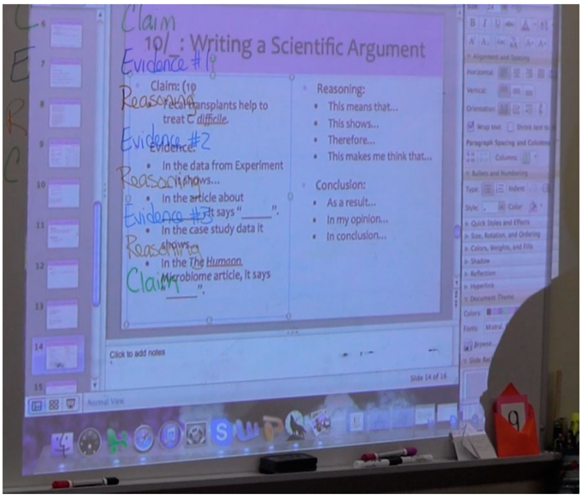

Figure 2. Sentence starters for writing arguments.

seen in Table 3, all of the language supports Ms. Newbury used in Lesson 3 supported argument structure. These observations of Ms. Newbury's language supports parallel our findings of the presence and quality of students' argumentation (see Figure 1), particularly in terms of their attention to the structure of an argument.

Dialogic interactions were most often facilitated by productive language supports

The language supports Ms. Newbury incorporated into her instruction to encourage dialogic interactions between students (e.g. questioning or building on peers' ideas) most often occurred when students partook in argumentation through productive language functions (i.e. writing or speaking). Table 3 illustrates this trend by the majority of language supports coded around dialogic interactions appearing in the bottom row of the table.

For instance, Lesson 5 entailed students gathering evidence from a virtual metabolism simulation, analysing it, and then orally debating which of two competing claims was better supported by their evidence. One claim articulated that when the human body has to do extra cellular growth and repair (which occurs when a person is sick), it cannot maintain the same level of activity as it normally would. The other claim expressed the counter argument. Both claims were embedded within the context of a fictional character, Cooper, and whether he could run during soccer practice as hard as he normally would, considering that he was sick. The teacher provided students with the opportunity to work in small groups (*Support 10–Working with peers*) in order to come up with the language they wanted to use to make their argument. Moreover, Ms. Newbury encouraged students to ask each other questions, which helped them to engage in the types of dialogic interactions that are important to argumentation. For example, while working together one student was heard saying, 'I think he can run but not umm how you say como antes?' to which a peer responded, 'Like before.' Another student then asked, 'Why you think that?' This question urged the first student to then justify his claim with evidence from the simulation. Thus, working with peers was a language support that helped students to collaboratively find the words to describe their stances all the while facilitating their engagement in dialogic interactions.

As a different example, in Lesson 6, students engaged in a whole group argumentation activity called a science seminar in which they orally debated answers to the question: When a person trains to become an athlete, how does her body become better at releasing energy? Throughout the lesson, Ms. Newbury provided many conversational sentence starters to help her ELL students enter the discussion (*Support 11–Conversational sentence starters*). For instance, before the start of the activity, she explained to them:

> And then after Soledad (a pseudonym) is done talking about her idea, right, I'm looking for people to jump in and say 'I agree with Soledad because _____' or 'I disagree with Soledad because _____' right? Or 'That's really interesting, I also read about this _____'. Right? Understand?

These sentence frames cued students to interact with their peers, while also providing them with the language through which to do so. Students adopted these language practices during the seminar. For instance, after Soledad, expressed, 'An athlete body change to become better at releasing energy by doing exercise and the things that the person eat,' a peer critiqued her by saying, 'I disagree with Soledad because the idea is not complete.' This evaluation resulted in Soledad realising that her claim was not grounded in evidence. Later on during the seminar, a different student used another one of the sentence frames Ms. Newbury had provided:

> I agree with Teresa (a pseudonym) because she's using the evidence and she is telling that 'the data shows' and she is telling what happens when the umm when the heart is pumping faster and the umm is going more faster to get more energy.

In this contribution, the student articulated agreeing with her peer because she not only used evidence, but also explained her reasoning. Thus, the use of sentence frames encouraged students to interact with other students' ideas during this oral argumentation activity, facilitating their engagement in the dialogic components of this science practice.

Some language supports offered a rationale for argumentation

Most of the language supports Ms. Newbury implemented into her instruction were geared at helping her ELL students to generally remember to include or attend to an aspect of argumentation (e.g. justify claims with evidence, or articulate whether you agree or disagree with a peer's argument). Yet, some of her language supports focused on rationales for the structural or dialogic components of argumentation (e.g. articulating reasoning makes an argument more persuasive because it makes the connection between the claim and evidence clear). This pattern is apparent in Table 3, as most of the language supports were identified as general (represented as 'S' or 'D') and not as centring on a rationale (represented as '$\boldsymbol{S_R}$' or '$\boldsymbol{D_R}$').

An example of a general language support occurred during Lesson 3 in which students created video arguments meant to persuade a government official that faecal transplants (an operation that helps to cure people infected with the bacteria *C. difficile*) should be legalised. When creating the videos, students were directed to incorporate information gathered from three investigations into their arguments. Each investigation allowed students to support a different claim about how faecal transplants help those infected with this bacteria. In order for students to better comprehend these claims, Ms. Newbury had previously helped them to simplify the language within them (*Support 3–Simplification of claim)*. For instance, one claim was originally expressed as: The bacteria in the faecal transplant helped the patient's body to produce immune cells that killed the invading *C. difficile* bacteria. With the help of the teacher, students reduced this claim to its main elements – bacteria helped to produce immune cells, killed *C. difficile*. Simplifying the language of the explanatory claim enabled students to not only understand the claim, but also find supporting evidence for it and then incorporate the information into their persuasive video arguments. This language support was categorised as general because it helped Ms. Newbury's students to attend to the structural component, but did not help them understand why this component was important.

However, during a few occasions Ms. Newbury provided language supports that not only reminded students to address an argumentation component, but also provided them with a rationale for why it was important to do so. For instance, in Lesson 1, students engaged in a card sort activity in which they learned to distinguish between irrelevant information and relevant evidence in support of a given claim. In this lesson, the claim was: Antibiotics cure infection by killing all types of bacteria in the body, including the harmful bacteria that cause the infection. While students engaged in this task, they were encouraged to explain why they sorted cards as irrelevant or relevant, which prompted them to articulate their reasoning.

In particular, one language support that offered a rationale helped Ms. Newbury's ELL students to understand why including relevant evidence was important. Before the card sort activity, the teacher took the time to discuss with students the meaning of the word 'relevant', a term students needed to understand in order to successfully accomplish the activity (*Support 5–Vocabulary instruction of argumentation related words*). The transcript in Table 4 is from this classroom conversation.

After this discussion, Ms. Newbury went on to explain why liking French fries was not relevant to the question:

Table 4. French fries analogy used to explain why relevant evidence is important.

Speaker	Quote
Ms. Newbury	In order to make the most persuasive argument possible, we're going to need to make sure we're only using information that is relevant. Okay? We've sort of talked about this word before, it's a really important word when you're talking about claim, evidence, and reasoning. [*Walks over to the white board and writes the word 'relevant' on it*] Okay. What does it mean? Everybody take a second, talk to your partner, what does relevant mean? *[Students are given approximately 45 seconds to talk with a partner about the meaning of the word relevant. Once they come back together as a class, students continue to struggle with the meaning of this word, explaining it to mean 'declarative.']* I can be declarative without being relative. For example, let me give you an example. You guys are trying to learn more about me, right, and you ask me where I'm from. Right? Marina, ask me where I'm from.
Marina	Where are you from?
Ms. Newbury	Oh, I really like to eat French fries.
Guadalupe	That is not relevant.
Ms. Newbury	But it is declarative. Right? I'm telling you something that I believe is true. I like to eat French fries, but it doesn't answer the question right?

> I'm telling you something that I believe is true. I like to eat French fries. But, it doesn't answer the question you asked me about me. I gave you information about me. But, it's not really connected to the question.

Ms. Newbury used the French fries analogy throughout the lesson to remind her students of both the meaning of the word and the importance of using relevant evidence to justify a claim. For instance, while students engaged in the card sort, the teacher was heard using this analogy to help a pair of students who were having challenges with a particular card:

> Does the information on the card directly relate to, or connect to, our claim? Does it answer the question or is it French fries? Okay? And remember, we need information not just about bacteria, but also about how bacteria are affected by antibiotics. Make sense?

This strategy not only helped Ms. Newbury's students to successfully engage in this argumentation task, but also enabled them to do so with an understanding of how relevant evidence makes an argument more persuasive.

Discussion

This study examined the language supports employed by one middle school science teacher as she taught an argumentation-focused curriculum in a self-contained ELL classroom. Specifically, we took an in-depth look at the language supports around argumentation for both the structural and dialogic components of this science practice. Our findings suggest a need to identify and develop supports for the dialogic aspects of argumentation. Furthermore, engaging students in argumentation through productive language functions could be leveraged to support the dialogic interactions inherent to this science practice. Lastly, our work points to the need for language supports that make the rationale for argumentation explicit since such transparency could further increase access for all students.

It is important to note that the supports identified and discussed in our work were specific to promoting ELL students' engagement in argumentation. However, research bridging science and literacy development contends that instructional practices shown to be effective for ELL students can be effective for all students (Lee & Buxton, 2013). Thus, as science teachers learn to better attend to the linguistic needs of their ELL students with respect to the learning of and engagement in argumentation, all students benefit.

The need of language supports for dialogic interactions

Overall, most of the language supports Ms. Newbury employed in her argumentation instruction pertained to the structural component of this science practice. For instance, she simplified the language of claims to make them more comprehensible for her ELL students. The teacher's frequent implementation of language supports for argument structure mirrored the ways her students most often, and most strongly, engaged in argumentation. Specifically, Ms. Newbury's students were observed using the structural features of an argument to some degree across all target lessons. The emphasis of Ms. Newbury's language supports aligns with previous research expressing that a prevalent instructional approach for teaching students about argumentation has been through its structure (Jiménez-Aleixandre & Erduran, 2008; Von Aufschnaiter et al., 2008). Using a framework that highlights certain features of an argument can increase content learning (Zohar & Nemet, 2002); prompt students to consider, include and evaluate critical features of an argument, such as the need for a claim to be supported by sufficient and appropriate scientific data (McNeill et al., 2006); and might also facilitate students in developing richer understandings of the dynamic nature of science (Bell & Linn, 2000).

However, students need to attend to more than structure to appropriately engage in argumentation. Although the arguments students generate can become the foundation for situations in which students challenge and question each other's ideas, these discourses are difficult and do not happen on their own (Sandoval & Millwood, 2005). Argumentation also encompasses the dialogic aspects of critiquing and debating the strength of a particular claim with others (McNeill et al., 2016). If argumentation instruction is centred on structure, students miss the opportunity to engage in critique, which is essential to this science practice (Ford, 2012). Therefore, it is critical that research and practice push towards a more holistic conceptualisation of argumentation so that students have opportunities to foster a stronger understanding of how science knowledge comes to be constructed and refined over time by engaging in these processes themselves. In terms of instruction, this might include teachers developing classroom goals that purposefully focus on students engaging in dialogic interactions (Berland & Hammer, 2012).

Yet, these types of interactions require intensive and in-time language use, which may be particularly challenging for ELL students (Hakuta et al., 2013). As seen through Ms. Newbury's instruction, there is a need to identify and develop language supports to facilitate ELL students' engagement in the dialogic aspects of argumentation. Such supports ought to go beyond conversational sentence starters like 'I agree _____' or 'I disagree _____'. Although useful, these sentence frames are no more than *entry* points into a conversation. It is important to identify language supports that help students more deeply interact with their peers' ideas, such as questioning the quality of a piece of evidence. By engaging in these types of discursive moves, students can begin developing a 'grasp' of this science practice (Ford, 2008). Without such a deliberate shift, this science practice could lose its epistemic drive, and instead become reduced to students completing a formulaic template for constructing arguments.

Leveraging productive language functions to support dialogic interactions

Although observed less frequently, Ms. Newbury also used instructional strategies to facilitate her ELL students' engagement in the dialogic component of argumentation. During these instances, the language supports the teacher used were most often intended to help her students engage in argumentation through productive language functions (i.e. speaking or writing). For example, in preparation for a debate, Ms. Newbury provided students the opportunity to work with peers to make sense of evidence and then to decide which of two claims was best justified. These interactions helped students to discover ways to use their developing English to meaningfully engage in the argumentation task. This instructional move aligns with research from the field of second language development that takes on a socially oriented position and is concerned with understanding how speakers become *users* of a second language (e.g. Valdés, Capitelli, & Alvarez, 2010). This perspective argues that the goal of learning a second language is to use the new language to function competently in a variety of contexts, and for a range of purposes.

This broadened conception of language learning promotes the development of skills for engaging in valued meaning-making processes in content classes (Hakuta et al., 2013; Lee & Buxton, 2013). Specifically within a science classroom, this means using a developing language to learn, communicate, and engage in disciplinary practices (Lee et al., 2013). Thus, incorporating language supports that focused on helping students to use English benefited Ms. Newbury's students' English development and argumentation engagement.

This finding suggests that productive language functions could be leveraged to help students learn about and engage in the dialogic interactions inherent to argumentation. We argue that writing and speaking might be easier entry points because they make competing arguments readily apparent. For instance, if during a discussion one student argues eating small portions while exercising provides athletes with more energy, but another states athletes could get more energy by eating a lot before exercising then there is observable disagreement. Such differences provide an authentic reason for students to interact with each other's ideas to settle the dispute (Henderson et al., 2015). For example, the student in favour of the eating before exercising claim might question the source of evidence that their peer used to develop their argument. Similarly, when students are tasked with writing scientific arguments, they can be encouraged to include a rebuttal. Writing rebuttals prompts students to consider not only what another person might question or critique about their argument, but also what a counter argument might be.

This does not mean that the dialogic component of argumentation should only happen through productive language functions. Students could also read and evaluate text that offers competing explanations for a scientific phenomenon. However, classroom science textbooks tend to present established scientific information, void of the people and processes by which the information came to be known (Knain, 2001). Students would be better able to interact dialogically with science texts if they were written to illustrate multiple views (e.g. deciding which of two written arguments about Pluto is best substantiated by evidence and scientific reasoning). However, researchers have cautioned that students do not automatically engage in these types of dialogic interactions, and that when designing learning experiences focused on the dialogic component of argumentation, it is important to integrate scaffolds for students (Evagorou & Osborne, 2013).

Importance of making transparent rationales that inform disciplinary practices

When characterising the language supports in Ms. Newbury's argumentation instruction, we realised that they took on two forms. The majority of these supports were general, in that they prompted students to justify their claims with evidence and reasoning, or they encouraged students to interact dialogically with their peers. However, these language supports did not provide students with a rationale for *why* they should do so. Yet, Ms. Newbury did employ a few language supports that made explicit to her students why particular aspects of argumentation are important. For instance, the French fries analogy enabled students to comprehend what the term 'relevant' meant while also helping them to understand that supporting claims with relevant evidence makes arguments more persuasive. Given that previous work has found there to be a positive relationship between teachers making explicit the rationale behind disciplinary practices and students' learning (McNeill & Krajcik, 2008), it would be productive for future research to further examine rationales for argumentation, and the ways that different rationales impact student engagement in this science practice. Additionally, more meaningfully engaging in argumentation and other science practices can help the development of students' epistemic knowledge of science (Osborne, 2014).

Furthermore, making rationales explicit might also help students better navigate across the various cultural repertoires of practice that they encounter and use on a daily basis, including different disciplines in school (Nasir, Rosebery, Warren, & Lee, 2014). The structures and expectations that inform when and how to engage in science practices, such as argumentation, are not inherent to students (Rosebery & Warren, 2008). This is particularly the case for students who have been historically marginalised in science education, including those whose native language is not English (Lee et al., 2014). Thus, highlighting the *why* behind science practices holds promise for supporting all students. As demonstrated by this work, the intersections between scientific sensemaking and the intensive language demands that are embodied in science practices (Lee et al., 2013) give rise to new opportunities in research and practice; opportunities that have the potential to increase accessibility for all students.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the National Science Foundation under the Constructing and Critiquing Arguments in Middle School Science Classrooms: Supporting Teachers with Multimedia Educative Curriculum Materials grant [DRL-1119584] and Division of Research on Learning in Formal and Informal Settings.

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