Teachers' beliefs and practices around argumentation during a curriculum enactment

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Teachers' beliefs and practices around argumentation during a curriculum enactment

Recent reforms in education have pushed for an overall increase in the science proficiency of students. Emphasizing not only the knowledge of scientific concepts, proficient students are now expected to understand and effectively participate in scientific practices (NRC, 2012). One key scientific practice is argumentation, which includes constructing claims using evidence and critically evaluating arguments produced by others (Osborne, 2010). Teachers' roles are critical in the successful implementation of this educational reform (Evagorou & Dillon, 2011). However, practicing teachers can experience difficulty in constructing arguments and in understanding the function of argumentation in the science classroom (Sampson & Blanchard, 2012). Teachers need support to develop new knowledge and teaching skills to effectively teach science through argument (Simon, Erduran, & Osborne, 2006). One avenue to improve practicing teachers' understanding of this scientific practice is through the development of educative curriculum materials (Davis & Krajcik, 2005). Still creating these resources is challenging, and numerous factors cause teachers to enact curricula in different ways (McNeill, 2008; Schneider et al., 2005). In order to better support teachers in integrating scientific argumentation into their classroom practice, we need to understand more about teachers' decision making around curriculum implementation. Consequently, in our research, we investigated the following questions: 1) How is argumentation presented in an earth science curriculum? 2) What variation exists in the teachers' classroom practice around argumentation? 3) What factors impact the teachers' classroom practice around argumentation?

Theoretical Framework

Argumentation in Science Education

Scientists frequently engage in argumentation as they socially construct knowledge by assessing alternative explanations through discursive activities (Driver, Newton & Osborne, 2000). For instance, the development of new data from an experiment often leads to the reexamination of an existing scientific explanation or to the creation of a new idea. With sufficient evidence supporting a new or modified idea a scientist will then present the explanation to a group of peers. These peers will critique the idea and its supporting data and if the proposal survives this process it enters the world of conceptually accepted knowledge. This cyclical process is fundamental to the field of science and occurs through both oral and written modalities. Although argumentation is an essential part of science, authentic scientific argumentation is often lacking in school settings (Newton, Driver & Osborne, 1999). Science education tends to overemphasize students learning a myriad of uncontested facts rather than understanding how this information is developed and transforms over time. When applied purposefully, students' involvement in argumentation can encourage deeper understandings of scientific concepts (Zohar & Nemet, 2002) and strengthen students' abilities to engage in this practice (McNeill, 2011; McNeill, 2009).

Similar to other researchers (Jiménez-Aleixandre & Erduran, 2008), we define scientific argumentation in terms of both its *structure* as well as a social and *dialogic process*. Numerous science education researchers have adapted Toulmin's (1958) model of argumentation to analyze the structure of students' arguments (Sampson & Clark, 2008). Similar to this work, we consider the *structure* of an argument to consist of a claim about the natural world that is supported by both evidence and scientific reasoning (McNeill, Lizotte, Krajcik & Marx, 2006). A claim is a

statement or conclusion about a question or problem. Evidence is scientific data such as observations or measurements that supports the claim. While evidence provides support for the claim, the reasoning justifies how the evidence links to the claim through accepted scientific knowledge or principles.

Argumentation is also a social or *dialogic process* that includes the interaction amongst individuals in which the objective is to persuade or convince one another of a particular claim (Jiménez-Aleixandre & Erduran, 2008). This process can occur in talking, but also in terms of written arguments in which an individual attempts to convince an audience of a claim. This social process includes both the construction of arguments, but also the critique of arguments in which claims as well as their justifications are questioned and evaluated. In classroom instruction, a culture that permits and encourages student-to-student interactions is important for supporting students in engaging and understanding argumentation as a dialogic process (Osborne, Erduran & Simon, 2004).

The Role of the Teacher

The role of the teacher is essential for successfully incorporating scientific argumentation into classroom practice (Evagorou & Dillon, 2011). However, teachers may have a limited understanding of argumentation as well as view numerous potential barriers for integrating argumentation into their classroom instruction (Sampson & Blanchard, 2012). Furthermore, classroom instruction can still include a wide range of quality in terms of argumentation (Simon, Erduran, & Osborne, 2006). For many teachers the implementation of argumentation into classroom instruction will require a shift in classroom norms and instructional practices (Berland & McNeill, 2010). Science classrooms can be exemplified by the following image: the teacher solely provides undisputed information and facts to be memorized by students. However, in a science classroom in which students learn through argumentation, the students play a more active role in their learning, using this scientific practice to engage in dialogic interactions with their peers. Teachers require a range of pedagogical strategies to successfully introduce and integrate scientific argumentation into their classroom instruction (Osborne, Erduran & Simon, 2004).

Curriculum Materials

Curriculum materials can be essential in supporting change in classroom instruction, because they offer teachers concrete materials around new reform efforts (Powell & Anderson, 2002). Often including tasks, activities, suggestions, and common student conceptions, the fundamental role of curricular resources is to provide teachers with guidance and ideas for instruction (Remillard, 2005). It is important to distinguish the recommendations made by curriculum from the idea that the materials are to be followed verbatim. Research around fidelity of implementation examines how closely the curriculum user's enactment aligns with the designer's intended design, with the idea that all of the structures and features from the curriculum are adhered to exactly (O'Donnell, 2008). Earlier work in this field presumed users of curriculum to be passive receptors, following the given lesson precisely. However, the relationship between teacher and curriculum is not simple and unidirectional. Teachers are not passive but instead active adapters of curriculum, modifying resources to fit their needs and the needs of their students.

Recent work around curriculum materials has included an expanded view that includes supporting teacher learning to better assist teachers in implementation (Ball & Cohen, 1996). Curriculum materials that support teacher learning, or educative curriculum, support teachers'

knowledge base about teaching and learning as well as the ability to apply that knowledge in classrooms to make effective instructional decisions (Davis & Krajcik, 2005). Educative resources can incorporate additional support to help educators learn and implement new content and instructional practices, such as scientific argumentation (Beyer, Delgado, Davis, & Krajcik, 2009). Still, as previous work has indicated, creating these resources for teachers is complex. Numerous external and internal factors will cause teachers to interpret curriculum differently and consequently enact it in various ways, which consequently impacts student learning (McNeill, 2009; Schneider, Krajcik, & Blumenfeld, 2005).

Factors Impacting Curriculum Enactment

In order to better support teachers, it is important for curriculum developers to understand more about teachers' decision making around curriculum implementation. Factors that can impact curriculum enactment and how argumentation is practiced in the science classroom, including the classroom context, the teacher's relationship with the curriculum, and reflective instructional practices. Another issue influencing teachers' curriculum implementation is their varying knowledge base of science content, pedagogy and pedagogical content knowledge (Schneider et. al, 2005; Remillard, 2005; McNeill, 2009). Teachers draw on their own individual knowledge when they interpret, analyze and enact curriculum materials. As a result, the way that teachers understand and make sense of curriculum impacts their enactment. Consequently, in this study we investigated both teachers' enactment of curriculum materials as well as their curricular decisions around those enactments for supporting students in scientific argumentation.

Method

Context

This study took place in the context of a pilot of an earth science curriculum in which the teacher materials were delivered digitally on a tablet computer (e.g. iPad). The design of the earth science curriculum is a collaboration between The Learning Design Group at the Lawrence Hall of Science and Amplify Learning (www.amplify.com). Building on an elementary integrated science and literacy curriculum called *Seeds of Science/Roots of Reading* (Cervetti, Barber, Dorph, Pearson & Goldschmidt, 2012), the curriculum utilizes a multimodal approach in which students experience science concepts in four modalities: Do-It, Talk-It, Read-It and Write-It (Pearson, Moje & Greenleaf, 2010). Furthermore, the curriculum engages students in the scientific practices identified in *A Framework for K-12 Science* Education (NRC, 2012). This includes an emphasis on constructing and critiquing arguments across reading, writing and talking.

For this study, we investigated the teachers' enactments of two different six-week units: *Currents and Earth's Climate* and *Plate Tectonics. Currents and Earth's Climate* focused on how differences in density cause currents in the Earth's ocean and atmosphere as well as how air currents, ocean currents and the water cycle affect regional climates. *Plate Tectonics* focused on how interactions between tectonic plates cause surface features and events on Earth, and have caused the Earth's surface to change and shift over millions of years. Each teacher piloted one of the two units. For each unit, we selected two argumentation lessons for analysis. In the first argument lesson, the class read and critiqued a scientific argument. In the second argument lesson, the class engaged in a Science Seminar in which the students (divided into two groups) debated their explanations for a scientific question using evidence collected during previous lessons. While one group engaged in the argument, the other group observed and provided

feedback, and then the groups switched roles. Table 1 provides a summary of the focal argument lessons. Specifically, we were interested in how argumentation was presented in the lessons, the variation in the teachers' enactment of the lessons and the teachers' rationales behind their curricular enactment.

Table 1: Summary of Focal Argumentation Lessons

Curriculum Unit	**Lesson Focus**	**Lesson Description**
Currents and Earth's Climate	Reading an Argument	• Warm-up: writing about the phrases *surface currents* and *deep-ocean currents*. • Introduce reading by talking about the Ice Age. • Read and analyze a scientific argument – How were the deep-ocean currents different 18,000 years ago? • Discuss example of an everyday argument - Do video games make you smarter?
	Science Seminar	• Review the purpose and process of a Science Seminar. • Project South America Precipitation Map and remind students of the question – Why is the Atacama Desert the driest place on Earth, with some parts that haven't had any precipitation in hundreds of years? • Group 1 debates their explanations while Group 2 observes. • Group 2 debates their explanation while Group 1 observes. • Reflect on the class participation in the Science Seminar.
Plate Tectonics	Reading an Argument	• Warm-up: writing three sentences containing one of these words – *argument*, *crust* and *zone*. • Add everyday and scientific meanings for *argument*, *crust* and *zone* to the Multiple Meanings Word Chart. • Read and analyze a scientific argument – Why use wax to study rock?
	Science Seminar	• Warm-up: think about students' arguments to address the question – How will the Indian plate be different in 50 million years? • Review the purpose and process of a Science Seminar. • Group 1 debates their explanations while Group 2 observes. • Group 2 debates their explanations while Group 1 observes. • Reflect on the class participation in the Science Seminar.

Participants

Across the country, sixty-five teachers piloted the curriculum materials. This study specifically focuses on ten pilot teachers that taught either 5th or 6th grade science who were selected based on their vicinity to the two research teams (one on the east coast and one on the west coast). Table 2 below describes the backgrounds of the ten pilot teachers.

Table 2: Teachers' Backgrounds

Teacher	Type of Teaching Credential	Highest Level of Education	Years of Teaching Experience	Classes Taught
Ms. Lynn	Multi-subject (elementary)	BA	6-10	Science, Mathematics, Art, Computer skills, Religion
Ms. Brennan	Multi-subject (elementary), single subject (secondary), Montessori (pre-primary)	BA	More than 20	Science, Art
Ms. Allen	Multi-subject (elementary)	BA	1	All subjects
Ms. Richardson	Single subject (secondary)	MA	11-15	Science, Mathematics
Ms. Owens	Multi-subject (elementary)	MA	6-10	Science, Mathematics
Ms. Klein	Multi-subject (elementary), single subject (secondary)	MA and MS	11-15	Science
Ms. Norman	Single subject (secondary)	BA	11-15	Science
Ms. Kelly	Single subject (secondary)	MA	6-10	Science
Mr. Reyes	General science (6-8), middle school math/Spanish	EdD	11-15	Science
Mr. Carter	Single subject (secondary)	MS	11-15	Science, Administration

Note: N/A = Not available

The teachers had a range of backgrounds from one first year teacher to one teacher with more than 20 years of teaching experience. Furthermore, some of the teachers had elementary certifications while others had backgrounds in science.

The teachers also taught in a range of school contexts. Table 3 provides information about the school and classroom contexts.

Table 3: School and Classroom Context

Teacher	Type of School (e.g. public, private)	Grade of Students in Field Trial	Class Size	% Free and Reduced Lunch	% Non-White	% ELL
Ms. Lynn	Private (religious)	6	21-25	N/A	N/A	N/A

Ms. Brennan	Private (religious)	6	31-35	N/A	24%	N/A
Ms. Allen	Public	6	26-30	54%	75%	33%
Ms. Richardson	Charter	5	26-30	81%	98%	56%
Ms. Owens	Charter	6	26-30	81%	98%	56%
Ms. Klein	Public	6	21-25	89%	88%	35%
Ms. Norman	Public	6	26-30	86%	95%	31%
Ms. Kelly	Public	6	21-25	86%	95%	31%
Mr. Reyes	Public	6	21-25	29%	45%	9%
Mr. Carter	Public	6	26-30	64%	76%	15%

Note: N/A = Not available

The schools in the study included two religious private schools, two charter schools and two public schools. For the two religious private schools, we were unable to obtain information about the student population. The rest of the student information is included in the table and reflections a diversity of backgrounds in terms of % of students eligible for free and reduced lunch, % non-white students, and % English Language Learners (ELLs).

Data Collection

This studied examined three data sources: the four argumentation lessons, classroom videotapes and teacher interviews. For the four argumentation lessons, we examined all teacher materials related to each lesson including the lesson description, presentation materials (e.g. PowerPoint), student materials and educative notes. The educative notes were included in the sidebar of the digital curriculum materials and included a range of foci such as – Encouraging Students' Participation, Using Native Language to Help English Learners Access Content, and What Counts as Evidence. Some of the educative notes specifically focused on argumentation while others focused on other aspects of the lesson. The teacher could see the title and the beginning of the description on the interface. The teacher then needed to click on the educative note to read more detail.

From each teacher, we collected two additional data sources: videotapes of two argumentation lessons and follow-up interviews for both lessons. As we mentioned previously, the videotaped lessons included one lesson in which students read and critiqued a written argument and a second lesson in which students engaged in a Science Seminar in which they engaged in an argumentative discussion. After each lesson, the teacher was interviewed for approximately 30-45 minutes about their beliefs about argumentation and their curricular decisions when enacting the argumentation lessons. The goal of the interview was to develop an understanding of why the teacher chose to enact the lessons in particular ways. All interviews were transcribed for analysis.

Data Analysis

In our analysis of the data, we were interested in how argumentation was presented in the curriculum. Furthermore, we were interested in the similarities and differences in the teachers' instructional practices in relation to the original curriculum as well as their rationales for those decisions specifically around argumentation.

Curriculum analysis. We began the development of the coding scheme for the argumentation features in the curriculum by examining the educative criteria used by Beyer and

her colleagues (2009) in their analysis of high school biology curriculum. Specifically, we focused on their coding of educative supports for pedagogical content knowledge of scientific inquiry. We adapted their criteria for rationale and implementation guidance. We included the idea of rationale under Category 1 - Description of Argument as well as expanded on it to include a specific definition of argument. Category 2 – Implementation Guidance stemmed from their work and included two sub-categories focused one focused on common student conceptions and the second on instructional strategies. In addition, we added two more categories – Category 3 - Image of Practice and Category 4 - Teacher Reflection. After the design of the initial coding scheme, we shared the codes with the curriculum designers to receive their feedback on the codes and process. The scheme was then revised based on this feedback.

For the sub-categories, we coded each of the four lessons separately. We looked for evidence of the sub-category across the entire lesson including all supporting materials (e.g. lesson description, educative notes). We then coded each lesson at Level 2: Present and High Quality, Level 1: Present and Low Quality or Level 0: Not Present. Table 4 provides a summary of the coding scheme in terms of both the sub-categories and a description of the high quality code.

Table 4: Argumentation Coding Scheme for Curriculum

Category	**Description of High Quality Code**
Category 1. Description of Argument	
1A. Argument Structure	Describes argument structure as a claim about the world that is supported or critiqued using evidence and scientific knowledge or principles.
1B. Rationale for why structure is important	Provides multiple reasons for why an argument has a particular structure.
1C. Argumentation as a Dialogic Process	Describes argumentation as a social or dialogic process that includes both: 1. convincing or persuading an audience about the strength of a particular claim over other claim(s). 2. includes student-to-student interactions such as students listening to each other, building on each others ideas and critiquing ideas
1D. Rationale for why process is important	Provides multiple reasons for why the process of argumentation is important.
Category 2. Implementation Guidance	
2A. Common student conceptions	Describes one or more student conceptions about argumentation in depth.
2B. Instructional strategies	Describes an instructional strategy for supporting students in argument in depth. The instructional strategy includes an example or description that is content or lesson specific to help illustrate what this looks like in a particular context.
Category 3. Image of Practice	
3A. Image of argument	Provides a student example (or multiple examples) of argument – student writing, transcript from classroom conversation, video of classroom enactment. The example should illustrate a particular purpose and describe why the example illustrates that particular purpose.
3C. Image of something that is	Provides a student example (or multiple examples) of something that is NOT argument – student writing, transcript from classroom conversation, video of

NOT argument	classroom enactment. The example should illustrate a particular purpose and describe why the example illustrates that particular purpose.
Category 4. Teacher Reflection	
4A. Teacher Reflection	Presents an active opportunity for teachers to engage in reflection. The teachers have to actively make a choice or actively construct a response to a question

Each lesson was independently coded by three member of the research team – the first author, a graduate research assistant and an undergraduate research assistant. The team met and discussed their codes and evidence for each category. Any disagreements were resolved through discussion with feedback from the entire research team (one faculty member, three doctoral students, two undergraduates). In addition, the results of the analysis were shared with the curriculum designers who offered an important perspective in making sense of the results.

Videotape and interview analysis. To analyze the classroom videotapes and teacher interviews, we developed coding schemes using our theoretical framework as well as an iterative analysis of the data (Miles & Huberman, 1994). The coding scheme for the classroom videotapes included three categories: 1) Argument Structure, 2) Argumentation as a Dialogic Process and 3) Instructional Strategies. The first two categories were informed by our definition of argumentation that includes both a focus on the structure of an argument and argumentation as a dialogic process (Jiménez-Aleixandre & Erduran, 2008). These categories each included three sub-categories the first of which focuses on how the teacher defines or discusses that aspect of argumentation, the second focuses on whether the teacher provides a rationale and the third examines the students language and whether or not the students are actively participating in that aspect of argumentation. The third category captured the teachers' use of other instructional strategies (e.g. such as modeling, everyday examples or sentence starters) that would support the goals of argumentation either in terms of the structure or dialogic process. We coded each sub-category as Level 2: Present and High Quality, Level 1: Present and Low Quality or Level 0: Not Present for each lesson. Table 5 includes a summary of the coding scheme in terms of the sub-categories and a description of the high quality code.

Table 5: Argumentation Coding Scheme for Curriculum Enactment

Category	**Description of High Quality Code**
Category 1. Argument Structure	
1A. Teacher defines argument structure	The teacher describes an argument product as a claim or explanation about the natural or designed world that is supported or critiqued using evidence and scientific reasoning. Teacher discusses that students arguments should include both scientific data and scientific knowledge to support the claim.
1B. Teacher provides a rationale for structure	The teacher provides multiple reasons for why the product of argument is important. Examples of reasons could include: • Is a key scientific practice • Is an important aspect of disciplinary literacy across content • Is a 21st century skill for both inside and outside the classroom • Supports learning science content • Develop epistemological understandings
1C. Students use argument structure language	Numerous students provide or critique the quality of the argument(s) taking into consideration the quality of the claim and evidence or justification for that claim. This code is given when the structure of the argument seems to be a part of the classroom norms in terms of the students' participation. For

	example, students frequently use terms such as claim and evidence in their comments and questions.
Category 2. Argumentation as a Dialogic Process	
2A. Teacher defines argumentation as a dialogic process	Teacher describes argumentation as including both: • convincing or persuading an audience about the strength of a particular claim over other claim(s). • includes student-to-student interactions characterized by students listening to each other, building on each others ideas and critiquing ideas, debating ideas
2B. Teacher provides a rationale for argumentation as a dialogic process	Teacher provides multiple reasons for why the process of argumentation is important. Examples of reasons could include: • Science is a discourse that includes science talk • Science is a social process in which scientists debate knowledge claims. • Students need to actively engage in this type of science talk in order to gain greater proficiency in science (science content). • Engaging in this social process may change students' understanding of science or views about science.
2C. Students engage in argumentation as a dialogic process	The students in the classroom engage in argumentation which includes the students: • convincing or persuading an audience about the strength of a particular claim • includes student-to-student interactions such as students listening to each other, building on each others ideas, critiquing ideas, debating ideas This should include multiple students engaging in student-to-student interactions building on the ideas of their peers.
Category 3. Instructional Strategies	
3A. Teacher uses instructional strategies to support students in argument	Uses an instructional strategy for supporting students in argument in depth. The instructional strategy includes an example or description that is content or lesson specific to help illustrate what this looks like in a particular context. Instructional strategies could include: modeling science examples, comparing to everyday examples, using questions or sentence starts to support discussion, and engaging students in peer feedback.

The development of the coding scheme for the interviews included a focus on two categories: Category 1. Knowledge of Argumentation and Category 2. Factors that Impact Argumentation Instruction. In terms of knowledge, we focused on the teachers' discussion of argument structure and argumentation as a dialogic process in order to align with our coding of the curriculum enactment. We were interested in the accuracy and depth at which they discussed these ideas. In terms of factors impacting their instruction, we developed an initial potential list of factors based on the research literature such as the role of curriculum materials (McNeill, 2009) and students' backgrounds on instructional choices (Sampson & Blanchard, 2012). In addition, we were open to emergent themes for each teacher as well looked for reoccurring ideas and language in the data about what factors impacted their instruction (Marshall & Rossman, 1999). We were interested in what ideas the teachers brought up in terms of what influenced their enactment of the argumentation lessons. For Category 1. Knowledge of Argumentation we coded each sub-category as Level 2: Present and High Quality, Level 1: Present and Low Quality or Level 0: Not Present for each lesson. For Category 2. Factors that Impact Argumentation

Instruction, we coded for the presence or absence of individual factors. In order for a factor to be coded as present, the idea needed to come up multiple times over the course of the interview. Table 6 provides a summary of these codes.

Table 6: Argumentation Coding Scheme for Teacher Interviews

Category	Description of Code
Category 1. Knowledge of Argumentation	
1A. Argument structure	Describes an argument product as a claim or explanation about the natural or designed world that is supported or critiqued using evidence and scientific reasoning. AND Provides definitions of key terms such as a claim is a conclusion, evidence is scientific data, and reasoning is the justification for why the evidence supports the claim using scientific knowledge or principles.
1B. Rationale for structure	Provides multiple reasons for why the product of argument is important. Examples of reasons could include: • Is a key scientific practice • Is an important aspect of disciplinary literacy across content • Is a 21st century skill for both inside and outside the classroom • Supports learning science content • Develop epistemological understandings
1C. Argumentation as a dialogic process	Describes argumentation as including both: • convincing or persuading an audience about the strength of a particular claim over other claim(s). • includes student-to-student interactions such as students listening to each other, building on each others ideas and critiquing ideas, debating ideas
1D. Rationale for argumentation as a dialogic process	Provides multiple reasons for why the process of argumentation is important. Examples of reasons could include: • Science is a discourse that includes science talk • Science is a social process in which scientists debate knowledge claims. • Students need to actively engage in this type of science talk in order to gain greater proficiency in science (science content). Engaging in this social process may change students' views of science.
Category 2. Factors that Impact Argumentation Instruction	
2A. Other educational goals	Discusses how argumentation supports students in other educational learning goals such as supporting language arts
2B. Curriculum materials	Discusses how the curriculum had a major impact on their inclusion of argument.
2C. Students	Discusses how the students' backgrounds or abilities had a major impact on argumentation.
2D. Standards and tests	Discusses how standards and tests had a major impact on their instruction (either in a positive or negative way)
2E. District, administrators or teachers	Discusses how initiatives in their school district, administrators or other teachers had a major impact on their argumentation instruction
2F. Self-efficacy	Discusses how their self-confidence has a major impact on their argumentation instruction
2G. Knowledge	Discusses how their knowledge of argument (either lack of or that they feel like they

	have a lot) had a major impact on their instruction
2H. Other Emergent Factors	Add other emergent factors that appeared to have a major impact on their argument instruction (open coding from the teachers' responses).

All videotapes and interviews were independently coded by four members of the research team – the first author, two graduate research assistants and one undergraduate research assistant. We focused on one case study teacher at a time in order to develop a rich understanding of that teacher's practice and decisions around argumentation. After independently coding the videos and interviews for one teacher, the entire research team met to discuss the codes and the evidence for each code. These discussions entailed revisiting videotapes and transcripts in order to look for confirming and disconfirming evidence to challenge, refine and enhance our coding of each teacher (Erickson, 1986). During the discussion, we developed a summary document for each teacher including the final codes and providing specific examples from classroom videotapes and transcripts to support those codes. The first author used these documents to develop a detailed case study for each teacher that captured the complexities within the classroom (Stake, 2000). The goal of the detailed case studies was to develop a narrative that accurately depicted the most important features of each case study teacher around their argumentation instruction and the factors that impacted that instruction (Stake, 2000). After the first author developed each case study, a doctoral student who originally coded the videos and interviews read and evaluated each case study keeping in mind the coding and decisions of the research team. Overall, the case studies were consistent with her experiences. The few discrepancies or areas that needed clarification were discussed and revised. The final detailed case studies were between seven and eight single-spaced pages for each teacher.

In presenting case studies, there is a tension between providing sufficient detail to accurately represent the complexities of the case and considering the needs of the reader to highlight the important findings (Stake, 2000). To examine the themes across the ten case study teachers, we developed a summary table highlighting the key aspects of each case study. We used the table to identify important trends and to select four teachers (two low quality argumentation instruction and two high quality argumentation instruction) that best represented the themes across the group. For those four case study teachers, we then created shortened case studies to present in this paper to illustrate the key aspects of the teachers' argumentation instruction and the factors impacting that instruction.

Results

In this section, we begin by presenting the results from the analysis of the curriculum materials. As we will discuss, the curriculum includes a clear focus on argumentation; however, some aspects of argumentation were more and less explicit in the lessons. We then provide an overview of the ten teachers' enactment and curricular choices around argumentation. Although all ten teachers discussed argumentation as an important learning goal for their students, they appeared to have considerably different understandings of what counted as argumentation as illustrated in both their actual classroom instruction and their discussion of their curricular choices. After providing a synthesis of all ten teachers, we then present the cases from four of the teachers to illustrate the trends in relation to the lower and higher quality enactments of the argumentation lessons.

Argumentation in the Curriculum

Our analysis of the curriculum suggests that all four lessons included a specific focus on argumentation. Table 7 includes the results for the analysis in terms of the first two categories of the coding scheme – Description of argument and Implementation Guidance.

Table 7: Analysis of the Four Argument Lessons

	Currents Reading Argument	*Currents* Science Seminar	*Plates* Reading Argument	*Plates* Science Seminar
Category 1. Description of Argument				
1A. Argument structure	2	1	2	1
1B. Rationale for structure	1	0	0	0
1C. Argumentation as a dialogic process	1	1	1	1
1D. Rationale for dialogic process	0	1	0	2
Category 2. Implementation Guidance				
2A. Common student conceptions	2	0	1	0
2B. Instructional strategies	2	1	2	1

2 = Present and high quality. 1 = Present and low quality. 0 = Not present

For the first two categories, the curriculum defines as well as provides implementation guidance for both the structure of an argument as well as argumentation as a dialogic process. Not surprisingly, in both units the lesson on reading and critiquing an argument included more of a focus on the structure of an argument, while the science seminar lesson included more of a focus on argumentation as a dialogic process.

We did not include the last two categories in Table 7, Image of Practice and Teacher Reflection, because all four lessons received zeros for the codes of these sub-categories. In discussing the curriculum with the designers, they did not see this as surprising since the curriculum was not designed with these categories in mind. However, we will return to these two categories in the discussion as potential strategies to better support teachers with some of the challenges that arose in their argumentation instruction.

Synthesis of Ten Teachers' Enactments

Across the ten teachers, we observed a wide range in their enactments of the argumentation lessons. Although all of the teachers were clearly teaching the same lessons (e.g. all teachers used and discussed the argument reading), they made different decisions in terms of both the language they used in their instruction and the activity structures to support student learning. In order to look for trends across the ten teachers in terms of both their enactment and the factors impacting their instruction, we developed Table 8 that includes a summary of each case study. We used the coding of each teacher's instruction in terms of both the structure of argument and argumentation as a dialogic process to order the teachers from lower quality argumentation instruction to higher quality argumentation instruction.

Table 8: Summary of Ten Case Study Teachers

	Argument Structure	Dialogic Process	Factors Impacting Instruction
Ms. Brennan	• Used CER language, but vague • No rationale • Students did not use structure	• No definition of process • Provided a rationale - may change students' minds. • No student-to-student interactions	• Limited argument understanding • Desire to closely follow the curriculum. • Prior teacher-centered teaching style and focus on outcomes
Mr. Carter	• Used CER language, but vague • No rationale • Students did not use structure	• Discussed student-to-student interactions and persuasion • No rationale • Limited student-to-student interactions.	• Limited argument understanding • Used the curriculum as a guide that he adapted • Prior teacher-centered teaching style as an entertainer
Mr. Reyes	• Used CER language and defined components • No rationale • Limited number of students used structure	• Only discussed student-to-student interactions • No rationale • No student-to-student interactions	• Understanding of argument as a structure, but not as a process. • Used the curriculum as a guide that he adapted • Prior teacher-centered teaching style using questions
Ms. Klein	• Used CER language, but vague. • No rationale • Students did not use structure	• Discussed student-to-student interactions and persuasion • No rationale • Frequent student-to-student interactions.	• Different view of argumentation as literacy and not science. • Used the curriculum as a guide that she adapted • Prior teaching focused on doing science and content, not discourse.
Ms. Kelly	• Used CER language and defined components • No rationale • Limited number of students used structure	• Discussed persuasion • Provided a rationale - may change students' minds. • No student-to-student interactions	• Understanding of argument as a structure, but not as a process. • Used the curriculum as a guide that she adapted • Prior experiences with CER in her school district
Ms. Lynn	• Used CER language, but vague	• Discussed student-to-student interactions	• Limited argument understanding • Desire to closely follow the

Lower Quality Argumentation Instruction ←----------

Higher Quality Argumentation Instruction ↓

	• No rationale • Students did not use structure	• Provided a rationale - may change students' minds • Limited student-to-student interactions.	curriculum. • Prior teacher-centered teaching style
Ms. Owens	• Used CER language, but vague • No rationale • Limited number of students used structure	• Discussed student-to-student interactions and persuasion • Provided a rationale - may change students' minds • Frequent student-to-student interactions	• Different understanding of argumentation than curriculum • Used the curriculum as a guide that she adapted • Time constraints both on preparing and teaching as important.
Ms. Richardson	• Used CER language, but vague • Provided a rationale – connection to scientists • Limited number of students used structure	• Discussed persuasion • Provided multiple rationales – scientists engage in this process, may change students' minds, increase understanding of content • Limited student-to-student interactions.	• An understanding of argument • Followed curriculum, but also learned from the curriculum • Prior teaching style and background in science in terms of science as a practice
Ms. Norman	• Used CER language and defined components • No rationale • Students used structure.	• Discussed student-to-student interactions and persuasion • Provided multiple rationales – scientists engage in this process and may change students' minds • Limited student-to-student interactions.	• An understanding of argument • Followed the curriculum, but was a reflective and critical user. • Teachers' prior teaching style with a focus on questioning students.
Ms. Allen	• Used CER language, but vague • Provided a rationale – connected to ELA • Students used structure	• Discussed student-to-student interactions and persuasion • Provided a rationale - may change students' minds • Frequent student-to-student interactions	• An understanding of argument, but limited in terms of science • Followed the curriculum, but also used it to support existing norms across subjects. • Made connections and built on her background from ELA

Because the instruction was coded for multiple dimensions, there are a number of instances when we debated which teacher should be placed as having higher or lower argumentation instruction in the table. For example, Ms. Klein's instruction was stronger in terms of argumentation as a dialogic process, while Ms. Kelly's instruction was stronger in terms of the structure of an argument. However, the extremes in the table are clearly different in terms of their instruction. For example, Ms. Brennan is ordered as the lowest quality argumentation instruction. Her students did not use the language around the structure of an argument or engage in dialogic student-to-student interactions. In contrast, we included Ms. Allen as the highest quality argumentation instruction. Her students frequently used the language of the structure of an argument and engaged in student-to-student interactions in which they debated their explanations using evidence.

After ordering the teachers in terms of their instruction, we then examined the factors impacting their instruction to look for trends across the lower versus higher quality argumentation instruction teachers. There appeared to be three key areas that influenced their instruction – teachers' understanding of argument, the way they used the curriculum, and their prior experiences or teaching style. The bullets for each teacher in Table 8 are ordered based on these three key areas.

Four Argumentation Case Studies

We selected four teachers to present their case studies in order to illustrate some of the trends we observed in the data. Specifically, we decided to focus on two teachers with lower quality argumentation instruction and two teachers with higher quality argumentation instruction in order to represent the range in this group of teachers. We also purposefully selected one teacher who taught the *Currents and Earth's Climate* unit and one teacher who taught the *Plate* Tectonics unit for each pair. For lower quality instruction, we selected the two teachers with the lowest codes – Ms. Brennan and Mr. Carter. Although their instruction was similar in terms of certain characteristics, they offered different rationales for their curricular choices that captured the difference we observed in the teachers in terms of the factors that impacted their argumentation instruction. For higher quality argumentation instruction, we selected the two teachers with the second highest codes – Ms. Norman and Ms. Richardson. We chose not to include Ms. Allen, because although her instruction did exhibit the highest quality argumentation instruction, the factors that impacted her instruction differed compared to the other teachers. She was one of the only teachers not to mention her prior teaching experiences or teaching style. She also focused more on English Language Arts throughout her interview compared to any of the other teachers. These two differences may be the result of her different background. Ms. Allen was the only first year teacher and she was also the only teacher who had the students all day for every subject. All of the other teachers in the sample had at least six years of teaching experience and the majority of them were science specialist or taught science and one other subject (e.g. math). Instead, we selected Ms. Norman and Ms. Richardson. Even though their argumentation instruction was not as high quality in terms of argumentation as a dialogic process, the factors that impacted their instruction were more representative of the group of teachers as a whole, which we felt offered greater insight into the design of future educative features.

Ms. Brennan. Ms. Brennan's instruction included limited instances of argumentation with those existing instances exhibiting low quality. In terms of the structure, she used the language of claim, evidence and reasoning, but did not clearly define the terms. For example, in the Reading the Argument Lesson, she asked students to identify the claim and evidence in the

reading. Specifically, she asked the students to place an asterisk next to every piece of evidence they found in the reading. After she introduced the task, she told the class, "I am going to be looking. I am going to be looking at your papers and I am going to be counting the evidence that you find." As the students worked on this assignment, Ms. Brennan walked around the room and could be heard making statements such as, "It looks to me like there is a lot of evidence to be found" and "I am seeing lots of asterisks. Oooh. I am liking that." She never specifically defined evidence for students; furthermore, she never questioned a student about whether or not something they placed an asterisk next to actually counted as evidence. Rather, her actions suggested that the more asterisks the better regardless of what text they were placed next to. Furthermore, as she walked around the room, one of the students asked her a question about the difference between evidence and reasoning:

> *Student: "What is the difference between this and this? Wouldn't they be pretty much the same?" (Points to paper with parts of an argument)*
>
> *Teacher: "A claim is - "*
>
> *Student: "I mean the second and the third one."*
>
> *Student 2: "Reasoning is what supports the claim – "*
>
> *Teacher: "Well, that is, that is, that is relevant in that it is a significant observation, but is that relevant to making it a good model for rocks? The first one is absolutely. Ok. All right. Ladies and gentleman if I could have your attention."*

Ms. Brennan's response to the student's question is unclear. She only said to the student, "…that is, that is relevant in that it is a significant observation, but is that relevant to making it a good model for rocks? The first one is absolutely." Then instead of allowing the student to ask further questions or asking the student a question to determine his level of understanding, she called the whole class together and started them on a new task. Consequently, although she told the class that an argument consists of claim, evidence and reasoning, she did not offer them an explanation of what these terms mean. Furthermore, she never provided a rationale for why it might be important to use this argumentation structure in either science class or by scientists. The students also did not use the structural language in either critiquing the written argument or when they constructed their own arguments.

In terms of argumentation as a dialogic process, during the science seminar, there were no instances of student-to-student interactions; instead, Ms. Brennan changed the lesson to students formally presenting their ideas in the front of the room. To set-up the science seminar, she did follow the curriculum's suggestion to split the students into two groups. She had half the class sit in an inside horseshoe and the other half of the class sit in an outside horseshoe (i.e. the inner and outer circles). But instead of having the inner group talk directly to each other, she had one student at a time come up to the front of the room by the map that was projected and share their argument. The excerpt below is from the very beginning of the science seminar:

> *Teacher: Elena why don't you come on up. Ok. And you guys be attentive. Guys this is a little bit different than a presentation where someone – this is, this is um a give and take where you are going to be um listening. The inner circle as well is going to be able to – um as they come up – when they come up they will give*

their evidence for their part, but we can't clap between speakers. Your engaged and listening. It is like as if you were a grown-up and you were going to a workshop. That is exactly what it is like. Ok. Elena.

Elena: Well, I thought that the um Indian plate would get bigger over 50 million year period because of spreading zones which could easily spread the plates apart and make them wider.

Teacher: Ok. Alright. (Elena sits down). Ok. I am going to need um – why don't you go ahead. Once this starts, why don't you come on up. Jordan why don't you come next. (Jordan stands up). And I am just going to move this right over here so you guys can go in and out (Teacher moves iPad). Ok.

Jordan: I thought that um that the Himalayans would get taller, because when the plates like started crashing into each other – this one is going in this direction (Jordan points to the map) and it should make it bigger.

Teacher: Ok. (Jordan sits down). Thank you very much. Another person. Come on up.

The "science seminar" continued in this fashion with one student standing up in the front of the room and presenting their idea and then sitting down. The students never talked directly to each other and never asked each other questions about their arguments.

A number of factors appeared to impact her argumentation instruction: 1) her limited understanding of argumentation, 2) her desire to closely follow the curriculum, and 3) her prior teacher-centered teaching style and focus on measurable science outcomes. Throughout both interviews, she exhibited limited understanding of argumentation. For example, in her interview for the science seminar, she used the language of claim, evidence and reasoning, but it is unclear what she means by these terms. When discussing the students' presentations she stated:

I think that they were successful in as much as they were the beginning, by having to present out loud, using the language of the discipline, I think it brought clarification and clarity, both to the presenters and to the listeners of what they were trying to do, specifically, having the claim and trying to link evidence to the claim, which I didn't think was strong, but I felt it was much stronger at that presentation, than it was up to that presentation. Because before they'd give me a claim and they'd give me evidence and they'd give me a reason, but they weren't necessarily tied together.

This quote is interesting, because it suggests that the students were including evidence and reasoning to support their justifications for their presentations. However, if we look back at the students' arguments (such as Elena and Jordan's arguments), they provided limited justifications for their claims. Consequently, it is unclear what Ms. Brennan thought counted as the evidence and reasoning in the students' arguments.

In terms of argumentation as a process, this idea did not emerge in either of the interviews. This is particularly interesting in the science seminar lesson in which the goal was to encourage student-to-student interactions. However, Ms. Brennan interpreted the lesson differently and throughout her interview talked about it supporting presentation skills, "I think it reinforced guidelines, solid guidelines for presentation, I thought that was awesome, I feel that it gave them the opportunity specifically with argumentation, to use the language of the discipline and to follow the sequence."

As a curriculum user, Ms. Brennan attempted to closely follow the curriculum. The language Ms. Brennan used during the lessons often came verbatim from the curriculum. During both interviews, she talked about how she appreciated the structure of the curriculum and being able to follow it, including being able to read text directly from the curriculum. For example, for the first lesson she said, "Yes the teacher's guide. The flow of the teacher's guide the fact that the things we should say directly uhm are, are you know put in that special little speech box." In talking about the science seminar, she made a very similar comment:

> *the way that lesson is set up again, I so much appreciate getting that, you know you can practice it, but you can also walk through it and it stays with you, you know even to the point of "say this" in the textbox, you know that just was real helpful.*

Ms. Brennan appreciated the structure of the curriculum and often read text directly from the curriculum, which clearly impacted her enactment of the two argumentation lessons.

Although Ms. Brennan followed the curriculum, her enactment may have also been influenced not only by her understanding of argumentation, but also by her prior teaching style and focus on measureable science outcomes. For example, in the science seminar lesson she talks about how the structure of the lessons was very different from how she typically structures her classroom. For example, she said:

> *I usually, usually, usually I have them, depending on the class and what we're doing, there's floor outlets for example, so if we're using anything with electricity, the configuration changes, but usually, they are more geared toward people all facing the front of the room, and you know, which is more like - not like a lecture hall necessarily, but they wouldn't necessarily be moved for group work.*

Typically, Ms. Brennan structured her classroom so that the students were "all facing the front of the room." During the science seminar, while she physically had the students sit in two concentric horseshoes, the act of having one student at a time come to the front of the room aligned more closely with her traditional classroom structure. This suggests there was a tension between following the guidelines in the curriculum and Ms. Brennan's prior teaching style. Furthermore, throughout the interview after the science seminar, she frequently brought up the ideas of "accountability", "tests" and "the right answer", which were in opposition with what Ms. Brennan compared to as the argumentation goals of the curriculum. For example, she said:

> *In this specific lesson for this event, it doesn't impact this specific lesson but it does impact the idea of teaching argumentation. I think that it is important for us to be able to demonstrate value and in a way that it can be measured so that others see the value, and again it comes back to being able to generate grades or something that is a form of Yes.*

Throughout the interview, she expressed concerns about being able to use argumentation to generate grades for the students as well as to address the standards and meet her accountability goals. This concern may be another reason why she enacted the science seminar as a more traditional presentation lesson in which each individual student was responsible for sharing his or her ideas; instead, of having the students work as a community to debate their arguments.

Mr. Carter. Mr. Carter's lesson exhibited limited instances of argumentation instruction with those examples including low quality argumentation. For the structure of an argument, Mr. Carter used the language of claim, evidence and reasoning, but never clearly explained this structure for his students. For example, in the science seminar lesson Mr. Carter introduced the

everyday example about videogames making you smarter. He projected a presentation to show weaker and stronger arguments and discussed the characteristics that differentiate the arguments. In discussing a stronger argument he stated:

> They have taken the data, the evidence, the scientific knowledge and put it into a statement. *(Shows slide with scientific knowledge in red)* That is the scientific knowledge. That comes from research. That comes from research. *(Shows slide with data in blue)* That is the data. That comes from an investigation. As you guys move up in science, this is what they ask you to do. They ask you to take scientific questions find the scientific knowledge behind the question and then perform an investigation or experiment to give yourself data.

In this section, Mr. Carter stated that both evidence and scientific knowledge are important; however, it is not clear how he was defining evidence and scientific knowledge. For example, in the first sentence he stated "They have taken the data, the evidence, the scientific knowledge and put it into a statement." The language in this sentence suggests that data, evidence and knowledge are all distinct from each other. Furthermore, after making this statement, he showed a slide that just highlighted the scientific knowledge in red. Was he suggesting that the red text includes data, evidence and scientific knowledge? Although students may have understood that these aspects are important, it is unclear whether or not they would understand what counts as these different characteristics of an argument. Consequently, it is not surprising that the students did not use the language of claim and evidence during discussions in either lesson. Finally, Mr. Carter never provided a rationale for why an argument in science has a particular structure or why students should use this structure to strengthen their own arguments.

In terms of argumentation as a dialogic process, he mentioned this idea, but it was not highlighted in his instruction. For example, during the second lesson in which the students engaged in a science seminar, Mr. Carter introduced the activity by explaining that the students would be talking to each other. He told the class:

> So science seminar. (*Projects Slide)* What we are going to do today is to work together to understand the best explanation of a problem or phenomenon. You guys are going to run the conversation by using evidence, listening to one another, responding to one another, and then agreeing or disagreeing with what each other said. (*Text read from slide)* In order to agree or disagree with one another, you need to actually listen to what the other person is saying. (*Switches slides)* How it is going to run is like this. Half the class sits in the inner circle. (*Reads this from the slide)*. Well, we are not going to do half the class. Four people are going to be called up to sit here. The rest of you are on the outside part of the circle. We are going to do this in two rounds. So first we are going to have four of you sit here. Listen, do your argument. And then we are going to switch with four other people. Four other people will come up here and do their argument and you guys will move to the back.

This quote illustrates that although he followed some aspects of the curriculum, like encouraging students to talk to each other, he changed the physical structure of the activity. The curriculum recommended that half the class (i.e. the inner circle) at a time engage in an argumentation

debate. Instead of having half his students in the inner circle, Mr. Carter chose to have only four students debate and then he switched and had another four students debate. As a result of this structural alteration only eight of the approximately 26-30 students in his class had the opportunity to engage in this debate.

During the discussion of the four students, some student- to-student interactions did occur. The first group talked for approximately seven minutes and the second group talked for approximately five minutes while the rest of the class observed. During these discussions, the conversation mainly entailed one student initially presenting their explanation for why the Atacama Desert is the driest place and then the other students agreeing with that explanation. Below is the beginning of the transcript for the first student group:

- Teacher: So what we are going to do – let's say Mason is going to start. Mason is going to read his claim. Mason what was – what was the claim you made? Nice and loud please.
- Mason: I think the Atacama Desert gets little precipitation because of the mountains and prevailing winds.
- Teacher: Now you guys can agree with him, disagree with him, talk to him about that statement.
- Rashona: I agree because – the water – the wind – like the water goes up the mountain and (inaudible) and can't get to the other side.
- Sophie: I agree with Rashona.
- Teacher: Speak up a little. We all need to hear you.
- Sophie: I agree with Rashona because um the desert does not get any rain because the mountains are blocking the desert. So the rain from the wet area tries to get to the desert, but it does not get it because the mountains block it.
- Jaylen: I agree but I think I disagree because, because the prevailing winds are coming from - one is coming from the east and one is coming from the west. So I will show you (*points to a map on the table)*. If the ocean (*inaudible)*. As it rises, the water condenses bringing it all over here. And then, before it goes down, it is cooler but it is drier. And also on the other side it is cool and dry water – no not water - cool and dry air.
- Mason: I would not really disagree or agree. I am sort of in between. But um, the mountains get in the way of the prevailing winds, which are moist. And so they rise and make it rain on the side that is not the desert.
- Rashona: (Inaudible)
- Mason: Yeah. So the prevailing winds those go up. And they form on this side. And on this side there are cold prevailing winds so that is why the Atacama Desert is so dry.
- Rashona: Perfect.
- Mason: Anything else anyone had? (silence)
- Teacher: I heard you guys say a lot about winds and prevailing winds. In this picture here, this part here is dry and this part here is wet. Any explanation why the desert right here is dry but when you go down farther it becomes wet?

Mr. Carter did initially provide the students with space to talk to each other and encouraged the students to agree or disagree with the initial explanation. All four students in the group spoke and for the most part agreed with each other. Jaylen seemed to potentially be offering a new idea, but his explanation was a little unclear. None of the other students questioned him or critiqued his idea. Instead, Mason stated his original explanation again and the group seemed

satisfied with that since there is silence after he brought up his idea. After the silence, Mr. Carter stepped in again and asked about a different area of the map. However, he never asked questions or provided comments that pushed students on the structure of the argument or encouraged students to question each other. Consequently, we saw some students engaged in the process of argumentation, but it was only a sub-set of the class and the students offered limited critique or questioned each other's ideas. Instead, the four students mainly seemed to be presenting the same idea and agreeing on that explanation with little discussion or debate. Finally, Mr. Carter never provided a clear rationale for why they were engaging in the process of argumentation.

Three major factors that may have impacted his argumentation instruction are: 1) He exhibited limited understanding of argument including a tension with content, 2) He used the curriculum as a guide that he adapted based on his prior teaching practices and 3) His prior teacher-centered teaching style as an entertainer impacted his enactment. During the interviews, Mr. Carter exhibited a limited understanding of argument in terms of both product and process. For the structure of an argument, he only talked about the different components of an argument in the first interview and similar to his instruction did not clearly define the components. In terms of argumentation as a dialogic process, Mr. Carter discussed wanting to have students agree and disagree with each other as well as have students share their ideas. Specifically, he said:

> *Uhm, I like to have kids give ideas and then I'll, you know - who agrees with that. Who disagrees with that. I like to be - I'm the net in a tennis match, so everything had to go over or through me. Um. The better they get at it then I can step back and they can do it with each other. At this point I like to be the one - okay who else, and what else. I'm going to call on this person. You know, so it's not just people talking out, you know, people want air time. But I'm trying to limit or diversify the air time people get.*

Although Mr. Carter discussed having students share their ideas and listen to each other, he also expressed a desire to have a certain amount of control over these discussions.

Furthermore, he expressed a tension with having students engage in argumentation and develop an understanding of the science content. He talked about how he was worried that the students did not understand the science content so they spent a lot of time as whole class before the science seminar understanding the science concepts. Specifically, he said:

> *We had a lot of challenges in the getting ready for the science seminar lesson. (Interviewer – Can you talk a little about that?) Because the idea of reading a map, making inferences about, uhm, why something's dry or not dry, they really were like at a, at a standstill. Uhm. So we had to do that as a whole class where we had to say okay, now lets really explore these ideas as a whole class, I gave a lot of explanation um, so a lot of what they had in their claim came out of the group - class that we all did together which is why a lot of them had the same thing written. Because we spent so much time doing it together. Uhm, having not done that - done more individually - then I think it would have been more diversity in what they were saying.*

This explanation of his preparation for the lesson suggests that the students wrote an explanation as a whole class for why the Atacama Desert is the driest place on earth. Considering this, it is

not surprising that the four students in the small group did not really debate their ideas, but rather appeared to agree on the same explanation. At multiple other points later in the interview, Mr. Carter again comes back to this idea of content. For example, Mr. Carter brings up the idea that he made "some corrections before the science seminar" and his "Fear of [students] getting misinformation." to make sure all of the students understood the correct science ideas. Consequently, although he seemed to understand the purpose of argumentation is to have students talk to each other, he does not seem to understand that this process should help students debate and change their ideas. An important part of argumentation is actually bringing forth a diversity of ideas and then using evidence and reasoning to agree upon the strongest explanation. In Mr. Carter's lesson, the class had already agreed on an explanation so there was little incentive to actually debate these ideas.

In terms of his curriculum use, Mr. Carter discussed getting ideas from the curriculum that did impact his instruction. For example, in the first interview, he stated, "Well, the lesson plan drove - the lesson plan drove the, the entire lesson. Uhm, you know, without the lesson plan I'm not sure I would have done a lesson on argumentation at all." Although the curriculum influenced his instruction, he also discussed the importance of teachers adapting the curriculum based on their own individual teaching styles. Specifically, he explained:

> *For every teacher there is their teaching style, right? So – so, even though you have a prescribed lesson, and you have a script, every teacher is different, everyone's going to play to their own teaching style, some are showmen, some are just facilitators, some are -- so my teaching style definitely plays into the way I teach, no matter what lesson you gave me, it would have to fit—I'd always mold it to me.*

Mr. Carter saw the role of the teacher as being important for how specifically the curriculum was used in a classroom. After Mr. Carter expressed the importance of teaching style, the interviewer followed up by asking, "How would you describe your teaching style?" In response, he stated:

> *I like the attention of students. Umm, but they'll only be—They'll only pay attention if they're being entertained. So, in a lot of ways I am an entertainer, who is delivering knowledge. The more I can entertain, the more engaged they, they will be. The more engaged they are, the more they'll catch on to what I'm saying. So, I try to make it as fun as can be, and I try to be as much fun as I can be, while maintaining a level of academics in the classroom."*

Consequently, the last factor we saw as important was Mr. Carter's prior teaching style that included a more teacher-center teaching style as an entertainer that may have impacted the decisions he made around the argumentation lessons.

Ms. Richardson. Ms. Richardson's instruction included a clear focus on scientific argumentation, with many instances of high quality instruction. In terms of the structure of the argument, she explicitly used the language of claim, evidence and reasoning in both lessons. Although she often used the language, she did not clearly define the terms for students, though her instruction also suggested she had already discussed the structure with her students earlier in the school year. For example, in the beginning of the first lesson before analyzing the argument

reading, Ms. Richardson reminded the students of when they had previously engaged in scientific argumentation in an earlier unit.

- Teacher: "Raise your hand if you can remember or think about a scientific argument that you have already had practice writing before."
- *About 1/3 of students in video screen raise their hands.*
- Teacher: "Samantha"
- Samantha: "Why the dinosaurs went extinct."
- Teacher: "Yeah. Does anyone remember what their claim was? What was their claim? Annabel"
- Annabel: "Meteors."
- Teacher: "Another claim - that you used. Christina."
- Christina: "Volcanoes."
- Teacher: "Good. And another claim that you used to say why the dinosaurs went extinct. Mahlik?"
- Mahlik: "Supernova."
- Teacher: "Excellent. Ok. So do you guys remember that? And then what did you use to convince somebody that your claim was true. Do you remember what you did to communicate that? Miguel."
- Miguel: "Um (inaudible) Supernovas (inaudible)."
- Teacher: "I am not sure that you understood my question. Sorry about that. What did you use in your writing to convince people about your claim?
- Miguel: "Evidence."
- Teacher: "Good. Evidence."

During this discussion, Ms. Richardson connected to a lesson in which the students had constructed arguments including three possible causes of the dinosaur extinction – meteors, volcanoes and supernovas. When she asked her students to provide a claim, the students appeared to understand what she was looking for. Furthermore, when she further inquired how to convince someone of a claim, one student brought up the idea of evidence. This suggests that the students had some comfort with the structural language and were able to use it at times during the lessons. For example, during the science seminar, there were also instances when the students used the language:

> David: "One of my evidence is that there are spreading zones in the [inaudible] and my reasons is that in a spreading zone there is new crust formed"
> Julia: "What's your claim?"
> David: "Oh my claim is the Indian Plate will get bigger."

In this case, Julia followed up and asked for David's claim suggesting that she realized he needed to include one and was comfortable using that language. In terms of a rationale for using this structure, Ms. Richardson focused on the idea that this practice is similar to what scientists engage in. Specifically, she said, "We are also going to be talking about and looking at an example of a scientific argument and thinking about how that is important when scientists communicate their findings." She discussed the idea that students would be communicating in similar ways to scientists.

During both lessons, Ms. Richardson included the idea that argumentation is a process in which you are trying to convince someone of the claim. For example, in the transcript above from the first lesson she said "And then what did you use to convince somebody that your claim was true?" She also connected this argumentation process to the practices of scientists:

> *And scientific ideas are often examined very closely by other scientists – they're critiqued. Remember how we are looking for holes in theories in how dinosaurs went extinct. We were trying to prove why our claim was stronger than the other claim. Well, that is what scientists do. Sometimes they have different ideas – for example what causes climate change. They are trying to critique different ideas, but also try to learn from them.*

She described scientists as engaging in a social process in which they share and critique different claims in order to develop stronger explanations.

Although Ms. Richardson discussed the idea of convincing or persuading, she never brought in the idea that students should be talking directly to each other during the science seminar. For the majority of the discussions, Ms. Richardson led the discussion in that she called on the students as well as asked the majority of the questions during the seminar. However, there were a couple of instances in which the students talked directly to each other. The excerpt below starts with a more "typical" section of discussion in that Ms. Richardson led the discussion. However, after Tony's contribution the conversation shifts to being more student-driven.

- Teacher: Jose.
- Jose: My claim is that the Indian plate will get bigger and my evidence is that there are spreading zones around the boundaries of the Asian plates. (inaudible) - at spreading zones plates move apart from each other.
- Teacher: So, Jose are you saying you agree with Pablo or you agree with Ian?
- Jose: I agree with Pablo because he said it - oh, I agree with Ian that the Indian plate will get bigger.
- Teacher: ok. Marcus.
- Marcus: Um, I disagree with Ian and Jose. I see what they are saying. Um. Ian's theory it is still going to the Eurasian plate, because that entire area is still the Eurasian plate.
- Tony: But it's also colliding with the – what plate is that?
- *Several students go over to point to map Tony is holding.*
- Teacher: So you're talking about the countries of South Asia and Indonesia. You're saying that forms a different plate?
- Tony: Yeah. And it is also colliding with the Indian plate.
- Ian: Well, I (inaudible) cause – yes it is going to collide, but right here there's many – there's lots of spreading zone. It is going to get lots of crust – lots of new crust to make the plate bigger
- Eduardo: It is also a subduction zone.
- Ian: Yeah, but look – the subduction zone has like ¼ of the subduction zone and like 1, 2, 3, 4, 5, 6, 7, 8 – eight spreading zone
- Eduardo: But it is really small.
- Ian: Yeah but they have 8 that's ¼.
- Teacher: Is there anybody else who would like to join in the conversation with agreeing or disagreeing with um - the ideas that have been presented, or providing more evidence or new evidence? Bill?

The beginning of the discussion started off with a traditional teacher, student, teacher, student pattern in which Ms. Richardson called on students and asked them questions. However, there is then a shift in which the students presented their arguments to each other without Ms. Richardson calling on them. The student-led interaction between Tony, Ian and Eduardo ended once Ms. Richardson invited more students into the conversation. The students did appear to listen to each other throughout as well as agree and disagree with each other's ideas. Unfortunately, Ms. Richardson still led the majority of the conversation.

In terms of factors that may have influenced Ms. Richardson's instruction, there were three ideas that surfaced in both interviews: 1) An understanding of scientific argument, 2) A desire to follow the curriculum, but also to learn from the curriculum about scientific argument, and 3) Her prior teaching style and background in science.

In terms of an understanding of argumentation, similar to her lessons Ms. Richardson used the language of claim, evidence and reasoning throughout the interview. For example, in reflecting on the quality of the students' arguments in Lesson 2.8 she said:

> *Umm, I mean I think it was successful in that kids had claims and they were using evidence to back their claims. Umm again the reasoning may not have been there as much as I would have liked. But definitely they were using evidence to support their claims, I feel like. And they were listening because of the I agree or the I disagree, like there was a lot of that.*

She clearly used the language of claim, evidence and reasoning. She was also one of the only teachers who discussed evidence in a way that suggests that she had been thinking about what counts as strong evidence in science. For example, in her interview after Lesson 2.8 she talked about the challenges of coming up with high quality evidence in earth science:

> *I also just feel like it was really good modeling for me, thinking about how you can take something, like Earth Science, that is hard to you know have data to use as evidence to support some sort of a claim, so I really liked the modeling, oh I can see how this would help support the development of those skills during the Earth Science unit where it's hard to collect data.*

The fact that she was wrestling with what counted as strong evidence suggests that she was considering what actual data the students could use. Over the course of the interviews she did not discuss in depth the meaning of the different components, but her ideas suggest that she did think about this perhaps in more depth than some of the other case study teachers.

In terms of the curriculum, she talked about it being helpful for teaching, but unlike other case study teachers, she discussed it as a resource to learn from rather than as a script to follow. Specifically after the first lesson she said:

> *Umm I think for me the biggest benefit in working with umm this curriculum project is just umm you know helping me with some explicit language and exemplars and tasks for teaching the whole scientific argumentation. I feel that I have not done that in the past. So for me the curriculum has been very helpful in those ways. Umm yeah it's been absent from my science curriculum so I've appreciate the explicitness, the examples.*

Here she talked about the explicitness helping her understand argumentation. In Lesson 2.8, she took this idea even farther when she explained:

> *I feel like this has been the most professional development and support I've had with teaching argumentation….I mean generally I understand that I have been exposed to this idea of you know, making claims and using evidence to support it.*

> *But in terms of the language of making a scientific argument and being this explicit and clear with it, I feel like this curriculum has provided that for me.*

In her discussion of the curriculum, Ms. Richardson never discussed liking having a script to follow or specific suggestions of what to say. Rather she seemed to view the curriculum as a resource that could support her understanding of argumentation not only for these two specific lessons, but for her instruction more generally.

Although the idea of argumentation was new to Ms. Richardson, the structure of an argument seemed to align with her past ideas and experiences in science. For example, after the first lesson she talked about her background in geology. Specifically, she said:

> *Yeah I definitely feel that this was very helpful for me in highlighting a gap I have in my own teaching and learning. I mean it's been a part of my science background as a geology major but you know, the longer you're out of the research field, the science field, you know, you kind of forget these important things. You just kind of get into the nitty gritty of following procedures and you know collecting data and analyzing the data so I appreciated this*

While the structure itself was new to her, it seemed to align with her ideas about how science knowledge is constructed and science instruction. In contrast, the idea of argumentation as a dialogic process seemed to be a little different than her prior teaching style. At the beginning of the interview after the second lesson while discussing how she felt the lesson went, Ms. Richardson said:

> *So the kids are used to their ideas, you know having to justify their ideas, explain their ideas. And then I think that goes you know, the same in our language arts class. You know, since kindergarten the kids are used to you know collaboration is sort of our guiding principle of communication. So kids are used to this idea of dialogue, justifying, having discussions… So starting in second, fourth, sixth, eighth and tenth, students give what we call passage presentations. So they present their portfolios to their parents and other students' parents. Umm and so that gives them an opportunity--*

Although she connected the argumentation process to students explaining their ideas, she also connected it to more formal presentations. This suggests that having students justify their ideas may be similar to her previous teaching experiences while engaging students in debates in which they engage in student-to-student interactions may be different. This may be one reason why she taught the Socratic Seminar as a more teacher directed discussion.

Ms. Norman. Ms. Norman's instruction included high quality argumentation in both lessons; however, the quality of instruction was stronger in terms of the structure of the argument compared to the process of argumentation. In terms of the argument structure, the idea that a claim should be supported with evidence (e.g. data) and scientific principles was prevalent in Ms. Norman's classroom instruction. During the first lesson, as the class discussed these terms she also provided definitions for what she was looking to have included in an argument. For example, Ms. Norman had the students evaluate an argument in the curriculum, which addressed the question – Do video games make you smarter? While discussing the argument with her students, Ms. Norman brought up the idea that you need to include both data and scientific knowledge to justify your claims in science:

> *Your data comes from these observations from an experiment and you have to make sure that you set-up the experiment in a controlled way so that you can see*

> *what is creating the change. All right. This is something we have started to talk more about lately. Where not only do you need data, but you need scientific knowledge to support your claim. So these are the facts, the ideas, the concepts that have been developed over time by scientists doing experiments over and over and building up the knowledge.*

In this quote, Ms. Norman talked about using data and what counts as data to support a claim. She also brought in the idea of using scientific knowledge, which she further elaborated on later in the lesson such as when she asked the class, "Does anybody have any scientific knowledge that they know about that we could use to back up the data to make a stronger argument?" Although Ms. Norman discussed the argument structure, she never provided students with a rationale for why to use this framework. Her interview suggests that she has used this language with her students in the past. Unfortunately, we do not have video from when she first introduced the language and whether or not she provided a rationale at that time point.

In terms of the students, they also used the structural language without being prompted by Ms. Norman. This suggests that some of the students had some comfort or familiarity with the language. For example, after the science seminar, Ms. Norman asked the students to reflect on the quality of the discussion during the seminar. During this discussion, one of the students brought that he thought there was a lack of reasoning in the conversation.

- Mario: "Some people they had like evidence, but like no reasoning."
- Teacher: "Oh. Say more about that. You said they had evidence, but what would you have wanted them to do with the reasoning part"
- Mario: "Well, explain how it connected with the claim."
- Teacher: "Ok. So even if their evidence was good, you did felt like they did not make the connection for you as a listener?"

In his comments, Mario identified not only a lack of reasoning, but explained that he felt that students were not connecting their evidence to their claim, offering a general definition of what he felt counted as reasoning. The teacher and students use of the language during the two lessons suggests that language and structure were becoming a part of the classroom norms in terms of how they constructed and critiqued arguments.

Although the argument structure was prevalent in the two lessons, the process of argumentation as dialogic interactions in which individuals try to convince each other of their claims was not as strong. In introducing the science seminar, Ms. Norman brought up the idea that students should be building on each others' ideas and talking directly to each other. Before the first group began their debate, she stated:

> *You don't have to raise hands. All right. But as long as we are not talking over each other. If you just want to respond to each other that is fine. It does not have to be as formal as raising hands… Listen you can argue and discuss with each other. I am on the outside of the fishbowl. Um. All right. So you can respond*

In this quote, Ms. Norman encouraged the students to "discuss with each other" suggesting that she wanted students to engage directly with each other, rather than through the teacher. Furthermore, unlike the previous two case study teachers, she did physically set-up the format of

the classroom with half the class in a circle debating each other at a time. After introducing the science seminar, the discussion then began with the following student-to-student interactions:

> *Bryan: Also, I think that the Andes Mountains might be creating the rain shower effect on the Atacama dessert um so like all the water vapor and something can't get there.*
> *Susannah: I agree with Bryan, because like the mountains they like, they like – may be like blocking the water*
> *Diana: I disagree that they might be like blocking, because clouds go like higher than the mountains. But they can – the clouds might get tired and rain on the Andes Mountains*
> *Bryan: I also agree with what Matarra said about the current being cold. Because like the cold water won't evaporate easily so they won't have water vapor to condense.*
> *Teacher: Did everyone hear that one?*
> *Students: No*
> *Teacher: Say that again Bryan.*
> *Bryan: Um I agree with Matarra that it is also because of cold currents, because like um - the water will be harder to evaporate so like it won't condense into clouds because there will not be much water vapor.*
> *Teacher: Why is the water harder to evaporate?*
> *Bryan: Because it is cold.*
> *Teacher: How do you know that? What is the evidence?*

After the first couple of students shared, Ms. Norman began asking questions, which continued throughout the rest of the first group's discussion. In these questions she really pushed the students to expand their thinking, which is a strength, as well as consider the structure of the argument (e.g. what is the evidence?). However, because of her dominant role the students had little student-to-student interaction.

Three major factors appeared to impact Ms. Norman's instruction: 1) An understanding of scientific argument, 2) A desire to follow the curriculum, but also to be a reflective and critical user, and 3) Her prior teaching style with a focus on questioning students. In terms of her understanding of scientific argument, in both interviews she demonstrated an understanding of the structure of the argument. For example, when talking about the first lesson and the video game example, she discussed how claim and evidence are easier for her students, as well as herself, compared to reasoning. She stated, "I felt like they were successful in terms of evidence, and claim. But not reasoning. And that, that parts coming next and that is the part personally I struggle with, and that the students struggle with." She then went to discuss how the claim, evidence and reasoning were represented in the presentation slides and how that representation helped her understanding of reasoning:

> *Yes, what uhm, the thing I love, in that paragraph where they color coded, and then they turned the basic chunks of data and scientific knowledge then they show you how to turn it into a paragraph. That really helped me a lot. Again like I'm saying like I feel like I'm good at the claim and evidence part, but I feel like that paragraph pulled it all together. So it took the claim and the evidence and it added in the reasoning and the explaining in a way that makes it structural.*

In this example, Ms. Norman talked about how the curriculum helped her think about the reasoning in terms of the scientific knowledge and connections. Her discussion of the claim, evidence and reasoning framework suggests this is something she was already thinking about and that working with the curriculum was increasing and clarifying her understanding.

In terms of the argumentation process, she seemed conscious that the second lesson did not include the student-to-student interaction and debate that she would have liked. For example, in terms of discussing how she introduced the lesson, she stated:

> *I didn't launch it the best way because they were all looking at me, I didn't really want them to look at me. I wanted them to have the discussion amongst themselves and so I have to think about how I do that with the other classes. So that I don't- I don't want to be who their directing this to I want them to be talking to each other more.*

She discussed how she wanted the students to be talking more directly to each other. Later on in the interview she came back to this point and provided suggestions of how she might teach the second lesson differently in the future. For example, one strategy she suggested was that she could have told the class, "Listen, for the first five minute of the discussion I'm not going to say anything. I'm just gonna be- I'm just gonna be an observer and a listener too." Her suggestion of not talking for five minutes has potential to support students in greater dialogic interactions and suggests she had some understanding of argumentation as a process even though the enactment of the lesson did not include a lot of student-to-student interaction.

Another factor that may have impacted her enactment was her desire to follow the curriculum, but in a reflective and critical way. For example, she discussed

> *…like I said I tried to stay true to it for the sake of just going through the curriculum the way they want us to. Uhm, the, a lot of the questioning is not from them. I do not follow their script 100%. And because I don't feel like it really captures like the give and take that goes on in discussions, in, in a classroom.*

In this section of the interview, she discussed how she did follow the lesson and intent, "to stay true", but she did not say quotes verbatim from the curriculum. Rather, she used her own questioning strategies and phrases with her students. She taught the curriculum, but in a reflective and critical way.

In terms of argument as a structure, the previous language she had used around claim, evidence and reasoning may have been an asset to her instruction. However, one possible reason that the student-to-student interactions were more challenging for her may be because of her prior teaching style in terms of her use of questions. A characteristic of her teaching that she talked about in both interviews was her use of guiding questions to encourage greater student critical thinking and reflection. For example, in the first interview she talked about her use of questions stemmed in part from a book she read, *The Skillful Teacher.* She said:

> *The Skillful Teacher is a really good source that I've used to developing how you question in a way that's challenging, that doesn't give things away, but that doesn't give the answer away. And it's that higher order thinking - but it's actually different in science, so they know a part of it, but you know like in any good argument, like that you're having with a friend, and someone says "really, why do you think so?" or "where'd you get that information" or you know, just that kind of pushback*

During the interview, she frequently brought up this idea of using questions to really encourage student thinking. The idea also came up in the second interview where she talked about "That you have this pool of, this pool of even you know, contradictory questions that really challenge the kids in a way that's really provocative to think it through." Again, she talked about the importance of having questions to really help students think through their ideas. In many ways, this aspect of Ms. Norman's teaching style was a strength, such as in helping students think through what counts as high quality evidence or how they needed to justify their claims. However, her frequent use of questioning may have prevented more dialogic interactions between students in the second lesson, because the major role she played in directing the discussion.

Discussion

Across the ten teachers, we observed a wide range in teachers' enactment of the argumentation lessons. In order to successfully integrate argumentation into classroom instruction, teachers need a range of pedagogical strategies to both introduce argumentation as well as to support students over time (Osborne, et. al., 2004). The three main factors the teachers discussed as impacting their instruction offer insights into areas to provide greater teacher support around argumentation in the future – teachers' understanding of argumentation, teachers as curriculum users and the importance of prior experiences and teaching styles.

Teachers' Understanding of Argumentation

We observed a range in the teachers' understanding of argumentation in terms of both the structure of the argument and argumentation as a dialogic process. The teachers with higher quality argumentation instruction were more likely to have stronger understandings of argumentation that aligned with the curriculum materials. Furthermore, the teachers with lower quality instruction were more likely to express a concern or tension between supporting students' understanding of argumentation with developing an understanding of science content or accountability measures. Osborne and his colleagues found that teachers expressed similar fears by some teachers who were concerned that, "…the presentation of plural explanatory theories would confuse the children or lead to the development or strengthening of a belief in a scientifically incorrect idea" (2004, p. 1014). Consequently, it may be important for future versions of the curriculum to help teachers understand that debating and critiquing alternative claims or explanations can in fact support students in developing a richer understanding of the science content. Understanding not only one a particular scientific idea is accurate, but also why alternatives are weaker, can ultimately enrich students' conceptual understanding.

Teachers as Curriculum Users

Teachers can use curriculum materials in a variety of different ways. For example, Brown (2004) talks about teachers as three types of curriculum users 1) Offload – adhere closely to curriculum, 2) Adapt – use a combination of personal resources and curricular resources and 3) Improvise – rely more fully on their own personal activities and resources than the curriculum materials. In our case, all ten teachers either attempted to adhere closely to the curriculum or adapt the materials based on their prior experiences or teaching styles. Interestingly, some of the teachers who discussed trying to closely follow the curriculum actually had lower quality argumentation instruction. Although these teachers did state some text verbatim from the curriculum and were following the general instructional sequence, they made changes to the

activity structure that in particular resulted in diminishing the focus on argumentation as a dialogic process.

Zohar (2008) argues that when teachers use instructional materials based on reform-oriented ideas that they are not familiar with, they can end up paying attention to superficial aspects rather than the core ideas. In this case, teachers may have focused on the idea that argumentation was an important part of the curriculum; however, the teachers did not develop a strong understanding of what counts as argumentation. Consequently, we feel this suggest the importance of providing images of practice (such as videos, transcripts and student work) in teacher learning environments that illustrate and contrast argumentation with other forms of instruction to help teachers develop a richer understanding of this scientific practice.

We also found that some of the stronger argumentation instruction came from teachers who tended to be more reflective curriculum enactors who thoughtfully connected to similar experiences with their students in the past as well as tried to learn from the materials about argumentation in general. Online environments that included a tool to support individual's reflection or self-assessment resulted in stronger outcomes (U.S. Department of Education, 2009). In future versions of the curriculum, we feel it may be important to encourage this type of teacher reflection. Instead of encouraging teachers to follow the curriculum verbatim, it may be more important to encourage teacher reflection on the big ideas in the curriculum and how to successfully incorporate them into their own classroom instruction.

Prior Experiences and Teaching Style

The introduction of new instructional strategies requires a transformation of the manner by which a classroom community interacts. Introducing the practice of argumentation into the science classroom requires such a change, and like any other change has challenges. Pre-existing classroom conditions such as rules, expectations, and dialogic norms influence how argumentation is adopted into instruction (Berland, 2011). Consequently, it is not surprising that the teachers' pre-existing teaching styles greatly impacted their enactment of the argumentation lessons. The teachers with lower quality argumentation instruction were more likely to discuss how the instructional model for argumentation in the curriculum differed from their prior teacher-centered teaching style. This is in contrast with the teachers with higher quality argumentation instruction who were more likely to make connections to pre-existing strategies such as the use of questioning or classroom discussion norms.

Future versions of the curriculum need to provide greater support for those teachers who have previously utilized more teacher directed strategies. This could include images of practice to help teachers, like Ms. Brennan, visualize classroom instruction in which students play a more active role. Furthermore, other teachers, like Mr. Carter, may need greater support in terms of a rationale for why it may be more effective to change their teaching style as well as opportunities to reflect on the nature of their classroom instruction and how it does and does not support students in important scientific practice learning goals such as argumentation.

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