

**Explanations, Arguments and Evidence in Science, Science Class
and the Everyday Lives of Fifth Grade Students**

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Abstract

Science is a practice that includes more than just concepts and facts, but also encompasses scientific ways of thinking and reasoning. Students' cultural and linguistic backgrounds influence the knowledge and experience that they bring to the classroom, which impacts their degree of comfort with the norms of scientific practices. Consequently, the goal of this study was to investigate fifth grade students' views of explanation, argument and evidence across three contexts - what scientists do, what happens in science classrooms, and what happens in everyday life. Furthermore, I was interested in how students' ability to engage in one specific practice, argumentation, changed over the school year. Multiple data sources were collected and analyzed: pre and post student interviews, videotapes of classroom instruction, and student writing. The results suggest that students' views of explanation, argument and evidence, varied across the three different contexts. Furthermore, students' views of the meanings of the terms for scientists and for science class changed over the course of the school year, while their everyday meanings remained more constant. Students developed more sophisticated views of these scientific practices and were able to write stronger scientific arguments by the end of the school year.

Explanations, Arguments and Evidence in Science, Science Class and the Everyday Lives of Fifth Grade Students

The National Research Council (Duschl, Schweingruber, & Shouse, 2007) report, *Taking Science to School*, provides a new framework for proficiency in elementary science, which includes a focus on students being able to “generate and evaluate scientific evidence and explanations” and “participate productively in scientific practices and discourses” (p.2). Science is a practice that includes more than just concepts and facts, but rather also encompasses scientific ways of thinking and reasoning (Lehrer & Schauble, 2006). In order to succeed in science, students need to be able to navigate different discourses or ways of knowing, doing, talking, reading and writing (Moje et al., 2001).

Argumentation is a central scientific practice in the discourse of science in that scientists socially construct knowledge through evaluating scientific claims, weighing evidence and assessing alternative explanations (Driver, Newton, & Osborne, 2000). Engaging students in scientific argumentation has many potential benefits such as learning science concepts, engaging in scientific discourse, altering students’ views of science, and supporting them in socioscientific decision making (Erduran & Jiménez-Aleixandre, 2008). Young children are capable of quite sophisticated scientific thinking and reasoning, which has been historically underestimated (Duschl, et al., 2007). When provided with the appropriate opportunities and support, even elementary students can move beyond simply observing and describing to negotiate and debate meanings and explanations (Varelas, Pappas, Kane & Arsenault, 2008). One important strategy is to consider students’ everyday ways of knowing as a resource to support them in engaging in scientific practices (Warren, Ballenger, Ogonowski, Rosebery & Hudicourt-Barnes, 2001). Yet little research has been conducted examining students’ everyday sense making practices around evidence, explanation and argumentation. Consequently, in this study I investigate the following research questions: What are elementary students’ ideas about explanation, argument and evidence in the context of science, science class and their everyday lives? How do elementary students’ ideas and their ability to write scientific arguments change over the school year?

Theoretical Framework

Evidence, Explanation, and Argument

Teaching students about science requires engaging them in the disciplinary practice of science with a focus on constructing reliable knowledge claims that provide explanatory accounts of nature (Ford & Forman, 2006). The construction of knowledge claims in science occurs through argumentation in which scientists debate and justify claims using evidence (Driver et al., 2000). This social construction of knowledge is essential to the scientific community in which claims are disputed and change over time as new evidence arises and different theories are debated.

Schools often prioritize final form science instead of engaging students in science as a practice in which students engage in scientific ways of thinking and reasoning (Lehrer & Schauble, 2006). Key practices of science include using evidence, generating explanations and participating in argumentation, which are all essential for k-8 students to develop proficiency in science (Duschl et al., 2007). Developmental constraints have been inappropriately cited as reasons why elementary students should not engage in scientific inquiry and reasoning in science (Metz, 1995). Yet recent research suggests that even young students can engage in these essential scientific practices (Duschl, et al., 2007; Varelas et al., 2008). Zembal-Saul (2009) argues for

the importance of moving elementary science along a continuum to move beyond just focusing on fun hands-on activities to engaging students in inquiry in which they need to support claims with evidence and ultimately construct arguments in which the coordination between evidence and claims are discussed and consideration is given to alternative explanations.

Developing an understanding of and ability to use evidence is not only important for individuals who obtain jobs in science related fields; rather it is an important practice of the discourse of science for all individuals. Evidence is data, which can consist of either quantitative or qualitative measurements, that is used to answer a question, solve a problem or to make a decision (Aikenhead, 2005). Tytler and colleagues (2001) argue that the use of evidence is central to the interactions between the public and science. Individuals need to consider, ask questions about and use evidence when engaged in regulation, policy formation and decision-making that involve science in their everyday lives. For example, using evidence is important for individuals to engage in problem solving or decision-making in everyday circumstances around a science related matter, such as deciding to have a child immunized (Aikenhead, 2005). Furthermore, the use of evidence is a central component of constructing explanations and arguments in science.

Explanation and argumentation are related scientific practices. An explanation in science provides an account of how or why a phenomenon occurred (McNeill, Lizotte, Krajcik & Marx, 2006; Berland & Reiser, 2009; Chinn & Brown, 2006). An important goal of science is to understand how and why the natural world works in particular ways. Not only is this a goal of science, but it is also a goal for k-8 students to not only know scientific explanations, but also to be able to generate and evaluate them (Duschl et al., 2007). Berland and Reiser (2009) argue that in terms of explanation as a practice of science, it is important for students to understand and participate in how explanations are constructed, questioned, evaluated and revised through the practice of argumentation. They further describe argumentation as when, "Individuals compare conflicting explanations with the support for those explanations and work to identify/construct an explanation that best fits the available evidence and logic" (p. 28). As such, they see explanation and argumentation as complementary practices. Argumentation can be defined in terms of both an individual or structural meaning as well as a social or dialogic meaning (Jiménez-Aleixandre & Erduran, 2008). In terms of the structural meaning or argument product many science educators adapt Toulmin's (1958) model of argumentation in that a claim or explanation is justified using various supports such as evidence, logic, warrants and reasoning (see Sampson & Clark, 2008 for a review). The dialogic or social perspective on argumentation focuses on the interactions between two or more individuals in which the participants try to persuade or convince each other of the validity of their claims. Consequently, engaging in argumentation can include the use of evidence as well as the construction and critique of multiple explanations. I see all three practices as being related and essential goals for k-12 science, beginning with elementary students.

Engaging in these practices can have multiple benefits for students. Supporting students in constructing scientific explanations and arguments through the use of curricular scaffolds (McNeill et al., 2006), technology tools (Schwarz, Neuman, Gil & Ilya, 2003) and teaching strategies (McNeill, 2009; McNeill & Krajcik, 2008) can increase students abilities to construct scientific claims that they appropriately justify using evidence and reasoning. This ability to construct strong arguments can also potentially transfer to other contexts outside of the science classroom. For example, Zohar and Nemet (2002) found that students were able to transfer their argumentation skills from a genetics unit and successfully apply them to dilemmas from

everyday life. Not only does participating in these practices support students' in developing these abilities, but it can also support them in developing conceptual knowledge as well as alter their view of science. For example, Venville and Dawson (in press) found that explicitly teaching scientific argumentation through modeling and other instructional practices as well as providing students opportunities to engage in argumentation supports students in developing stronger argumentation skills as well as conceptual knowledge.

In this study, I was interested in supporting elementary students in engaging in scientific discourse (both talk and writing) that included the practices of using evidence, generating explanations and participating in argumentation. As students engage in these practices, the goal was for students to justify their claims about how or why the natural world works through the use of evidence and reasoning, consider multiple alternative explanations as well as build on and critique the explanations of their classmates.

Science and Everyday Discourses

Students' cultural and linguistic backgrounds impact the knowledge and experience that they bring to the classroom, which impacts their degree of comfort with the norms of scientific practice (Duschl, et al., 2007). Success in school is impacted by students' ability to acquire academic social language, which can have different norms compared to their "lifeworld" or everyday discourse (Gee, 2005). Learning occurs in a wide variety of activities outside of school, which often include complex cognitive tasks, but students may not display these same skills in school tasks (Nasir et al., 2006). In classrooms, science discourse can present a challenge for students and can serve as a gatekeeper preventing access to the culture of science (Brown, 2006).

Students need to be introduced to scientific discourse in ways that allow them to bridge their everyday discourse and experiences with the academic language (Varelas, Pappas, Kane & Arsenault, 2008). Educators can use the varied repertoires of practice students develop in their everyday lives in order to support them with academic disciplinary practices (Nasir et al., 2006). The knowledge students obtain in their everyday lives can be similar to, but also quite different from academic disciplinary practices. It is important for educators to understand these similarities and differences in order to address them in curriculum and instruction (Taylor, 2009). Warren and her colleagues (2001) argue for the importance of taking into consideration the continuities between students' everyday and scientific ways of knowing and talking. By continuities, they suggest that the relationships are more complex than just similarities and differences, but needs to take into consideration the depth and complexity of students' sense-making in science. Making the language of science explicit can support students in engaging in scientific discourse and in developing conceptual understandings (Brown & Spang, 2008). Making visible the structure of the domain, building from students' everyday ways of knowing, actively engaging students in academic discourse and providing timely and flexible feedback can help support students in developing expertise in science (Nasir et al., 2006). Classroom instruction should be informed by students' everyday ways of knowing, which can be a generative practice for informing science discourse in elementary classrooms (Warren et al., 2001).

Yet there has been little research in the science education community specifically comparing students' everyday practices and scientific practices, such as explanation, evidence and argument. The research in this area suggests that some practices do seem to have similar meanings in everyday and scientific contexts, such as the use of evidence (Bricker & Bell, 2007),

while other practices can have different meanings, such as students' viewing argument as yelling or fighting (Bricker & Bell, 2008). Other research on argumentation has found more continuity between everyday and scientific argumentation. In Hudicourt-Barnes' (2003) work with elementary and middle school students, she found that the Haitian cultural practice of *bay odyans* is a similar form of discourse to scientific argumentation. This common form of talk in Haitian culture includes debate in which participants discuss divergent points of view and support those viewpoints using evidence or logic. These debates can also be quite theatrical including funny interjections and laughter, which differs from scientific argumentation, yet this everyday practice provides students with many resources they can draw upon to engage successfully in scientific discourse. Hudicourt-Barnes stresses the importance of incorporating students' existing everyday knowledge into science teaching. In previous work with my colleagues (McNeill & Pimentel, 2010), we found that when students engaged in argumentation around the socioscientific context of global climate change, that students frequently drew from their personal experiences and other experiences outside of their science classroom to use as evidence to support their claims. Although students made connections across their everyday lives and science classrooms, it was unclear if they viewed the use of evidence or the practice of argumentation as different in these two contexts. Consequently, in this study I was interested in investigating students' views about evidence, explanation and argument in science and in their everyday lives as well as how to best support them in successfully engaging in these important scientific practices.

Method

Context of the Study

This study took place in an elementary school in a large urban school district in New England with the grade 3-5 elementary science specialist, Mr. Cardone, and his fifth grade students. Mr. Cardone was certified to teach elementary education and general science for grades 5-8; furthermore, he had been teaching elementary science for six years at the time of the study. The student body at the school was ethnically diverse with approximately 15% African American, 60% Latino/a, 12% white, 12% Asian, and 1% Other. Approximately 82% of the students attending the school were eligible for free or reduced lunch. Mr. Cardone taught two sections of fifth grade with approximately 18 students in each class. The specific number of students varied over the school year, because of student mobility with students moving in and out of the school district. Table 1 provides a summary of the students' backgrounds in Mr. Cardone's two fifth grade classrooms. The table includes the thirty-three of the thirty-six students from the beginning of the school year who completed the background information sheet.

Table 1: Student Backgrounds (N= 33)

Gender	Race	Birth Country	Speak Another Language	What language
Male – 15	Black – 3	USA – 22	English only – 6	Bangia – 1
Female - 18	Asian – 7	Aruda/Bonire - 1	Other language - 27	Cambodian - 2
	White – 3	Colombia - 1		Creole – 1
	Latino/Latina – 17	Dominican Republic – 2		Portuguese – 2
	Multiracial - 3	El Salvador - 3		Spanish – 20
		Guatemala – 3		Vietnamese - 1
		Haiti- 1		

As the table illustrates, Mr. Cardone's fifth grade classes were very diverse with the majority of students speaking another language in addition to English.

Study Design

The study arose from conversations between Mr. Cardone and myself about challenges he observed with his elementary students around science writing, science talk and specifically supporting claims with evidence. Furthermore, I was specifically interested in students' everyday conceptions of evidence, explanation and argumentation and how they might change over the course of a school year in which they were specifically provided with support around these practices in science class. Consequently, we decided to engage in design-based research (Brown, 1992) during the 2008-2009 school year to investigate how to best support Mr. Cardone's students to become more adept at engaging in these important scientific practices.

Design-based research is important for understanding the how, when and why educational practices work in classroom contexts (The Design-Based Research Collective, 2003). Design-based research focuses on understanding the messiness of real-world learning environments through the collection and analysis of multiple data sources and the flexible design and revision of the learning environments (Barab & Squire, 2004). The research has the dual goals of impacting educational theory and classroom practice (Collins, Joseph, & Bielaczyc, 2004). As Barab & Squire (2004) argue, "Design-based research requires more than simply showing a particular design works but demands that the researcher (move beyond a particular design exemplar to) generate evidence-based claims about learning that address contemporary theoretical issues and further the theoretical knowledge of the field" (p. 5-6). Specifically in this study, we were interested in designing an elementary classroom environment that supported students in argumentation, but we were also interested in investigating how the students' views and abilities to engage in argumentation changed over the course of the school year.

Multiple data sources were collected to evaluate students' views of and ability to engage in scientific argument over the course of the school year. Data sources included: student pre and post interviews, student writing for the lessons focused on argumentation, student writing from a district wide common writing assignment, student writing from end of the year assessments and videos tapes of the seven lessons focused on argumentation.

For the pre and post interviews, twenty-three students were interviewed during the second week of school and then again during the last month of the school year. All students were interviewed who returned their consent forms providing permission to be interviewed before the second week of school. During the week before the interviews occurred, Mr. Cardone did not explicitly talk about the ideas of explanation, argument or evidence during science class. The interview focused on students' views of these three terms (i.e. explanation, argument, and evidence) in three different contexts – what scientists do, what happens in science classrooms, and what happens in everyday life (e.g. home or with friends). Appendix A provides the interview protocol that was used at both the beginning and end of the school year. During the interview if the student brought up a term or an important concept without explaining that idea, the interviewer followed up with the prompts at the end of the protocol. For example, if a student mentioned that explanations in science use data, the interviewer might follow up with – You mentioned data. What do you mean by data? Originally, thirteen students were interviewed in class A and eleven students were interviewed in class B (i.e. twenty-four students total). One of the interviewed students in class B moved during the school year and we were unable to

conduct a post interview. Consequently twenty-three students were interviewed at both the beginning and end of the school year.

Based on preliminary analyses of the beginning of the year student interviews and previous research supporting middle school students in scientific explanation and argumentation (McNeill & Krajcik, 2008; McNeill, 2009), Mr. Cardone and I designed an initial lesson to introduce his students to scientific argumentation. We used a framework that consists of three components (McNeill et al., 2006): 1) Claim – a statement that answers a question or problem, 2) Evidence – scientific data that supports the claim. The data needs to be appropriate and you need to have enough data and 3) Reasoning – Applies the science knowledge to solve the problem and explains why the evidence supports the claim. This initial lesson lasted two days. During the first day of the lesson, students went to the outdoor classroom in their schoolyard and collected data to answer the question: How many different habitats are in the outdoor classroom? After collecting the data, students were asked to write an argument that answered the question. On the second day of the lesson, Mr. Cardone used an everyday example – How long should recess be? – to have a discussion with his students about how to construct a strong argument. At the end of the discussion, Mr. Cardone introduced the framework of claim, evidence and reasoning using the definitions provided above. He then asked his students to revise the arguments they wrote the day before using this framework. The lesson was videotaped and I collected the student writing from the lesson.

The design process was ongoing throughout the year as we continued to design lessons, instructional strategies and curricular scaffolds informed by the videotapes and student writing from previous lessons as well as the current research literature. Mr. Cardone was scheduled to see each class three times a week for an hour at a time, though sometimes he saw his students less frequently because of fieldtrips, holidays or other special events. At the beginning of the year our intention was to design one lesson focused on scientific argumentation for each month. Two months we were unable to include a lesson, because of time restrictions (February and April). We designed a total of seven lessons throughout the school year, which incorporated scientific argumentation as well as two separate writing tasks. One writing task was a district wide common writing assignment, which was a collaboration between the language arts teacher and the science teacher. This assignment was completed between Lesson 6 and 7 and the students developed drafts and received feedback before writing their final arguments. The second writing task was a question included on the end of the year assessment that student answered independently and without feedback. Table 2 provides a summary of the lessons and the two writing tasks.

Table 2: Scientific Argumentation Lessons

Lesson	Days	Description
Lesson 1: Habitats	2	<ul style="list-style-type: none"> • Collect data in outdoor classroom addressing the question: How many different habitats are in the outdoor classroom? • Write initial argument • Discuss everyday example (How long should recess be?) and introduce claim, evidence and reasoning framework • Revise scientific arguments using the framework
Lesson 2: Adaptations	1	<ul style="list-style-type: none"> • Present example scientific argument – Write a scientific argument explaining why you think polar bears are able to survive in their natural environment. Class critiques two written examples – one strong and one weak. • Students observe their ecocolumns and use those observations as evidence to

		write an argument explaining how one of the organisms in their ecocolumn is adapted to survive in that environment.
Lesson 3: Stability of Ecosystems	2	<ul style="list-style-type: none"> Discuss stable versus unstable ecosystems. Examine pictures of ecosystems and discuss whether they are stable or not. Students organize data to answer the question of whether their ecocolumn is a stable ecosystem. Students fill out a chart summarizing the data they have collected for the past month in their science journals about their ecocolumns. Students write a scientific argument about whether their ecocolumns are stable. As a class, students share and discuss their arguments.
Lesson 4: Levers	1	<ul style="list-style-type: none"> Class critiques everyday example of an argument about skiing in which the students identify the claim, evidence and reasoning. Students use data they have been collecting during investigations about levers to write an argument that explains how levers can be used to make it easier to lift a load. As a class, students share and discuss their arguments.
Lesson 5: Levers and Pulleys	1	<ul style="list-style-type: none"> Class reviews key concepts they have been learning about levers and pulleys. Students review the results from their previous investigations and determine a claim they want to make about levers or pulleys. Students write an argument in which they support their claim with evidence and reasoning. As a class, students share and discuss their arguments.
Lesson 6: Force and Motion	1	<ul style="list-style-type: none"> Students work in groups in which they have to select the strongest claim, evidence and reasoning to answer the question – How can you design a car to go the fastest? They are given a multiple choice sheet in which they have to select 1 claim out of 3 choices, 2 pieces of evidence out of 6 choices and 1 reasoning statement out of 3 choices. As a class, the groups debate the strongest choices for claim, evidence and reasoning.
Common Writing Assignment	Multi ple	<ul style="list-style-type: none"> As part of a district initiative the students were asked to write a common writing assignment in collaboration between the language arts teacher and the science teacher. The students wrote an argument to address the question about which of two lever set-ups required less effort. Students used data both from their simple machines unit in science class and data provided for them within the writing prompt.
Lesson 7: Pendulums	2	<ul style="list-style-type: none"> Students collect data to investigate whether the variables mass, string length, and angle of release affect the frequency of a pendulum. As a class, they discuss the data and the discrepancies in the different groups' findings. Students write scientific arguments answering what variables impact the frequency of a pendulum
End of the Year Assessment: Food Webs	1	<ul style="list-style-type: none"> As part of students end of the year assessment, they are given a food web with the following organisms: hawk, squirrel, sparrow, rabbit, grasshopper, seeds and grass. The question states - <i>Write a scientific argument that answers the following question: What would happen to the size of the hawk population if all of the seeds were removed from the ecosystem? Remember to support your claim with evidence and reasoning.</i>

Mr. Cardone enacted all of the lessons with both of his 5th grade classrooms. One of the two classrooms was selected as the focal classroom, because all of the students handed in their

permission slips allowing them to be videotaped. This classroom was videotaped and the student writing was collected after each lesson.

Data Analysis

The coding schemes for the student interviews, student writing and videotapes of the seven lessons were developed from the theoretical framework and iterative analyses of the data sources (Miles & Huberman, 1994). The coding schemes were developed to inform the overarching research questions examining elementary students' ideas about explanation, argument and evidence in the context of science, science class and their everyday lives and how their ideas and the ability to write scientific arguments changed over time.

The analysis of the student interviews focused on students' ideas about evidence, explanation and argumentation in the different contexts. All student interviews were transcribed and the transcripts were used to develop the coding schemes and to code the data. The coding scheme was informed by previous research examining students' everyday meanings of evidence, explanation and argumentation (Bricker & Bell, 2008; Hudicourt-Barnes, 2003) and previous research examining scientific evidence (Aikehead, 2005), explanation (McNeill et al., 2006) and argument (Osborne, Erduran & Simon, 2004; Sampson & Clark, 2008). The development of the coding scheme for the interviews was also grounded in the students' own language (Strauss, 1987). We were interested in how the students described the terms explanation, argument and evidence in the three different contexts as well as how those definitions changed over the course of the school year. In the results, we include the specific codes (Tables 3-5) as well as examples to illustrate the most common codes during the interviews. Two independent raters, the author and a research assistant coded the interviews. Inter-rater reliability was calculated by percent agreement. The two raters overlapped on seven of the twenty-three students or 30%. The percent agreement for the interviews was 84%. All disagreements were resolved through discussion.

The student writing was coded using two different coding schemes: genre and argument structure. The genre coding scheme focused on whether the general structure was that of an argument or aligned more closely with another writing genre. The writing style was coded regardless of the accuracy of the science content using four different codes: 1. Argument, 2. Just claim, 3. Informational text and, 4. Personal narrative. For the argument structure, similar to other science educators (Sampson & Clark, 2008), we adapted Toulmin's model of argumentation (1958) to code student writing in terms of claim, evidence and reasoning (McNeill et al., 2006; McNeill & Krajcik, 2008). The claim is the statement or conclusion that answers the original question or problem. Claims were coded as either 0 or 1 for either appropriate or inappropriate. The evidence is scientific data that supports the claim, which needs to be both appropriate (scientifically acceptable for the claim) and sufficient (include enough pieces of data to support the claim). Evidence was coded as 0 for inappropriate or missing, 1 for appropriate and insufficient, and 2 for appropriate and sufficient. Reasoning is a justification that connects the evidence to the claim and shows why the data counts as evidence by using appropriate and sufficient scientific principles. Reasoning was coded as 0 for inappropriate or missing, 1 for appropriate and insufficient and 2 for appropriate and sufficient. Similar to the interviews, the student writing was coded by two independent raters. Inter-rater reliability was calculated by percent agreement. For the student writing, both independent raters coded all student writing. The percent agreement for the writing was 84%. All disagreements were resolved through discussion.

Finally, the seven videos were coded in order to provide an overarching context of the learning environment in which the students were being supported in constructing scientific arguments. For each video, a narrative description was created with time stamps provided throughout so the video could be referenced for clarification if needed. The narratives provided overarching summaries for aspects of the lesson not focused on argumentation (e.g. Lesson 3 defining stable versus unstable ecosystems) and detailed descriptions of the parts of the lesson focused on argumentation including specific quotes from Mr. Cardone and his students to illustrate the discussions. The narratives were then coded for instructional strategies that stemmed from previous research examining the role of the teacher in supporting students in scientific argumentation (McNeill, 2009; McNeill & Krajcik, 2008; Simon, Erduran, & Osborne, 2006). Each lesson was coded for the presence of six different instructional strategies: 1) Discuss a framework for scientific argument (claim, evidence and reasoning), 2) model and critique examples, 3) Connect to everyday arguments, 4) Provide students with feedback on their arguments, 5) Have students engage in peer critique and 6) Debate arguments as a whole class.

I also engaged in member check in that Mr. Cardone was an active participant in the research process. During the school year as the coding schemes for the student interviews and student writing were developed, he provided feedback to see if he felt the codes encompassed his students' ideas and abilities about scientific argumentation. The teacher instructional practices for the coding of the videos were all strategies that we discussed and developed with Mr. Cardone as part of the design-based research. After writing up the research, Mr. Cardone also read the results to provide feedback. He felt the results adequately represented his classroom in terms of his practices and the ideas and abilities of his students.

Results

The analyses address the following three questions: 1) What support did the teacher provide his students around how to construct a scientific argument with claim, evidence and reasoning? 2) What are students' ideas about the terms explanation, argument and evidence in the context of science, science class and their everyday lives and how do they change over the school year? and 3) How do students' abilities to write scientific arguments change over the school year?

Teacher Instructional Strategies

Throughout all seven lessons, Mr. Cardone consistently provided his students with support for scientific argumentation using a variety of different instructional strategies. Table 3 provides an overview of the lessons and the instructional strategies used in each lesson. Mr. Cardone used each of the six instructional strategies in at least one lesson and used one of the instructional strategies (i.e. Provide students with feedback) in six of the lessons. The specific strategies he used shifted some over the course of the school year.

Table 3: Instructional Strategies in Seven Argument Lessons

	Discuss Framework	Model and Critique Examples	Connect to Everyday Arguments	Provide students with feedback	Have students engage in peer critique	Debate arguments as a whole class
Lesson 1: Habitats	X	X	X	X		
Lesson 2: Adaptations	X	X		X		
Lesson 3: Stability of Ecosystems	X	X		X	X	
Lesson 4: Levers	X	X	X	X		
Lesson 5: Levers and Pulleys	X			X		
Lesson 6: Force and Motion						X
Lesson 7: Pendulums				X		

As Table 3 illustrates, in the beginning of the school year Mr. Cardone was more likely to spend time actually discussing the framework and defining the different components. Lesson 5 is the last time he explicitly defines the different components of the argumentation framework and here he is just reviewing ideas he has already discussed with his students. In introducing the levers and pulley activity he says:

Now again, just to review the process – the first step is to be making your claim. So you're going to look through the work that we've done together, in your notebooks, in the handouts that you have from levers and pulleys and you're going to come up with a claim that you have evidence for in your notes. Okay? So again, a claim is just a statement that you're making. Step two is to provide the evidence for your claim. So here you're going to be using your notes to find that evidence and this is going to be backing up the claim that you state. Okay? Any questions on that? Evidence. (Pauses). And then the last part, step three – we're going to be providing the reasoning. This part explains how your evidence supports your claim. Okay? So, any questions on the reasoning piece? Okay, it's all stuff that we've been done before and every time we do it you guys are getting better and better at it.

The later lessons focus more on having students create scientific arguments and providing them feedback on their arguments. He also tried a new strategy in Lesson 6 in which he had students debate the quality and strength of their claims, evidence and reasoning for an argument addressing the question: How do you design a car to go the fastest? In this lesson, the students worked in groups to select from a student sheet which 1 of 3 claims was the strongest, which 2 of 6 pieces of evidence was the strongest to support that claim, and which 1 of 3 reasoning

statements best explained why the evidence supported the claim. After the groups made their choices, they then debated as a class which choices were the strongest. In this lesson, the focus was on helping students develop a stronger understanding of what counted as the strongest evidence and reasoning. For example, Figure 1 includes the three different reasoning choices from which the students had to select. Mr. Cardone's goal was to help the students understand that choice C was the strongest reasoning, because it included an explanation of speed, which was an important science concept that they had to apply in order determine which evidence best supported the claim about the fastest car.

Figure 1: Three Reasoning Choices for Argument Debate

<p>REASONING Circle <u>ONE</u> of the following.</p> <p>A. The data from our experiments shows us how to build our car. Since the data shows that fast cars have a light load and fast cars are pulled by a large force then this is how we should build our car.</p> <p>B. Since car companies and race cars have cars that are really light and have large engines this means we should design our car in the same way. It should have a light load and be pulled by a large force.</p> <p>C. The speed was determined by how many seconds it took for the car to travel across the table. The car with less blocks had a lighter load and it traveled faster. The car that was pulled by more washers was pulled by a greater force and it traveled faster.</p>

Mr. Cardone started by having each group quickly state which reasoning statement they selected to see if there was disagreement in the class. One group selected B and the other groups were split between A and C. He then had the students debate as a class, which one they thought was strongest and why. Table 4 includes an excerpt from the beginning of the discussion.

Table 4: Class Debate about Reasoning

Participant	Transcript
Mr. Cardone	All right I'm going to let Lucia and Kiyana start us off. All right.
Kiyana	We chose A.
Lucia	I got C.
Mr. Cardone	Okay. Kiyana why did you think A? Hold on a second. Randall, everybody needs to now be listening to Kiyana. No, don't. We're done explaining, I need you to listen now, cause we're going to hear each others arguments, I appreciate your comment but you guys disagree, so you're going to convince the whole class not just her. That's why I don't want you to share with her right now. All right, Kiyana go ahead.
Kiyana	They chose B but they weren't correct because um in A it's explaining A it's explaining [evidence] A and D in reasoning because in [evidence] D it says the car was pulled by 5 washers by heavy force and it took 2 seconds and the other car had one washer and it took a lot of time because it's car was really heavy and in reasoning A is explaining [evidence] D and A.

Mr. Cardone	She's trying to say that A is -
Kiyana	In A it says the data shows that fast cars have a light load and fast cars are pulled by a large force. It's explaining [evidence] A and D.
Mr. Cardone	Okay, So, Lucia let's hear from you know you picked C so lets see why
Lucia	Okay it's C because it's the same thing it's also explaining [evidence] A and D because it's saying the speed is determined by how many seconds it took to travel across the table and um, and how um, the car with less blocks had a higher, had a lighter load and it traveled faster, the car that was pulled by more washers was pulled by a greater force and it traveled faster.
Kiyana	A and C both make sense. They're basically saying the same thing except one has more information then the other.
Mr. Cardone	So which one has more information?
Lucia	C

This transcript illustrates that by the end of the year the students were not asking Mr. Cardone what he meant by a scientific argument, rather they were debating how to construct the strongest argument. The students debated what counted as the strongest evidence or reasoning for a particular investigation as they applied the framework to try and make sense of a particular data set. They had developed an understanding as a class that scientific arguments consist of claims, evidence and reasoning and now were focusing on understanding what that meant in different contexts.

Students' Ideas about Explanation, Argument and Evidence

The analysis of the interviews revealed that students' views of explanation, argument and evidence varied across the three different contexts both at the beginning and end of the school year. Furthermore, students' views of the meanings of the terms for scientists and for science class changed over the course of the school year, while their everyday meanings remained more constant. Table 5 displays student's views about what it means to create an explanation in terms of a scientist, in science class or in their everyday lives. The shaded cells highlight the code, which the greatest percentage of students received in either their pre or post interview. Students' responses could receive multiple codes (e.g. both observation and exchange between people) if their response included multiple ideas. On the pre-interview students were more likely to say that they did not know what it means to create an explanation in science class (43%) compared to in the other two contexts. By the end of the school year, students' responses about explanations in science class shifted to focus more on how or why a phenomenon occurs. Students would often provide an example such as Mariela's response, "My explanation was that, like there was a lot, a lot of bees going around the flowers because they have pollen and that's why." Students' views about what it means for a scientist to create an explanation also shifted to focus more on how or why a phenomenon occurs, while in the everyday context they continued to focus on an explanation as an exchange between people.

Table 5: Students' Views about Explanation (n = 23)

	Scientist		Science Class		Everyday	
	Pre	Post	Pre	Post	Pre	Post
Link to argument	0%	0%	0%	0%	0%	4%
Link to evidence	4%	22%	0%	9%	0%	9%
Writing	4%	9%	13%	4%	0%	0%
Observation	48%	26%	39%	13%	35%	9%
Exchange between people	57%	17%	17%	30%	74%	83%
How or why a person does something	4%	9%	0%	13%	30%	70%
How or why phenomenon occurs	26%	70%	13%	52%	4%	4%
Other	4%	4%	9%	4%	4%	0%
Don't know	0%	4%	43%	17%	13%	4%

Table 6 provides the results from students' discussions of what it means to create an argument. Similar to explanation, at the beginning of the school year the students were most likely to say that in terms of science class that they did not know the meaning of argument.

Table 6: Students' Views about Argument (n = 23)

	Scientists		Science Class		Everyday	
	Pre	Post	Pre	Post	Pre	Post
Link to explanation	13%	9%	0%	9%	9%	9%
Link to evidence	4%	17%	0%	9%	4%	9%
Writing	4%	9%	4%	4%	9%	0%
Observation	13%	9%	13%	9%	4%	0%
Exchange between people	83%	83%	44%	70%	87%	91%
<i>Persuade or convince</i>	13%	17%	4%	57%	13%	13%
<i>Disagreement</i>	57%	65%	22%	57%	39%	70%
<i>Emotional or angry fighting</i>	22%	9%	13%	9%	35%	22%
One individual thinking through an idea	4%	4%	0%	0%	4%	0%
Other	9%	0%	4%	0%	9%	0%
Don't know	0%	9%	48%	22%	0%	9%

By the end of the school year, students' views of argument in science class shifted to focus more on an exchange between people. The focus on argumentation as discourse between multiple people was present in all three contexts. Because of the prevalence of this code, the student responses were further classified into three different sub-codes: persuasion, disagreement and emotional or angry fighting. Surprisingly, the majority of students did not bring up the idea of angry fighting in their interviews even in the everyday context. Rather, students tended to focus more on persuasion or disagreement.

Table 7 displays students' views about evidence. Unlike explanation and argument, the most prevalent response on the pre-interview about science class was not "I don't know". Rather, students began the school year by focusing on an exchange between people, but by the end of the year they focused on the idea that evidence is used to support an answer to a question. In this case (as in the previous two tables), students' responses at the end of the year about science class align more closely to their response about scientists.

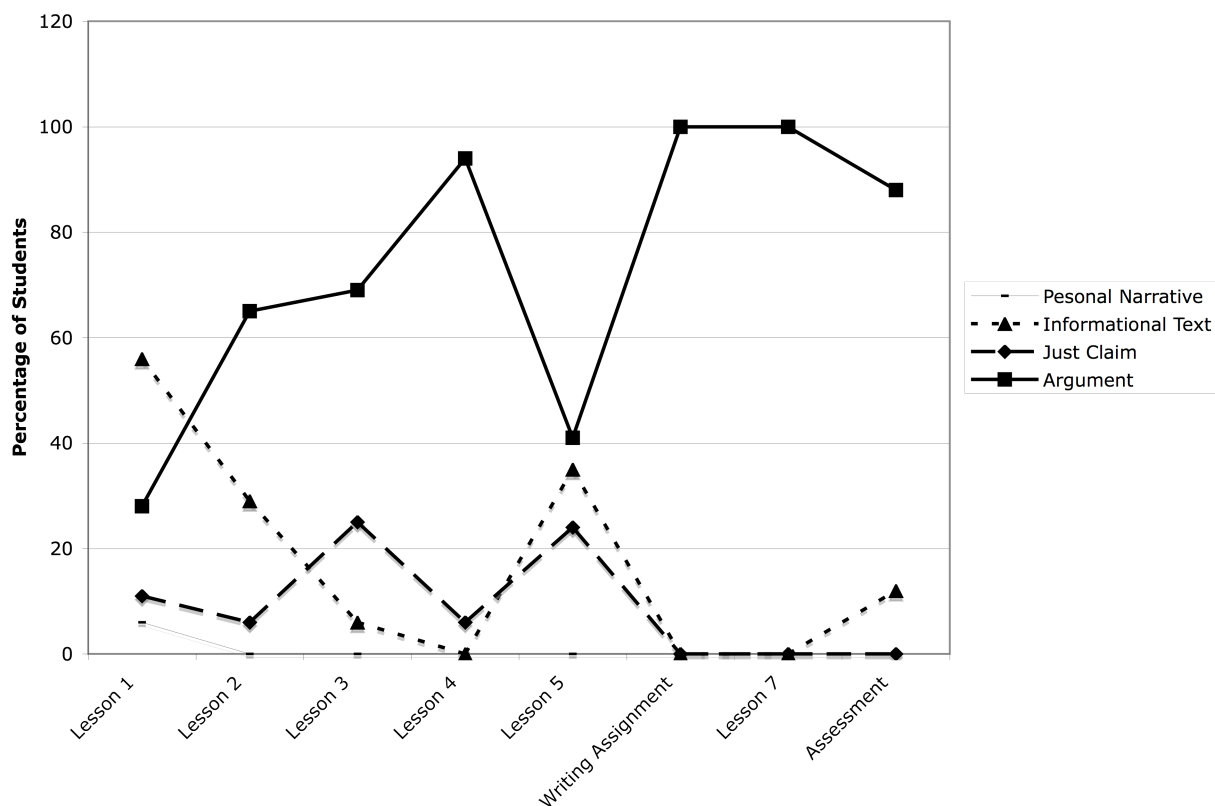
Table 7: Students' Views about Evidence (n = 23)

	Scientists		Science Class		Everyday	
	Pre	Post	Pre	Post	Pre	Post
Link to explanation	9%	4%	4%	4%	0%	9%
Link to argument	9%	13%	4%	0%	9%	9%
Writing	9%	0%	9%	22%	0%	0%
Observation	22%	9%	35%	4%	9%	0%
Exchange between people	48%	30%	43%	26%	70%	70%
Data	43%	43%	26%	48%	57%	65%
Results from an experiment	17%	13%	9%	39%	0%	0%
Support an answer to a question	52%	52%	13%	57%	9%	22%
Other	13%	9%	4%	0%	9%	4%
Don't know	0%	0%	22%	0%	4%	4%

Surprisingly, more students did not explicitly talk about “data” in their discussion of evidence, particularly when talking about scientists or science class. In terms of scientists, the percentage remained constant from the beginning and end of the school year. In terms of the science class, the percentage did increase but only half of the students specifically talked about data at the end of the school year.

Students' Ability to Write Scientific Arguments

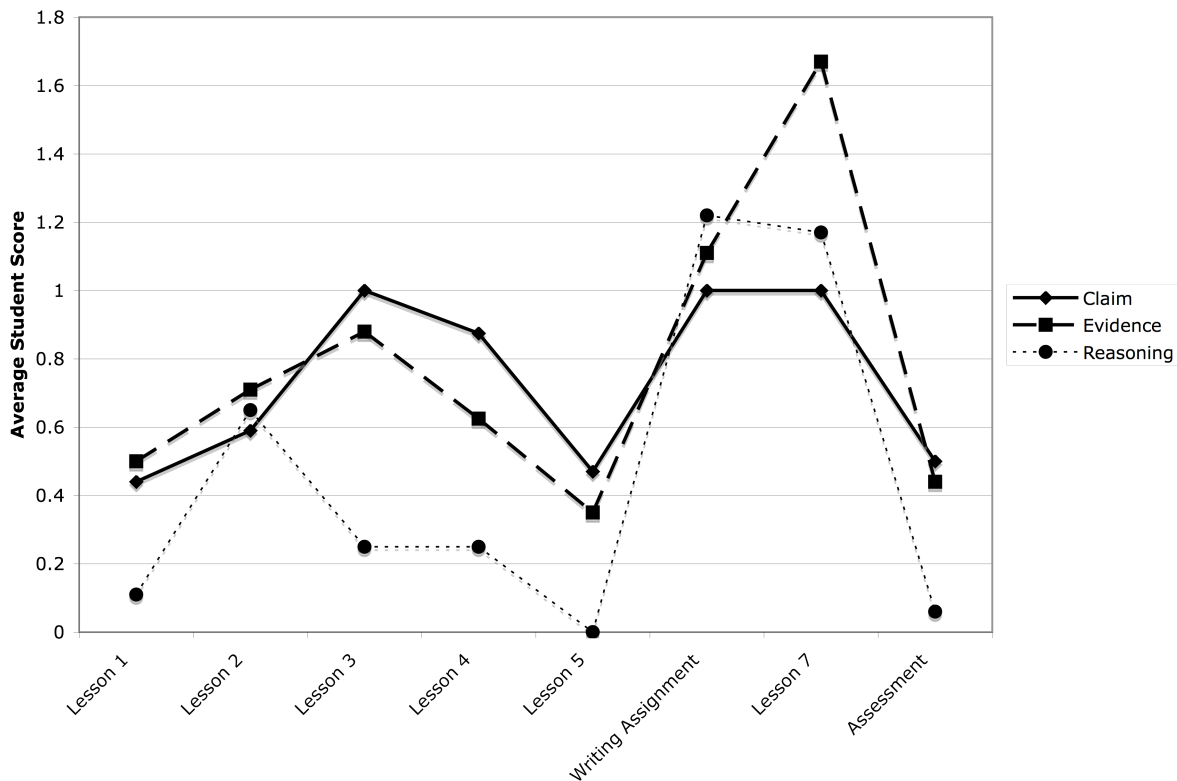
Over the course of school year, the fifth grade students written scientific arguments did show improvement. First, in terms of the genre of their writing the students' writing shifted to include a greater focus on argument at the end of the year compared to at the beginning of the year when students writing took on a variety of formats. Figure 2 includes the genre codes for students' writing from Lessons 1-5, the common writing assignment, Lesson 7 and for the end of the year assessment. Lesson 6 is not included, because students selected a prewritten claim, evidence and reasoning instead of constructing their own.

Figure 2: Genre of Student Writing

In order to be coded as an argument, the students writing needed to include a claim supported with evidence and/or reasoning. With the exception of Lesson 5, students writing included a greater focus on argumentation over the school year. For example, if you compare students' first written scientific arguments to their last argument in a lesson (Lesson 7) or the end of the year assessment, the structure of their writing is considerably different. In Lesson 1, the students writing consisted of 6% personal narrative, 56% informational text, 11% just claim, and 28% argument. The majority of the students wrote information related to the question about habitats, but did not provide a claim that explicitly answered the question. This is in contrast to their last sample of argumentation writing during a lesson where 100% of the students' writing was characterized as an argument or on the end of the year assessment where 88% of the students writing was characterized as an argument. Interestingly, in Lesson 5 there was a drop in the percentage of students that wrote arguments (41%) and an increase in the percentage of students who just provided informational text (35%) and did not explicitly address the question or problem asked. This lesson included the most open question of all the lessons in that Mr. Cardone asked his students to review the results from their previous investigations and determine a claim they wanted to make about levers or pulleys. In this lesson, the students had to more specifically define the question for themselves, which they did find challenging. Consequently, this suggests that the wording of the writing prompt can influence the genre of the students' writing and whether or not it consists of an argument in which they justify their claim compared to just informational or descriptive text.

In addition to coding for genre, the students' writing was coded for the quality and scientific accuracy of the arguments in terms of the claim, evidence and reasoning. Figure 2 displays the quality of students' written arguments for Lessons 1-5, the common writing assignment, Lesson 7 and for the end of the year assessment. As I mentioned previously, the maximum score for the claim is a 1, while for evidence and reasoning the maximum score is a 2.

Figure 3: Quality of Students' Written Arguments



In this coding scheme, the genre of the student writing could be characterized as an argument, but the students could still receive a 0 for claim, evidence and reasoning if their response was not scientifically accurate and appropriate for the question being asked. Although the structure of the students' writing more consistently moved towards argument over the course of the semester, the quality of the students' written arguments fluctuated. For some of the later examples of student writing, such as the common writing assignment about levers and Lesson 5 that focused on pendulums, the quality of the students' written arguments was quite strong. In both of these examples, all of the students received a 1 for their claim, because it was scientifically appropriate and accurate and the majority of students included some evidence and reasoning in their writing, with a number of students receiving a 2 for having appropriate and sufficient evidence and reasoning. In contrast, students' written arguments for Lesson 5, where students determined their own question about levers and pulleys, and for the end of the unit assessment about food webs were much weaker. As I mentioned earlier, the openness of the question in Lesson 5 was challenging for students and the genre of many of the students' writing did not consist of the structure of an argument. Since the majority of students did not provide a claim justified with evidence and/or reasoning, it is not surprising that they also received low scores for quality of the

evidence and reasoning. For the end of the year assessment, the majority of students did write an argument, but most of the students' arguments were scientifically inaccurate which is why they received low scores for quality. The correct claim for this question about food webs was that the hawk population would decrease, yet half the students wrote an incorrect claim such as that the hawk population would not change or that all of hawks would die out. This example illustrates that understanding the structure of an argument is not sufficient to write a strong scientific argument. Both an understanding of argument and an understanding of the content are necessary for students to write strong scientific arguments.

Discussion

In the context of a learning environment specifically designed to support students in argumentation, both students' views of scientific explanations, arguments and evidence changed over the course of the school year and students' abilities to construct written scientific arguments increased. Explicitly addressing and teaching scientific argumentation over an extended period of time can support students in gaining greater expertise in this complex practice (Osborne, Erduran & Simon, 2004). In the case of Mr. Cardone's class, his fifth grade students developed a stronger understanding of scientific argument yet that still struggled with the accuracy and appropriateness of their scientific arguments when they were asked to write them around challenging content.

Students' views of explanations, argument, and evidence

Moje and colleagues (2001) argue for the importance of classroom interactions that develop students' awareness of different Discourses and connect everyday Discourses to the discourses of the science classroom and science community in order to develop congruent third spaces for language, literacy and science learning in diverse classrooms. The results from the interviews suggest that even at the beginning of the year the fifth grade students were already aware that language could have different meanings in different contexts exemplified by their different definitions of explanation, argument and evidence in the three different contexts. Yet the high percentage of students that responded "I don't know" for the science classroom also suggests that they were unclear of the Discourse norms in the science classroom. The students had resources to draw from in both their everyday knowledge and knowledge of the scientists, but were unclear how to use those resources in their science classroom.

Explicitly supporting students through the use of a variety of instructional strategies in developing an understanding of scientific argument allowed the students to develop a stronger understanding of the norms in their science classrooms. Kelly (2005) argues that:

The cultural practices that *count as* science for a group are defined in and through social interaction, including, importantly, uses of language in particular ways for particular purposes. This suggests that in analyzing the educational opportunities for students, educators need to consider the linguistic resources made available and how students are positioned to engage with such resources. (p. 99)

By the end of the school year instead of saying they did not know what these terms meant in science class, the students were explaining them in a similar manner to how they talked about scientists with explanations focusing on how or why phenomena occur, arguments including an exchange between multiple people and evidence supporting an answer to a question or problem.

Mr. Cardone's use of the language of claim, evidence and reasoning as well as the different instructional strategies and activity structures he used throughout the school year acted as a linguistic resource to support his students in developing a stronger understanding of what counted as explanation, argument and evidence in science.

The instructional practices in Mr. Cardone's classroom align with the recommendations of Nasir and her colleagues (2006) around learning as a cultural process. They argue that in order to support students in recruiting their everyday practices to create meaningful opportunities for academic learning that three different design principles need to be considered: 1. Making the structure of the domain visible, 2. Actively engaging students in academic discourses in ways that create meaningful roles and relationships for learners, and 3. Engaging in metalevel analysis that help youth see the relationships between everyday knowledge and discourse compared to academic knowledge and discourse. All three design principles are prevalent in the instructional practices of Mr. Cardone's classroom: 1. He used the claim, evidence and reasoning framework to make the structure of the domain visible, 2. He frequently engaged his students throughout the school year in both talk and writing around the framework in which students focused on the meaning making of both first hand and second hand experiences, and 3. In two lessons, he explicitly discussed argumentation in everyday examples and discussed the similarity and differences compared to science. These strategies appeared to have supported students in developing a stronger understanding of explanation, argument and evidence.

Although the fifth grade students' ideas aligned more closely with scientific perspectives of explanation, argument and evidence for science and science classrooms at the end of the school year, there were still areas that could have been improved. First of all, in terms of argument at the end of the school year the majority of students did not link argument to the use of evidence either in terms scientists or science class. When considering argument as a structure, one commonality across the many different definitions in the field of science education is the inclusion of data or evidence (Sampson & Clark, 2008). The use of evidence in scientific argumentation is essential aspect of justifying claims, but not an idea that many students mentioned during their interviews. Instead, students focused more on the social or dialogic meaning of argument as the interaction between multiple people (Jiménez-Aleixandre & Erduran, 2008). Interestingly, relatively few students focused on the interaction as emotional or angry fighting, rather even in the everyday context they were more likely to talk about argument as a disagreement between two or more people. In students' discussion of evidence they talked about it as supporting an answer to a question in science, but were less likely to talk about evidence as data. Because of these two limitations during the next school year, Mr. Cardone focused more explicitly on discussing the important role of evidence in science as well as discussing what did and did not count as evidence.

One limitation of this study is that the primary data source of students' everyday understandings was through one-on-one interviews. The question-and-answer structure, typical of many classroom interactions, may underestimate the everyday resources that students bring to school science (Hudicourt-Barnes, 2003). Other research that follows students into settings outside of the school into their many everyday contexts can better measure the range of resources students bring to science class (Bricker & Bell, 2007). Yet the findings from this study offer some initial promising results. These fifth grade students successfully differentiated the meaning of the terms evidence, explanation and argument across the contexts of their everyday lives, their science classrooms, and their views about scientists. This suggests that even young students are able to understand that they are navigating discourses in different contexts in which they

meaning of terms can change. Furthermore, when provided with specific support about scientific argumentation in their science classroom, they were able to develop more sophisticated understandings of explanation and argumentation in science that align more closely with the academic norms for these terms.

Students' written arguments

In addition to students' ideas about explanation, argument and evidence changing, students' written arguments also improved. At the beginning of the school year, students struggled with argumentation as a genre of writing. For the majority of students, their initial arguments did not even include a claim that specifically answered the question. Rather, they provided information related to the topic, but not a claim that answered the question. Gee (2005) argues that everyday language shares features with other genres, such as poetry, myth and storytelling, which differ greatly from the features of science Discourse:

It is typical of everyday language that it tends to obscure the details of causal, or other systematic, relationships among things in favor of rather general and vague relations...Everyday language, in creating patterns and associations, is less careful about differences and underlying systematic relations, though these are crucial to science. (p. 33)

Students' initial writing did not include the relationships or causal patterns in which they justify a claim with evidence and/or reasoning. Rather their initial writing aligned more closely with Gee's (2005) description of more general or vague descriptions about the world around them. Providing students with the framework of claim, evidence and reasoning, supported students in understanding this genre of scientific writing and how the structure differed from other forms of writing. By the end of the school year, the structure of the majority of the students' writing did consist of a claim supported with evidence and reasoning.

The elementary students' struggles with constructing an initial claim does differ from work focused on older students where they typically initially provide a claim, but have more difficulty with the justification. Other work I have completed with my colleagues at the middle school level found that students were able to construct claims before being provided with the claim, evidence and reasoning framework (McNeill et al, 2006). The framework supported students in justifying those claims, but initially constructing the claims was easier for the older students. This suggests that it may be important to consider a learning progression for scientific argumentation that includes different focuses and support for students across grades k-12 in order to better support students in developing a more sophisticated understanding of argumentation over time (Berland & McNeill, in press).

Although the genre of the students' writing consistently improved, the students still struggled with the accuracy, appropriateness and sufficiency of their claims, evidence and reasoning as they applied the framework to new content areas and contexts. The quality of students' arguments did not show the same consistent pattern of improvement as the genre, but rather fluctuated more depending on the specific learning or assessment task. This fluctuation may have occurred for two different reasons: 1) The openness and scaffolding of the questions and 2) Students' understanding of the science content. Students' success in constructing scientific arguments is influenced by the wording of the question and the particular data set (Berland & McNeill, in press) and the scaffolding and other support provided for the particular question (McNeill & Krajcik, 2009). When questions are more open or include less scaffolding, students can struggle more with the expectations as well as what counts as appropriate evidence

and reasoning for a particular claim. Another potential impact on the quality of students' arguments is their understanding of the science content. This result aligns with previous research that suggests the importance of both conceptual knowledge and scientific inquiry practices when engaging in scientific reasoning (Duschl et al., 2007). When experts engage in scientific reasoning, their success is influenced by both domain-general knowledge, such as controlling variables, and domain specific knowledge, such as an understanding of forces and motion (Schunn & Anderson, 1999). Specifically, in terms of scientific argumentation students' success at writing claims that are appropriately justified by evidence and reasoning is influenced both by their understanding of the structure of an argument and the science concepts (McNeill et al., 2006). If students do not understand the science concepts, they are unable to construct a scientifically accurate claim or appropriately justify that claim. Considering the multiple factors that can influence students' written scientific arguments, it is not surprising that the quality of the students writing did not show a clear linear pathway. The students show promising growth, yet continue to need support applying the framework to new and more complex contexts and content areas.

Implications

Supporting elementary students in developing proficiency in science in which they are able to use and evaluate scientific evidence, explanations and arguments is an essential goal of k-8 science. Although these scientific inquiry practices can be challenging for middle school (McNeill et al., 2006) and high school students (Sandoval, 2003), the results from this study suggest that even elementary students can successfully engage in these practices. In order to be successful, students need to be able to navigate both everyday and scientific discourses (Nasir et al., 2006). Students can have very different everyday meanings of these practices, such as argument, compared to the meanings in science (Bricker & Bell, 2008), but this is not a barrier for students' successful participation in those practices. Elementary students are able to develop an understanding that "what counts" as an explanation, argument or evidence in their everyday lives is not the same as "what counts" for scientists and in their science classrooms. By providing elementary students with appropriate supports, they can successfully navigate everyday and science discourses.

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Appendix A: Student Interview Protocol

1. Scientists sometimes create explanations in science. (*Put down an index card that says explanation*). What do you think it means for a scientist to create an explanation?
 - a. What is an example of an explanation a scientist might create?
 - b. Have you ever created an explanation in science class? If yes, can you tell me about the explanation?
2. Scientists also sometimes create arguments in science. (*Remove explanation index card and put down an index card that says argument*). What do you think it means for a scientist to create an argument?
 - a. What is an example of an argument a scientist might create?
 - b. Have you ever created an argument in science class? If yes, can you tell me about the argument?
3. Scientists also sometimes use evidence in science. (*Remove argument index card and put down an index card that says evidence*). What do you think it means for a scientist to use evidence?
 - a. What is an example of when a scientist might use evidence?
 - b. Have you ever used evidence in science class? If yes, can you tell me about when you used evidence?
4. We have been talking about three different words – explanation, argument and evidence (*Put down all three index cards*).
 - a. How do you think these three words are different from each other?
 - b. How do you think they are similar to each other?
5. We have been talking about explanation, argument and evidence in terms of science. I want you to think about what each of these words means in your everyday life outside of science, like at home or when you are playing with your friends.
 - a. Let's start with explanation. (*Put explanation card on top. Cover up other two*), What does it mean to create an explanation in your everyday life?
 - b. Now, let's talk about argument (*Put argument card on top.*) What does it mean to create an argument in your everyday life?
 - c. Now, let's talk about evidence (*Put evidence card on top.*) What does it mean to use evidence in your everyday life?

Thank you so much for talking to me. Do you have any questions for me?

Follow-up Prompts

- You mentioned _____. What does that mean?
- Can you tell me more about _____?
- What do you mean by _____?