Comparing Students' Written and Verbal Scientific Arguments

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Reference as:
Knight, A. M. & McNeill, K. L. (2012, March). *Comparing students' written and verbal scientific arguments.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Indianapolis, IN.

Abstract

Scientific argumentation is an authentic scientific practice in which knowledge is socially constructed through evaluating scientific claims, weighing evidence, and assessing alternative explanations. While argumentation has become a noteworthy goal for science education, incorporating it into science classrooms is challenging and can be a long-term process for both teachers and students. Science talk has been shown to support science writing, and participation in science writing increases conceptual understandings and science achievement. Yet, the differences in the ways students construct oral and written scientific arguments have not been established. Consequently, our research with one middle school class in an urban New England school district addresses the following question: What are the similarities and differences between students' oral and written scientific arguments? Data sources included pre- and post-tests and interviews for a focus group of four students as well as transcripts from videotaped classes and associated student work. Our study suggests that there are commonalities and differences between modalities that teachers can explicitly address in an effort to strengthen students' arguments—both verbal and written—and conceptual understanding.

Introduction

The 2007 National Research Council report, *Taking Science to School: Learning and Teaching Science in Grades K–8*, provided a new framework for proficiency in science classrooms, which included a focus on students' ability to "generate and evaluate scientific evidence and explanations" and "participate productively in scientific practices and discourses" (Duschl, Schweingruber, & Shouse, 2007, p.2). This emphasis on disciplinary literacy again reverberates through the *Common Core English Language Arts Standards (2010)*, which calls for students to "write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence" (p.18). Moreover, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012) unprecedentedly seeks to interweave scientific knowledge and practices within learning experiences, of which argumentation is one such example. Such opportunities promote communication and "communicating in written or spoken form … requires scientists to describe observations precisely, clarify their thinking, and justify their arguments" (NRC, 2012, p.74). These policy changes reflect an expanded and more authentic perspective of science competence in which students are expected to participate in written and oral argumentation using the rules of evidence and reasoning that are respected in scientific discourse.

The policy changes reflect the view that argumentation is a noteworthy goal for science education; however incorporating it into classroom practice is a challenging endeavor (Osborne, Erduran, & Simon, 2004). Yet, this challenge is worth surmounting because scientific argumentation is an authentic inquiry-based discourse that "engage[s] the learners in the coordination of conceptual and epistemic goals" (Osborne et al., 2004, p. 688), and scientific discourse is a key mediator to knowledge access in science learning (Kelly & Greene, 1998). Moreover, because writing and talk are two modes of scientific discourse and argumentation traverses both the written and oral expressions of scientific discourse, learning is, therefore, supported across multiple modalities when students have the opportunity to construct and critique scientific arguments. Research has shown that to become scientifically literate students should engage in the language and methodology of scientific inquiry (Osborne et al., 2004), which results in not only active participatory science talk (Duschl, et al., 2007), but also increased conceptual understanding (Rivard & Straw, 2000). Furthermore, student talk associated with authentic scientific inquiry, such as scientific argumentation, has also been linked to stronger science writing (McNeill, 2009). As such, science talk has a fundamental role within the development of scientific knowledge and practices.

Despite these promising findings, most science classrooms are still largely taught from an authoritarian perspective that provides little opportunity for students to participate in small group or whole class discussion. Perhaps this norm is further reinforced by assessment systems that only consider the final form of expression in terms of writing. Therefore, a literature base and coinciding policy documents that tend not to differentiate between the oral and written modes of argumentation, despite likely fundamental differences, also perpetuates this situation because it leaves the reader to interpret at will. This makes it more convenient for the reader to envision how current classroom practices already meet the recommendations, as opposed to trying-out and reflecting on new practices designed specifically to meet the recommendations. As such, the direct instruction norm is further reinforced because the role science talk plays in producing better science writing and increasing conceptual understanding is never fully experienced.

To better justify why verbal scientific argumentation is of value as well as to support teachers as they transition into classroom discourse patterns in which students are building off of and refuting one another's ideas, the scientific education research community needs to clarify differences between the two modalities of argumentative expression. Consequently, our research addresses the following question: What are the similarities and differences between students' oral and written scientific arguments?

Theoretical Framework

Sociocultural Learning

As the goal of education has shifted from memorizing discrete facts to learning for understanding using some of the discrete facts, the process of knowing has become increasingly more important (Piaget, 1978; Vygotsky 1978). Knowing is dependent upon existing beliefs and knowledge, which are used to construct new knowledge (Cobb, 1994; Piaget, 1952, 1973a,b, 1977, 1978; Vygotsky, 1962; 1978). Furthermore, learners construct new knowledge in this fashion regardless of the method(s) of instruction (Cobb, 1994). For instance, when students listen to a lecture or participate in inquiry based investigations they are still filtering and constructing new knowledge based on their preexisting knowledge (Bransford, Brown, & Cocking, 2000). Papert (1980) expanded upon the relationships between old and new knowledge, detailing that learning occurs in interactions with others while creating socially relevant artifacts and thus highlighting the social aspect of constructing knowledge. Osborne, Erduran, and Simon (2004) apply the socio-constructivist perspective to science education explaining that students learn the ways of thinking and behaving in science through social interactions; however, they also introduce another key point—science as a culture. More specifically, if knowledge construction is dependent on social interactions, then it is also culturally bound. Lemke (2001) further clarifies the sociocultural perspective within science education explaining that science is a culture, the science classroom is a sector of the science community, the process of doing science is a cultural activity, and the equipment are the tools of the culture. By treating the science classroom as an extension of the culture of science, a learning environment is created where students begin to interact with the epistemologies of science and create socially relevant artifacts while building relationships between old and new knowledge. As such, scientific literacy is supported.

Scientific Literacy—Writing and Talking

More than a mere sets of concepts, science is a culture that includes ways of thinking, behaving, and reasoning that are learned through social interactions (Osborne et al., 2004). When such endeavors include engagement in the language and methodology of scientific inquiry then scientific literacy is also supported (Osborne et al., 2004) because scientific inquiry requires students to play an active role and engage in science talk (Duschl, et al., 2007). This sociocultural learning of language can be used as a linguistic bridge that permits students to link their everyday discourse with the academic language (Varelas, Pappas, Kane & Arsenault, 2008), and the students' participation in such science talk also supports their writing. More specifically, in investigating how curricular scaffolds and instructional practices support students' scientific arguments, McNeill (2009) determined that students produced stronger science writing when the classroom culture promoted scientific argumentation norms within talk.

Supporting science writing is a significant endeavor because conceptual gains are attained through the refinement and organization of the concept (Hand, Hohenshell, & Prain, 2004; Rivard & Straw, 2000). More specifically, participation in science writing enhances students' retention of science knowledge (Rivard & Straw, 2000), with higher quantities of writing resulting in higher levels of conceptual learning (Hand et al., 2004). This suggests that scaffolding the students' learning of the scientific register in a sociocultural context supports students along a mode continuum from oral discourse to writing where the negotiation of meaning is reinforced (Gibbons, 2003). However, it is important to consider that this is very specific type of discourse; one in which the coordination of the conceptual and epistemic goals of science are accomplished through the social construction of knowledge (Driver, Asoko, Leach, Mortimer & Scott, 1994). Because scientific argumentation does just this while also traversing both writing and speaking it has emerged in the limelight.

Scientific Argumentation

Scientific argumentation—the process of creating a scientific argument—is currently touted as both the language of science (Duschl & Osborne, 2002) and a metaphor for science (Kuhn, 1993). It is an authentic scientific practice—an accepted disciplinary norm in which scientists routinely participate—by which knowledge is socially constructed through evaluating scientific claims, weighing evidence, and assessing alternative explanations (Driver et al., 2000). Yet, it is also a beneficial pedagogical technique because it makes "student scientific thinking and reasoning visible to enable formative assessment by teachers" (Osborne et al., 2004, p. 995), which better enables teachers to identify misconceptions and redirect teaching in response to learning needs. Additionally, it is hoped that engaging in this process will move students' views of science away from a set of discrete facts and towards a body of knowledge that is constructed by a community through discussion, discernment, and revision in light of both contradictory and confirmatory evidence. In the classroom this expanded view of science is highlighted when competing viewpoints are presented and the students' theories are rebutted and revised as new ideas emerge (McNeill & Krajcik, 2012). In some situations consensus is achieved; in others, just as in science, multiple viewpoints are maintained. Ultimately, we hope that engagement in such activities will also support students in evaluating socio-scientific issues as informed citizens (Erduran & Jiménez-Aleixandre, 2008).

While scientific argumentation transverses both talk and writing, the similarities and differences in the ways students construct these scientific arguments orally as compared to the ways by which they write arguments have not been established. Identifying whether differences do exist between the modalities, and if so understanding the nature of the differences, will impact the science education community. More specifically, such differences could influence how both researchers support teachers and teachers in turn support students in not only creating high quality verbal and written arguments, but also in becoming science literate, making conceptual gains, and bettering science achievement. Consequently, we ask: What are the similarities and differences between students' oral and written scientific arguments?

Methodology

Context of the Study

This study took place in one middle school science classroom within in a large New England urban school district. The teacher, Mr. Keiffer, previously participated in scientific argumentation professional development (PD) workshops given by our research team. The PDs provided instructional strategies on how to integrate a framework for scientific argumentation into classroom practice, which was illustrated with video clips of teacher practice, student writing, and transcripts of classroom discourse. In small learning groups, participant teachers also designed learning tasks and reflected on their outcomes. The teacher also participated in an advanced series of workshops that were offered once a month for five consecutive months.

Three lessons including scientific argumentation were observed. Multiple data sources, informed by the theoretical perspective, were collected to measure the students' ability to engage in written and oral scientific arguments. As previous research has shown that partaking in science talk supports science writing (McNeill, 2009) and participation in science writing increases conceptual learning (Rivard & Straw, 2000), the teacher was requested to provide opportunities for oral argumentation—whole class and/or small group—in addition to written. When small groups were involved we followed a demographically mixed focus group of four students whom the teacher helped to identify. Accordingly, data sources targeted both the whole class and the focus group, in addition to both oral and written arguments.

Participants

Mr. Keiffer was a 7th grade math and integrated science teacher. He had six years teaching experience, and had both a bachelor degree in science as well as a master's degree in education. Mr. Keiffer was selected from teachers who had previously participated in a beginning level scientific argumentation PD series provided by our research team, and responded with intent to participate in an advanced level series of PDs. Teachers who had met the two prior qualifications and had previously developed good quality data-driven argumentation questions for their science curriculum were solicited to determine interest. The selection was based on teacher interest, grade level taught, and a minimum education level consisting of a bachelor degree in both science and education.

Mr. Keiffer taught in an urban New England public school that emphasizes math and science. The school demographic data suggests an ethnically diverse student body with approximately 61% African American, 32% Hispanic, and 4% white (MAESE, 2010). Of the 21 students in Mr. Keiffer's class, 20 of the students (10 females and 10 males) participated in this research. In a demographic survey 45% (n=9) of the students identified as being Black/African American, 10% (n=2) identified as being both Black/African American and Native American or American Indian, 20% (n=4) identified as being Latino/Latina, 5% (n=1) identified as being white and other, 5% (n=1) identified as being other, and 14% (n=3) did not respond. Additionally, 15% (n=3) identify as speaking a language in addition to English—all three identified the other language as being Spanish. Moreover 10% (n=2) identified that their parents speak to them in another language (Spanish and Portuguese), but that they respond in English. While only one student identified that he and his parents were born in a country other than the United States (Nigeria), 25% (n=5) of the students identified one parent as being born in a country other than the United States and 10% (n=2) identified both parents as being born in countries other than the United States. This data is provided to support our claim that this is an ethnically and linguistically diverse class, which is an increasingly more common phenomenon within our nation's urban public schools.

CERR Instructional Framework

As have many others within the scientific argumentation research literature, the instructional framework implemented in this research was adapted from Stephen Toulmin's (1958) argument pattern (Driver et al., 2000; Erduran, Simon, & Osborne, 2004; Jimenez-Aleixandre, Rodriguez, & Duscul, 2000). While Toulmin (1958) originally designed the framework to assess law arguments, the model has been used across many different domains because it dissects an argument into universally applicable structural components: Claim, data, warrant, backing, qualifier, and rebuttal. For a more detailed explanation of how Toulmin's argument pattern is applied to evaluate scientific arguments see Erduran, Simon, and Osborne

(2004).

The claim, evidence, reasoning and rebuttal (CERR) instructional framework employed in this research was previously developed and implemented (Berland & Reiser, 2009; McNeill & Krajcik, 2009; McNeill, Lizotte, Krajcik & Marx, 2006). The reasoning component resulted from merging Toulmin's (1958) warrant and backing into a single category to simplify the application in the classroom. Either student-collected or secondary data is acceptable for students selection of appropriate and sufficient evidence that supports their claim—an assertion that answers the question. The reasoning articulates why or how each piece of evidence supports the claim. A rebuttal takes into account the discursive nature of science and further strengthens the argument by justifying why an alternate claim is unacceptable. For further discussion regarding the rational for using CERR see McNeill, Lizotte, Krajcik & Marx (2006) and McNeill & Krajcik (2012).

Data Collection

Data was collected in regards to both oral and written arguments for the entire class. Student work was collected for each of three-videotaped lesson, and the lessons were transcribed for analysis. A panoramic view of the class was recorded when the focus was on class instruction, and a focus group of four students was recorded when students participated in small group work. While the first and third lessons spanned two class sessions, the second lesson was completed in one session. Prior to the first lesson and following the third lesson the same pre- and post-test was given to all students in which they were asked to construct two scientific arguments—one with qualitative data and the second with quantitative data. The underlying scientific concepts were limited to middle school level topics so as to minimize the scientific knowledge from interfering with the students' ability to provide reasoning. Additionally, the state science standards were referenced and, when possible, questions from previously released state standardized middle school science and technology/engineering questions were adapted (MCAS, 2006, 2010). In addition, student interviews were conducted with the focus group participants prior to the first videotaped lesson and after the last videotaped lesson in which they were asked to orally construct two scientific arguments. The purpose was not only to provide additional opportunities for the students to construct oral scientific arguments, but to also obtain oral explanations of the students' thinking process. The same protocol was followed for creating the student interview questions as was previously described for the written pre- and post-test. The students were given a copy of the data to reference during the semi-structured interview.

This paper will focus on a subset of the data. More specifically, we will discuss the first lesson, which transverses two days and addresses the following question: Should the Belo Monte Dam be built? The building of the Belo Monte Dam on the Xingu River in Brazil —a tributary of the Amazon River—has been under debate for nearly 25 years. While some argue that the relatively clean and consistent source of power is needed for the country to develop, others argue that the cost associated with the destruction of the rain forest is too high.

In the first day of the Belo Monte Dam lesson, small groups presented their oral arguments to the whole class. More specifically, the class was divided into five groups—the power company, hydrologists, ecologists, climate scientists, and the Kayapo Tribe—and each group presented the argument from the perspective of the group they were representing. Each initial oral argument presentation was followed by a question from each of the other four groups. The session wrapped-up with a final statement from each group. The second day of this lesson focused on students individually arguing their personal perspective in a written response. Students had access to a variety of resources, including a collection of short articles, video clips, and Internet searches to support both their oral and written arguments.

Data Analysis

A theoretical learning progression was constructed to analyze both the students' written and oral arguments in terms of increasing sophistication of the structure. While all learning progressions indicate successively more sophisticated ways of thinking about a topic (NRC, 2007, p. 205), we employ an approach that progresses from students' naïve forms on the lower border to scientifically accepted forms on the upper border (Furtak, 2009). The employment of the proposed learning progression as a coding scheme affords the opportunity to qualitatively analyze both oral and written arguments at the argument grain size as opposed to the components within the argument as is done routinely within the argumentation literature (Bell & Linn, 2000; Jiménez-Aleixandre & Rodríguez, 2000; McNeill, 2011; Osborne et al., 2004). For instance, instead of counting the frequency of claims, evidence, reasoning, and rebuttals, we focus on how the relevancy of the components interacts with the sophistication of the argument as a whole.

The argumentation learning progression used for initial analysis was informed by the theoretical framework and an iterative analysis of the data (Miles & Huberman, 1994) as well as by previous research focused on scientific argumentation (Jiménez-Aleixandre & Erduran, 2008; Osborne, et al., 2004; McNeill, 2009; McNeill & Pimentel, 2010; Sampson & Clark, 2008; Zembal-Saul, 2009). The levels of sophistication focused on the structure of argument: 1) Claim – an answer to the question, 2) Evidence – scientific data that supports the claim, 3) Reasoning – a justification of how or why the evidence supports the claim and 4) Rebuttal – a justification for how or why an alternative explanation is incorrect (McNeill & Krajcik, 2012). However, in analyzing the data for this pilot study with the initial progression, we found it both necessary and beneficial to collapse several categories. Table 1 presents the proposed learning progression in both the initial and collapsed forms. The darkened squares indicate where the collapsing occurred. The reasons and justification for collapsing categories will next be discussed.

Table 1. Proposed argumentation learning progressions.

<table>
<tr><th colspan="2">Levels</th><th colspan="2">Initial
Learning Progression</th><th colspan="3">Condensed
Learning Progression</th></tr>
<tr><td rowspan="2">4. Relevant Counter-Justification:

Is the counter-justification relevant</td><td>4b</td><td colspan="2">same as condensed</td><td>4b</td><td colspan="2">Student constructs an argument with only relevant justifications for the claim as well as an E&R-rebuttal that critiques the relevancy of both the counter-evidence AND counter-reasoning.</td></tr>
<tr><td>4a</td><td colspan="2">same as condensed</td><td>4a</td><td>1. Student constructs an argument with only relevant justifications for the claim as well as an E-rebuttal that critiques the relevancy of the counter-evidence.</td><td>2. Student constructs an argument with only relevant justifications for the claim as well as a R-rebuttal that critiques the relevancy of the counter-reasoning.</td></tr>
<tr><td rowspan="2">3. Relevant Justification:

Is the justification relevant?</td><td>3b</td><td colspan="2">Student constructs an argument that includes only relevant evidence & reasoning.</td><td rowspan="2">3</td><td colspan="2" rowspan="2">Student constructs an argument that includes only relevant justifications for the claim.</td></tr>
<tr><td>3a</td><td>Student constructs an argument that includes only relevant evidence.</td><td>Student constructs an argument that includes only relevant reasoning.</td></tr>
<tr><td rowspan="3">2. Justification:

How is the claim justified?</td><td>2d</td><td colspan="2">2c as well as a rebuttal that uses either or both evidence & reasoning.</td><td>2c</td><td colspan="2">2b as well as a rebuttal that uses either or both evidence & reasoning.</td></tr>
<tr><td>2c</td><td colspan="2">Student constructs an argument that includes some irrelevant or inaccurate data and science ideas as well as some relevant evidence and reasoning.</td><td rowspan="2">2b</td><td colspan="2" rowspan="2">Student constructs an argument that includes both irrelevant or inaccurate and relevant justifications for the claim.</td></tr>
<tr><td>2b</td><td>1. Student</td><td>2. Student</td></tr>
</table>

		constructs an argument that includes some ***irrelevant or inaccurate data*** as well as some ***relevant evidence***.	constructs an argument that includes some ***irrelevant or inaccurate science ideas*** as well as some ***relevant reasoning.***		
	2a	same as condensed		2a	Student constructs an argument that includes justifications for the claim, but the ***justifications are only irrelevant or inaccurate***.
1. Claim: *What is being argued?*	1	same as condensed		1	Student constructs the ***claim*** of an argument.
0. No Claim	0	same as condensed		0	Student ***does not provide a claim*** to argue.

To not only increase reliability, but also to address sufficiency within the relevancy categories we collapsed evidence and reasoning into one category—justifications. More specifically, in the initial learning progression the use of only relevant evidence (Level 3a1) and only relevant reasoning (Level 3a2) were coded separately. However, a student who included one relevant piece of reasoning in addition to a mixture of relevant and irrelevant evidence, or only irrelevant evidence was placed at higher levels of sophistication than seemed appropriate. The same situation also occurred when only one piece of relevant reasoning was present with either no relevant evidence or a mixture of relevant and irrelevant evidence. This was problematic because the arguments in these cases were not sufficiently supporting the claim with only one piece of relevant evidence or reasoning. However, when we collapsed the category into including only relevant justifications (Level 3), these situations dropped to less sophisticated levels of the learning progression (Levels 2b or 2c). Due to this change, we also collapsed some irrelevant and inaccurate forms evidence (Level 2b1) and reasoning (Level 2b2) into one category—irrelevant and inaccurate justifications (Level 2b). Irrelevant and inaccurate justifications were not separated from one another because they are similar in that neither is functioning to support the claim.

There is both precedent and recommendation within the argumentation research literature to take actions similar to our collapsing of evidence and reasoning into a justification category. More specifically, Osborne, Erduran, & Simon (2004) collapsed data, warrants and backings into one category—second-order elements—which were distinguishable from first-order elements that included claims, grounds, and rebuttals. Additionally, Sadler (2006) came to the conclusion that “distinguishing among data and warrants … may present unnecessary complexity for science teachers and students. … In reflecting on my own teaching practice and learner needs, I … will not require students to distinguish between data and warrants.” (p.343). In both examples the researchers came to the conclusion that data and warrants, which are the equivalent of our evidence and reasoning, could be and in the latter case should be coalesced. Therefore, after two persons, with a 20% overlap, independently coded the written arguments with the initial learning progression and differences were resolved through discussion, the codes were collapsed. Each written argument received one code indicative of its level of sophistication with 83% agreement.

Prior to coding the oral arguments, one coder chunked the transcript into sections according to changes in classroom activity. Because each group was presenting an argument from the perspective they were representing (power company, ecologists, hydrologists, climate scientists, and the Kayapo tribe) within three different activities (initial presentation, follow-up questions, and a final statement) that resulted in responses with varying sufficiency, the transcript was next rearranged so that all three activities for each group were organized in succession. Otherwise stated, each group received a code for the sophistication of their argument, which consisted of the initial presentation, answers to follow-up questions, and the final statement. Two persons coded the initial oral presentations with 20% overlap at 100% agreement.

Once reliability was achieved, the frequencies of the oral and written arguments were tabulated and graphed. This method afforded the opportunity to visualize trends across both modalities, between the modalities, and within each modality. The trends were then reduced into three emergent themes and quotes from the coding charts were compared and reflected upon in order to better understand their nature. The themes and supporting quotes will next be discussed.

Results

The analyses address the following research question: What are the similarities and differences between students’ oral and written scientific arguments? From the methodology previously discussed, three themes emerged. The themes are summarized in Table 3. We next discuss each of the three themes and support each with evidence from the students’ written and oral discourse.

Table 3. Themes around sophistication of students' oral and written arguments.

Theme 1	The students' written and oral arguments tended to include irrelevant or inaccurate justifications.
Theme 2	Oral arguments were less sophisticated than written arguments.
Theme 3	Including a rebuttal was not as difficult as including only relevant justifications for both writing and talk.

Theme 1. The students' written and oral arguments tended to include irrelevant or inaccurate justifications.

In terms of the students' sophistication in constructing arguments, both the oral and written arguments tended to include irrelevant or inaccurate justifications. Irrelevant or inaccurate justifications were captured in level 2 (2a, 2b, and 2c) of our learning progression. Figure 1 presents the frequency of responses at each argument level. When reviewing this figure as well as Figures 2 and 3, it is important to consider that the total number of responses for written arguments (n = 13) is larger than for oral arguments (n = 5). We present the actual sample frequencies as opposed to a percentage due to the small sample size; therefore it is important to compare trends between the groups as opposed to the magnitude of said trends. Regardless, it is evident that the largest number of responses for both modalities was at level 2b—Justification with relevancy and irrelevancy. Such irrelevancy is exemplified in the final statement the hydrologist group, which had a pro dam perspective:

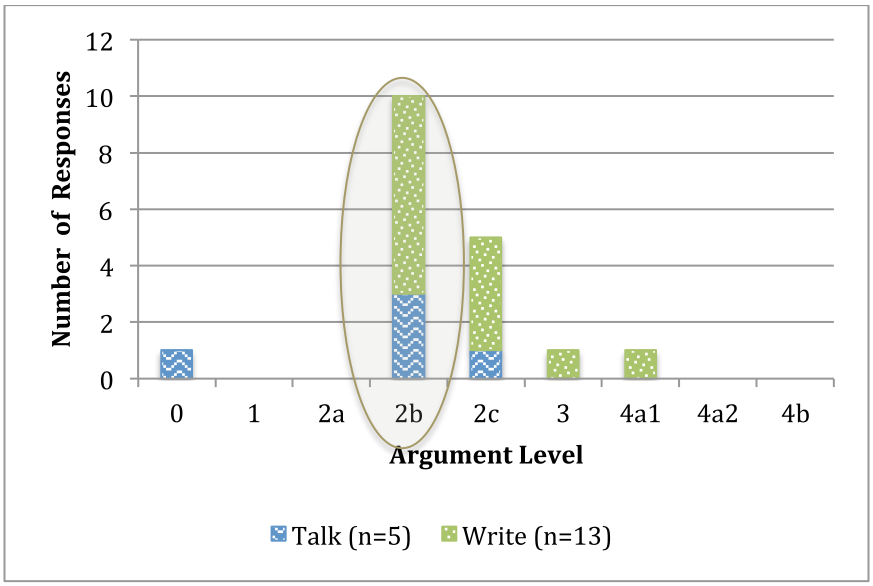
> *Alright, so, it's not only us. Not only dams can cut trees, kill fish, or have floods. You know, people, as we were talking about with salmon are being overfished. People, no people, loggers are cutting down trees and floods, like have you heard of [inaudible] that have floods? See, so it's not only us.*

This group was trying to argue that the dam would not hurt the environment, but then proceeded to admit that it would with the caveat that they would not be the only ones hurting the environment. This line of justification undermined the group's claim that the dam should be built. The same type of situation persisted in the writing. For example, Ben, who was arguing for building the dam, wrote:

> *[T]here have been a lot of blackout in brazil and those blackouts are caused by the powerline's not by the dams….In conclusion I think that the dam should be built because it brings electricity, prevents blackout.*

This justification is irrelevant because if the power lines were the cause of the blackouts, then building a new dam would not prevent future blackouts. Rather, the line of reasoning appropriate for evidence that suggests power line failures lead to blackouts should be on maintaining and/or preventing faults within the power line infrastructure. As such, this piece of evidence does not function to support the claim that the dam should be built. In summary, the issue of appropriateness of justifications, in terms of both accuracy and relevancy, was problematic for students in both their written and oral arguments.

Figure 1. Argument frequency at each progression level.



Theme 2. Oral arguments were less sophisticated than written arguments.

When comparing the students' oral and written arguments we learn that the oral arguments were less sophisticated than their written arguments. Within Figure 2, which compares the frequency of spoken and written responses at each level of the learning progression, we find two pertinent trends: Only instances of talk at the lowest argument level and only instance of writing at the highest two observed argument levels. More specifically, at the lowest level of the learning progression (0) an argument is not made because a claim is never justified. For instance, instead of presenting their claim that the dam should not be built, the group that presented the climate scientist perspective only presented justifications—both relevant and irrelevant—for how the climate would be affected if the dam were to be built. As, such they did not construct an argument. Rather, they provided more of a summary of justifications, which is exemplified by the following quote that served as the conclusion to their initial presentation:

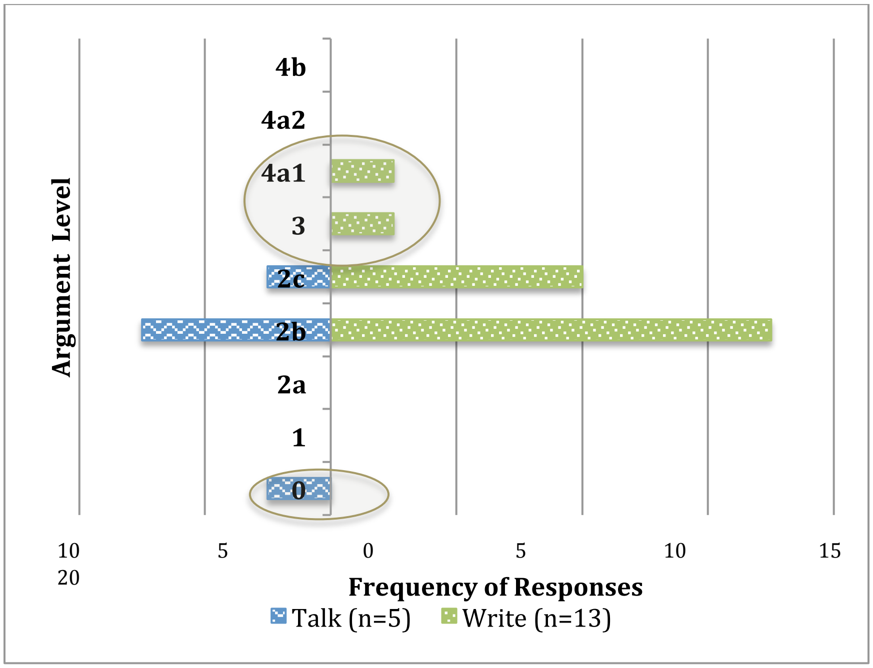
> *[T]he pro is that people are doing it [building the dam] to get electricity in Brazil. But, the con is people that live there will be losing their homes that they live, the probably all of their land.*

While this shows that the students understood there were two sides of the argument, it also indicates that they did not understand that they were supposed to be choosing a side of the argument to present. As this phenomenon did not occur in writing, it suggests that the written arguments were more sophisticated. Moreover, the previous quote from hydrologist's group can also be compared to how Jane presented both sides of the argument:

> *Some people who might disagree with me may say, "Well, we are producing electricity for our city". But I say you are only producing electricity for only the people who can afford it.*

We see than Jane goes beyond summarizing both perspectives; rather she weakened the counter-claim by critiquing the appropriateness of the counter-evidence. This rebuttal served to further justify her claim that the dam should not be built. Additionally, all of the justifications Jane made within in argument were relevant; as such her response was at the 4a1 (only relevant justifications as well as a critique of the counter-evidence). Because the highest two levels of sophistication we observed, 3 (only relevant justifications) and 4a1 (only relevant justifications as well as a critique of the counter-evidence) occurred only in writing, this further supports our claim that the written arguments were more sophisticated than the oral arguments.

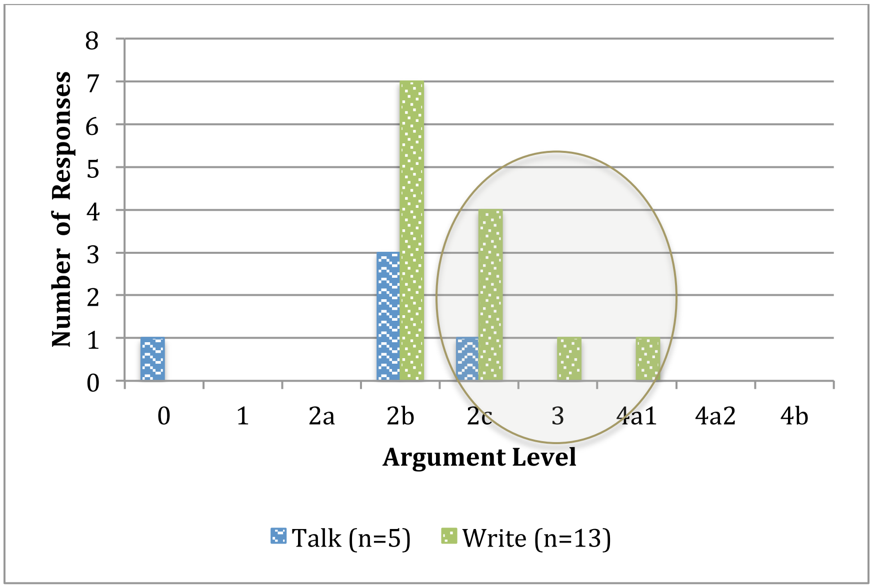
Figure 2. Comparing frequency of spoken and written responses by progression level.



Theme 3. Including a rebuttal was not as difficult as including only relevant justifications for both oral and written arguments.

In terms of the students' sophistication in constructing arguments, including a relevant rebuttal was not as difficult as including only relevant justification for both oral and written arguments. While rebuttals were present within levels 2c, 4a1, 4a2, and 4b, we only observed them at levels 2c and 4a1. In Figure 3, which presents the argument frequency at each level separated according to modality, we see that six arguments included a rebuttal across both modalities (n=1 at level 4a1; n=5 at level 2c). This can be compared to frequency of responses that included solely relevant justifications, which were only observed at levels 3 (n=1) and 4a1 (n=1) despite also being possible at levels 4a2 and 4a3. Having a larger frequency of arguments providing a rebuttal (n=6) than solely relevant justification (n=2) suggests that including solely relevant justifications was more difficult for the students than including a rebuttal. But, because frequency does not necessarily determine difficulty (i.e. many students could have mastered a difficult task), we will next provide evidence from both written and spoken arguments to support this assertion.

Figure 3. Argument frequency at each level by modality.



Written arguments. The ordering of the levels of sophistication, in regards to the difficulty of providing rebuttals as compared to solely relevant justifications, will first be illustrated by comparing writing from two students—Jane and Alfred—who were both arguing that the Belo Monte dam should not be built. Jane's rebuttal was previously presented within theme 2 and she was identified as being at the 4a1 level (only relevant justifications as well as a critique of the counter-evidence), however other students at the 2c level (relevant and irrelevant justifications as well as a rebuttal), including Alfred, provided rebuttals that were of the same quality. For instance, Alfred wrote:

> *A person that disagrees with me would argue that the Dam is a good thing because it produces electricity for the country of Brazil. I would respond by saying the electricity doesn't even go to the people in brazil that need it, it goes to the aluminum smolting factories that produce even more pollution to our world.*

Similar to Jane, we see that Alfred critiqued the appropriateness of the counter-evidence, and it is no less sophisticated than Jane's, although Jane's argument as a whole was classified as being more sophisticated. What distinguished these two responses, therefore, was not the rebuttal; rather the distinction is in that Jane supported her claim with only relevant justifications whereas Alfred also included some irrelevant/inaccurate justifications. For instance, while Jane argued, *"[T]he Belo Monte Dam shouldn't be built because 100 more dams will be built, animals will* *die, and the reservoir will cause major pollution"*, and provided relevant support for each of the three ideas, her final line of thinking presents the best comparison with Alfred:

> *And lastly, the dams' reservoir causes major pollution. As vegetation dies [when the reservoir is formed] it's releasing a very toxic gas called methane. Methane rises into the atmosphere and causes global warming. The dam can possibly release more than 100,000 pounds of methane…Clearly the Belo Monte Dam shouldn't be built because it has so many affects on the earth like global warming, and the harms of animals and nature.*

While Jane provided a relevant justification that included specific evidence (100,000 pounds of methane), reasoning about how the methane would be produced as well as an attempt to link methane to global warming, Alfred's justification included some inaccuracies:

> *[T]his dam shouldn't be built because of … the methane gas the reservoir produces. … The reservoir next to the dam will produce methane from decompose species. This makes our world over-heat. Most of Antarctica will melt if methane is produced. It can also make people severely sick and they can die. … Building this Dam going to be a bad idea for Brazil because … the methane it produces.*

We see that while Alfred did provide an accurate explanation of how the methane would be produced, his line of thinking quickly becomes over-exuberant. Because both students included rebuttals of similar quality, but Alfred included inaccurate and irrelevant justifications in addition to some relevant justifications whereas Jane only included relevant justifications, we argue that relevancy was more difficult than rebutting the opposing claim.

Oral arguments. While Figure 3 indicates that only one initial oral argument was at the 2c level—the inclusion of relevant and irrelevant justifications as well as a rebuttal—and no arguments are within level 4—inclusion of relevant justifications and a critique of the counter-evidence and/or reasoning—the response at level 0 also included a rebuttal. In the latter case, the climate scientist group never verbalized their claim; rather they assumed that everyone knew that they were against the building of the dam. After presenting both relevant and irrelevant justifications for their implied claim, the climate scientist group also presented a rebuttal:

> *Dams on the earth, say hydrologists, is pollution free, but they ignore how the reservoir produces a lot of methane.*

While this is a weak rebuttal and it was not captured in our coding scheme, it does provide evidence that even at the lowest levels of sophistication, students were able to provide an oral rebuttal. In comparison, the ecologist group's rebuttal, which followed a mixture of relevant and irrelevant justifications (level 2c), was stronger:

> *Although the power company argues that most of this area is already deforested, which means most of the trees in that area are already cut down (counter-evidence), history has shown that whenever you build roads to a new construction site in the Amazon rainforest, people use these, um, roads to sneak in and cut down more trees initially (critique).*

The ecologists argued that they were against building the dam and provided additional justification by weakening the counter-argument. More specifically, after presenting the counter-evidence they provided a critique of that evidence with a different line of reasoning. These two previous examples indicate that the students were able to construct rebuttals within their oral arguments, however from Figure 3 we see that no groups provided solely relevant justifications (level 3 and above). This, therefore, suggests that relevancy was more difficult than rebutting the alternative claim.

Discussion

Although it is often the case that existing classroom norms tend to constrain students' engagement in scientific argumentation (Berland & Reiser, 2009; Driver et al., 2000; Jimenez-Aleixandre et al., 2000) and scientific argumentation is challenging for some middle school (McNeill et al., 2006) and high school students (Sandoval, 2003), overall we found that these middle school students were constructing arguments both verbally and in writing. This suggests that scientific argumentation was a norm that had been established within this classroom over time. This is a reasonable assertion because of the teacher's previous and concurrent participation in professional development workshops on this topic, which can result in increased pedagogical content knowledge (Knight & McNeill, 2011; McNeill & Knight, 2011) as well as increased frequency of argumentation in the classroom (Simon, Erduran & Osborne, 2006). Apart from a classroom norm promoting argumentation, the students in this study were still developing these skills and had a range of abilities.

While the middle school students knew they were supposed to justify their arguments, it was not a practice they had mastered as evidenced by their routine use of irrelevant or inaccurate justifications both in written and spoken arguments. This is not dissimilar to McNeill and Krajcik's (2007) finding that students struggle with selecting appropriate data to use as evidence. While McNeill & Krajcik (2007) are more specific as to the type of justification, we both conclude that students find appropriateness—consideration of relevancy as well as accuracy—problematic when justifying an argument. It is, however, promising that teaching this complex practice over an extended period of time can support students in gaining higher levels of expertise (Osborne et al., 2004). As the students' arguments discussed in this paper were from the first of three lessons over two months, we hypothesize that there are also similarities and differences within the students' arguments at the different time points.

An important question, however, is raised in regards to the students marshaling of irrelevant and inaccurate justifications: Are the irrelevant and/or inaccurate justifications related to the students' content knowledge? While this is outside the scope of this study, other researchers have suggested that the determination of what counts as an appropriate justification is dependent on the students' content knowledge (McNeill & Krajcik, 2007; McNeill et al., 2006; Osborne et al., 2004). However, others would argue that because supporting and developing argumentation in a socio-scientific context is less difficult than a purely scientific context, the nature of the question reduced the content knowledge load and allowed the students to reference their own experiences as well as ethical values (Osborne et al, 2004). Clearly, this relationship between content knowledge and appropriate justifications—those that are both relevant and accurate—has important implications and, as such, necessitates further exploration. Furthermore, the students' use of irrelevant and/or inaccurate justifications becomes even more noteworthy with the realization that it is also an undercurrent within our latter two themes.

Contrary to Berland & McNeill's (2010) conclusion that students' verbal argumentation is stronger than written, we found that the students' oral arguments were less sophisticated than their written arguments. While this discrepancy could very well be a result of samples with varying abilities or distinctions within the nature of the questions, perhaps more pertinent to this discussion are differences in how sophistication was measured. More specifically, Berland & McNeill (2010) found that the students included oral rebuttals without prompting, but were less likely to include them in their writing. It was this inclusion of rebuttals that made the students oral arguments more sophisticated than their written arguments. However, we also found that regardless of modality the students had more difficulty with providing solely relevant justifications than in including a rebuttal. This finding speaks to not only how Berland & McNeill (2010) measured sophistication, but also a large body of literature that suggests that arguments with rebuttals are more sophisticated than those without (Clark & Sampson, 2008; Kuhn, 1991; Osborne et al., 2004; Schwarz, Neuman, Gil & Ilya, 2003; Voss & Means, 1991). We do not dispute that the inclusion of a rebuttal makes an argument more sophisticated, and, in fact, made use of this finding in our proposed progress variable. More specifically, level 2c is more sophisticated than 2b because while they both include irrelevant or inaccurate justifications, level 2c also includes a rebuttal. The same scenario makes level 4 more sophisticated than level 3. However, we suggest that there is an additional level of sophistication to consider above and beyond the presence or absence of rebuttals: Appropriateness of justifications—that is that they are both relevant to the claim and accurate. As such, our third finding—students had more difficulty with providing solely relevant justifications than in including a rebuttal—also serves to further justify our second finding—students' oral arguments were less sophisticated than their written arguments—because it provides evidence to support the progress variable levels and, therefore, how we measured sophistication within the oral and written arguments.

This does raise another important question: Why were the oral arguments less sophisticated? As this was outside the scope of our research, we can only conclude that the oral arguments tended to include irrelevant or inaccurate justifications, which did not always occur in writing. Perhaps it is because the verbal process of constructing an argument in the moment is inherently more difficult than writing a final product. For instance, the complex network of socio-scientific relationships involved in this lesson might have resulted in stronger written arguments because it provided the opportunity for the student's to think and reflect as they wrote and revised their responses. While this would conflict with literacy research that indicates oral skills develop prior to written (Kantor & Rubin, 1981), this discrepancy might be accounted for by differences between content areas and/or genres. However, one could also make a temporal argument: The written arguments were stronger than the oral arguments because the written arguments occurred after the spoken arguments, and both arguments were on the same topic. This would support McNeill's (2009) conclusion that student talk associated with scientific argumentation resulted in stronger science writing. Yet, still another argument could be made that the reason the oral arguments were less sophisticated was because the students were attending to an audience during oral argumentation. The inclusion of inaccurate or irrelevant justifications within the oral arguments could be the result of students' attenuation to the audience, which would reflect a need to provide further justification. As more justifications were added, it becomes more likely that inaccurate or irrelevant justifications were referenced. If this were the case, then it would suggest that the attending to the audience influences not only the number (Berland & McNeill, 2010), but also the type of justifications. Regardless, this discussion provides grounds for additional research to tease apart the reason why the oral arguments were less sophisticated than the written arguments.

While we acknowledge that our study is limited by a small sample size and is contextualized within a classroom that has developed a scientific argumentation norm, we believe our methodology and findings to not only build upon the extant literature base, but also raise pertinent questions for future research. We also acknowledge that our proposed learning progression is still within the theoretical phases. While this study has informed the levels, more research is necessary to confirm or refute the ordering of the levels.

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