Unpacking the Use of Talk and Writing in Argument-based Inquiry: Instruction and Cognition

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Abstract: The purpose of this study was to unpack the use of talk and writing to support students’ construction of scientific knowledge in argument-based inquiry. Grounded in interactive constructivism, this sixteen-week study utilized qualitative design and was conducted in one argument-based inquiry classroom with participation of 22 fifth-grade students. The results indicated (a) as students had more opportunities to practice, they developed more sophisticated understanding for oral argumentation, (b) students’ ability to craft a written argument improved over time, (c) when both talk and writing were used, student knowledge construction occurred more than when only one learning tool was used, (d) students’ higher cognitive processes were facilitated more than when talk or writing were used alone, and (e) the more talk and writing were used together, the more student-centered the classroom was.

Introduction

Argumentation is a core practice of scientific inquiry in which students engage in reasoning processes of constructing knowledge claims through interpreting data as sound evidence and debating those claims (Ford, 2008; Hand, 2008). Current research indicates that learning how to engage in productive scientific argumentation to build and propose knowledge is difficult for students (Sampson & Clark, 2009). Many scholars advocate strongly the need to create environments where students can talk in order to construct explanations, models, and theories just as scientists use arguments to relate the evidence they select to their claims (e.g., McNeill, & Pimentel, 2010; Mercer, 2008). Nevertheless, Yore and Treagust (2006) argued that talking is necessary for argumentation, “but not sufficient to do and learn science” (p. 296). They noted that writing also play an important role during argumentative processes. Wallace (2007) succinctly concluded about the effect of talking and writing on argumentation: “talk is most important for distributing knowledge, while writing is important for manipulating, consolidating, and integrating knowledge” (p. 11). Talking and writing are therefore complementary tools for argumentative practice.

However, Studies in the field of argumentation have investigated talk and writing separately and thus have tended to disconnect the relationship between the two in terms of the argumentative process due to different theoretical frameworks or methodologies adopted by the researchers. For example, some researchers emphasize the impact of engaging students in talking within groups or as a whole class (e.g. McNeill & Pimentel, 2010), while others focus on the important mechanisms for individually scaffolding the construction of students’ written arguments (e.g. Takao & Kelly, 2003). Those studies that point out the challenges, difficulties, and effects of using talk or writing in argumentation have contributed greatly to the field of science education. However, to learn better how to support students in this argumentative practice and to overcome the challenges, an examination of investigating how talk and writing combined can best support students’ construction of scientific knowledge through argumentation and what kinds of cognitive processes might be facilitated by the combination of talk and writing is needed. So far, only two quasi-experimental studies, conducted by Rivard and Straw (2000) and Rivard (2004), have directly reported interesting findings regarding the impact of both talk and writing on students’ conceptual learning. Rivard and Straw (2000) compared the effects of talk alone, writing alone, the combination with talk and writing, and control condition at a posttest and delayed posttest. They found that talk and writing together were more effective than other three groups in contributing to simple and integrated knowledge at a post-test and delayed posttest. They suggested that science teachers should endeavor to include more writing tasks in the classroom after students have had sufficient opportunities for collaborative exploratory talk while being guided by cognitive engagement in argumentative processes. Yet, their research was quantitative and still focused on the outcome of knowledge acquisition. The patterns of the combination of talk and writing that support students’ knowledge construction and cognitive processes still remain unknown.

In response to those research deficits, we try to unpack the use of talk and writing in an argument-based inquiry classroom and set up four research questions to guide this qualitative study: (1) How do students develop an understanding of using talk as a learning tool when participating in an argument-based inquiry classroom during two units over sixteen weeks? (2) How do students craft their written arguments over time in an argument-based inquiry classroom? (3) In what ways do talk and writing support scientific knowledge
construction in an argument-based inquiry classroom? (4) What are the characteristics of the cognitive processes associated with the use of talk and writing in the context?

**Theoretical Framework**

Grounded in interactive constructivism (Yore, 2001) and using language as a learning tool (Wallace, 2007), argumentation is defined in the current study as both an individual cognitive activity and a negotiated social act for knowledge construction (Hand, 2008). Both the individual and social aspects of argumentation are essential for classroom practice because they enhance students’ ability to reason and justify claims as well as to interact with their teacher and peers in the process of constructing and critiquing their ideas. When students move quickly and effectively between the two landscapes, their knowledge construction can best be facilitated. What makes their moves successful for knowledge construction is the use of language. Stated differently, knowledge construction involves an iterated process of negotiating meaning between a cognitive dynamic within individuals and social interaction in small group and whole class settings while simultaneously utilizing a variety of language forms and modes for representing those meanings. Although other forms of language are used to construct knowledge, talk and writing have been considered two critical and powerful learning tools of knowledge construction in science classrooms by a number of scholars (e.g. Yore & Treagust, 2006). In this study, writing includes not only texts, but also all representations which have the potential to improve students’ conceptual understanding such as graphs, pictures, diagrams, tables, etc.

To guide data analysis and interpretation, this study identifies the structure of scientific argument as consisting of three interrelated components: question, claim, and evidence (see Chen, 2011, for descriptions of the framework and the three components).

**Research Design**

To answer the first and second research question, a basic qualitative approach (Merriam, 1998) was conducted in a fifth grade science classroom taught by one white male teacher in the Midwestern United States. The teacher participating in the study had 10 years of teaching experience. He had been involved in a professional development project for using an argument-based inquiry approach—the Science Writing Heuristic (SWH) approach (Hand, 2008)—for the past three years. This teacher was selected using a purposeful sampling technique because he had incorporated the SWH approach into his classroom at a high level of implementation based upon his score on the Reformed Teaching Observation Protocol (RTOP). In the summer of 2010, he was recruited as an instructor for a SWH professional development project.

To understand in depth elementary school students’ perceptions, reasons, and thoughts about their actions and participation in the classroom, six students (two girls, four boys; three high achievement, three medium achievement; three initially talkative, three initially quiet) were selected for targeted interview from the 22 students in the class.

To answer the third and fourth research question, a multiple-case study was conducted. Three students were selected from the six target students for careful observation while they discussed, investigated, and wrote in whole class and small group settings over sixteen weeks. The purpose of only choosing three students was to examine the trajectory of students’ use of talk and writing for knowledge construction in a great deal.

**Data Collection**

To triangulate the findings, data were collected through a variety of sources during two classroom units (Ecosystem & Human Body System), including daily non-participant observations, semi-structured interviews, students’ writing samples, and researcher’s field notes. Interviews about individual students’ writing samples and about classroom observations were conducted in a semi-structured fashion to elucidate the reasons they wrote, drew, and organized datasets in particular ways. The average number of interviews with each student was 11 over sixteen weeks. Students had science class every day. Seventy four classroom videotapes were collected and transcribed.

**Data Analysis**

*Research Question 1&2:* Two different analytical approaches were used: (1) the constant comparative method (LeCompte & Preissle, 1993).

As a result of analysis via the constant comparative method, six core components of oral argumentation related to public negotiation were identified from five rounds of public negotiations over the course of the two learning units: 1) Information Seeking, 2) Elaborating, 3) Challenging (testing, relationship between question and claim, relationship between claim and evidence, the value of a claim, and the value of evidence—sufficiency, validity, and reasoning), 4) Defending (simple, evidence-based), 5) Supporting (simple, evidence-based), and 6) Rejecting (simple, evidence-based). Five core components related to students’ written arguments were also identified: 1) Accuracy of Claim, 2) Sufficiency of Evidence, 3) Reasoning of Evidence, 4) Relationship between Claim and Question, and 5) Relationship between Claim and Evidence. To gain a better
understanding of the change in the quality of students’ written arguments over time, a writing rubric was created based upon the core written argument components. Each component was rated using a five-point scale from 0= “Lack” to 4= “Proficient” for a possible total of 20 points for the instrument as a whole. In addition, six aspects related to students’ perspectives of argumentation emerged from interview and field notes: 1) Meaning of Negotiation, 2) Function of Talk, 3) Function of Writing, 4) Argument Structure, 5) Reason to Shift Ideas, and 6) View of Feedback.

Research Question 3&4: To capture individual students’ knowledge construction over time, and the way students use talk and/or writing for the knowledge construction, a purposeful approach was designed, called in-depth analysis of Knowledge Construction Trajectory (KCT). This approach consisted of four stages: a) dividing units into classes and identifying activities within a class, b) identifying events within an activity, c) synthesizing events into KCTs, and d) analyzing data related to the KCT by the constant comparative method and the enumerative approach (see Chen, 2011, for descriptions of KCT and the analysis process).

To answer research question 3, the data related to each KCT were first analyzed to identify the patterns in the use of talk and writing. As a result of the analysis, each of the 21 KCTs revealed one of the five patterns in the use of talk and writing: a) talk only, b) writing only, c) use of talk and writing in sequence, d) use of both talk and writing simultaneously, and e) a combination of sequential and simultaneous use of talk and writing. Table 1 shows examples of the five patterns.

Table 1: Examples of Five Patterns of KCTs

<table>
<thead>
<tr>
<th>Pattern 1: Talk Only (Blair, KCT 1)</th>
<th>Pattern 2: Writing Only (Kurt, KCT 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Growth</td>
<td>Conceptual Growth</td>
</tr>
<tr>
<td>Event 1: A small group test</td>
<td>Event 1: A small group test</td>
</tr>
<tr>
<td>Do a seeds need sunlight or darkness to germinate?</td>
<td>What does a seed need to germinate?</td>
</tr>
<tr>
<td>Event 2: A whole class discussion</td>
<td>Event 2: A whole class discussion</td>
</tr>
<tr>
<td>A Seed need sunlight and/ or darkness to germinate</td>
<td>A plant needs water to germinate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pattern 3: Use of Talk and Writing in Sequence (Blair, KCT 3)</th>
<th>Pattern 4: Use of Talk and Writing Simultaneously (Nolan, KCT 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Growth</td>
<td>Conceptual Growth</td>
</tr>
<tr>
<td>Event 1: Teacher’s question</td>
<td>Event 1: A whole class discussion and individual writing</td>
</tr>
<tr>
<td>Humans get all of their energy from the Sun?</td>
<td>Each part of digestive system works together by breaking down the food for the next part of the system</td>
</tr>
<tr>
<td>Event 2: A whole class discussion</td>
<td>Event 2: Small group discussion and writing</td>
</tr>
<tr>
<td>We get part of our energy from sun, but also part from food.</td>
<td>Our digestive system breaks down food for nutrients and energy</td>
</tr>
<tr>
<td>Event 3: Individual writing</td>
<td></td>
</tr>
<tr>
<td>Humans do not get energy from the Sun (pupils write about this event)</td>
<td></td>
</tr>
<tr>
<td>Event 4: A whole class discussion</td>
<td></td>
</tr>
<tr>
<td>Humans indirectly get energy from the Sun</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pattern 5: A Combination of Sequential and Simultaneous Use of Talk and Writing (Kurt, KCT 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Growth</td>
</tr>
<tr>
<td>Event 1: A small group writing</td>
</tr>
<tr>
<td>A plant needs water, soil, and air to live</td>
</tr>
<tr>
<td>Event 2: A whole class discussion</td>
</tr>
<tr>
<td>A seed needs sunlight to germinate</td>
</tr>
<tr>
<td>Event 3: A whole class discussion</td>
</tr>
<tr>
<td>A seed needs correct temperature to germinate</td>
</tr>
<tr>
<td>Event 4: A small group talk and writing</td>
</tr>
<tr>
<td>A seed needs water, air, and correct temperature to germinate</td>
</tr>
</tbody>
</table>

Note: Broken line boxes indicate that a student only used writing in the given event; solid line boxes indicate that a student only used talk in the event; double line boxes indicate that a student used both talk and writing in the event.
To answer research question 4, all data related to the KCT were analyzed using the constant comparative method to identify cognitive processes associated with the use of talk and writing in each KCT. Codes developed through the analysis include express, report, record, describe, elaborate, organize, challenge, compare, reflect, integrate, stimulate alternative ideas, defend, multi-model representation, audience awareness, and analogize. Then those codes were categorized using Bloom’s taxonomy to determine the level of a cognitive process involved in writing, talk, or both (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956). As a result, express, report, record, and describe were categorized in low level (knowledge/comprehension); elaborate, compare, and organize were categorized in medium level (application/analysis); challenge, defend, reflect, stimulate alternative ideas, multi-model representation, audience awareness, and analogize were categorized in high level (synthesis/evaluation). (see Chen, 2011, for descriptions of the coding schemes and procedures).

Findings

Finding 1: Increased Understanding of the Nature of Argumentation

First, the frequency of student utterances for each argumentation component increased from the first unit to the second unit (see Figure 1). This result suggests that student participation in argumentative discussions was increasingly encouraged and elicited the more they engaged in negotiation. When students’ oral participation increased and their argumentative practice was encouraged, they were observed to challenge others’ ideas, use evidence to back up their claims, and evaluate explanatory claims in terms of evidence to construct more complete scientific knowledge. Importantly, students gradually linked the use of argumentation components with the negotiated processes. Argumentative skills were not eliminated due to the change of the topic context, as students quickly adapted their argumentative responses to a new situation.

Second, three main dimensions through which students challenged each others’ ideas were distinguished in the different stages of negotiation. These dimensions were (1) a focus on the test and the accuracy of the claim (beginning stage), (2) a focus on the argument structure (middle stage), and (3) a focus on the quality of the evidence (late stage) (see Figure 2). These results confirmed those from other studies on scientific argumentation that suggest that the ability to understand the structure of argument and the quality of evidence does not come naturally to most individuals, but rather is grown through practice (Hand, 2008).

Figure 1. The Frequency of Argumentative Utterances Contributed by Students in Discussing Claim and Evidence in a Whole Class Setting through Sixteen Weeks

Figure 2. Frequency, Proportion, and Types of Challenging Responses Contributed by Students over Five Rounds of Negotiations
Third, these students developed a better understanding of how to adopt more evidence to defend, support, and reject an argument after they participated in more rounds of negotiation. The data revealed that the proportion of utterances made by students using evidence to defend, support, and reject an argument were 13%, 0%, and 0% in the first-round negotiation of the first unit. In the second round of the second unit, in contrast, the proportion of students who relied on evidence to defend, support, and reject was substantially increased to 88%, 74%, and 59%. This trend resulted in two characteristics: (1) students were more willing to accept other arguments or shift their original ideas, and (2) the discussion was more effective in terms of core concepts related to that topic.

**Finding 2: Increased Quality of Written Arguments**

The overall quality of students’ written arguments and their understanding of argument structure and components were improved when they were provided with more opportunities to craft their writing over time (see Figure 3). Students also incorporated multi-model representations to explain their ideas and back themselves up. This improvement in the quality of argument seemed to be due, in large part, to two factors: (1) the engagement in scientific writing embedded within argumentative practice, and (2) an awareness of the usefulness of feedback from peers.

**Figure 3. The Average Score for Written Scientific Arguments on Each Component over Two Units**

Taking the results from Finding 1 and Finding 2 together, the quality of writing was dependent on the way students participated orally in the argumentative practice, and vice versa. In other words, the result, with a parallel shift between oral argumentative practices and the quality of written arguments, indicates that talk and writing are interdependent. Building on these results, Finding 3 will discuss how talk and writing interact with each other and how the different interactions support student knowledge construction in argument-based inquiry. Finding 4 will discuss the characteristics of the cognitive processes associated with the use of talk and writing in the context.

**Finding 3: Increased Integration of Using Talk and Writing as Learning Tools**

An in-depth analysis of KCTs identified twenty-one KCTs in which students built scientific knowledge using talk and/or writing in an argument-based inquiry classroom during two units. As the semester proceeded, with increasing opportunities to engage in argument-based inquiry, the students came to use different combinations of talk and writing in activities to construct their understanding of core concepts. The number of KCTs in which students used talk and writing simultaneously increased from zero in the first unit to 7 in the second unit, whereas the frequency of the use of talk and writing in sequence decreased from 4 to zero (see Table 2). The use of talk and writing was embedded in the students’ investigations and negotiations and became an integral part of inquiry as students became capable of using the two tools to represent their arguments, analyze data, and debate their ideas. During the interview, students confessed that talk associated with writing helped them to clarify, visualize, and integrate their ideas which brought them to discuss concepts at a deeper level.

**Finding 4: Increased Higher Cognitive Processes by Using Talk and Writing in Sequence or Simultaneously**

When students perceived and used talk and writing as separated learning tools, their cognitive processes were constrained to lower level, such as reporting, sharing, and recording their ideas. In contrast, when students used those two learning tools together, students usually became involved in higher and more complex cognitive processes, such as integrating, defending, using multi-model representations, and analogizing, etc.

The function of writing extended from an individual learning tool supporting personal cognitive activities when used alone to a socially negotiated learning tool through combination with talk. Additionally, writing became both a product-based and process-based approach when students use it with talk simultaneously.
Writing is not simply a matter of translating preconceived ideas into text, but it is a knowledge-constituting process (Galbraith, 1999) in which students synthesize their ideas in written forms to communicate with their peers and external their mental model by using multi-model representation (drawing, tables, figures). The quality of talk was promoted to more evidence-based when writing was used in combination. This trend of using talk and writing together in constructing scientific knowledge over time might be the result of two reasons: (1) students came to take ownership of their learning, and (2) students came to understand the meaning of negotiation.

Table 2: Number of KCTs Identified in Each Unit for Each Student

<table>
<thead>
<tr>
<th>Topics</th>
<th>Students</th>
<th>Talk Only</th>
<th>Writing Only</th>
<th>Combination &amp; Writing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 1: Ecosystem</td>
<td>Calvin</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Betty</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>John</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Sub Total</td>
<td></td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Unit 2: Human Body System</td>
<td>Calvin</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Betty</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>John</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sub Total</td>
<td></td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Summary of Results

Table 3 summarizes the main findings addressing this study’s four research questions in terms of the following five aspects: (1) oral argumentation, (2) ability to craft written arguments, (3) use of talk and/or writing, (4) cognitive processes, and (5) meaning of negotiation. In examining these five major conceptual outcomes arising from this study, the researchers would suggest that the common critical element across these five areas is time. As students encountered more opportunities to obtain “a grasp of the practice” (Ford, 2008), they were observed to develop a more sophisticated understanding of argumentation, use talk and writing as learning tools to construct and negotiate their ideas with peers, engage in more complex and higher-order cognitive processes, and take ownership of their learning in science.

Discussion and Implication for Science Education

One of the major findings of this study indicates that there is a relationship between the way these students participated in oral argumentation and their abilities in crafting written arguments. Examining Finding 1 and Finding 2 together, at the beginning of the semester students focused on challenging the test procedure and accuracy of claims, which was reflected in the improved quality of their written arguments about the accuracy of claims. In the middle of the semester, students’ spoken challenges focused on the structure of the argument, which was also reflected in their improved quality of writing about the relationship between question and claim and the relationship between claim and evidence. At the end of the semester, students moved to challenge the quality of evidence, which was reflected in their improved quality of written arguments regarding reasoning and sufficiency of evidence. These observations, when taken together, indicate that there seems to be a positive relationship between students’ participation in oral argumentation and writing as outcome measures. As such this study would suggest that talk and writing are interdependent in this context.

However, it is believed that improved performance in one practice does not necessarily lead to better performance in the other; instead the students seemed to develop better awareness of audience and understanding of claim/ evidence, which guided how they engaged in both practices. This epistemic shift requires a different classroom culture and discourse environment (Cavagnetto, 2010). It is speculated that such a shift requires two conditions to occur: (1) students must be introduced to new criteria or norms for what counts as a claim and what counts as evidence in an explicit fashion in an appropriate context and time, and (2) students need to be encouraged by others to use these new criteria and norms in an appropriate context and time in which they are fruitful and make sense.

Berland and Reised (2011) have indicated that students rarely revise their ideas in light of the challenges and questions posed to them. However, this study did find that students at the end of the semester were more willing to revise their ideas if their peers provided evidence to support their opinions. This suggests that a challenge component is necessary for argumentative practice, but it is not enough to generate complete and convincing scientific arguments. Evidence-based defending, supporting, and rejecting components may also
help students to more carefully rethink, reflect on, and compare their ideas to those of others with evidentiary support. The significance here is that only using talk as a learning tool may not produce evidence-based discussion. When students engaged in evidence-based discussion, they usually used writing associated with talk as negotiation tools to help them explain and elaborate upon their ideas. In addition, asking or encouraging students to use multi-model representations may foster their ability to clarify and revisit their ideas instead of relying only on talk or one model (text) for reasoning concepts.

Table 3: Matrix of Argumentative Practices in Five Aspects

<table>
<thead>
<tr>
<th>Time Line</th>
<th>Oral Argumentation</th>
<th>Written Arguments</th>
<th>Use of Talk and/or Writing</th>
<th>Cognitive Processes</th>
<th>Meaning of Negotiation</th>
</tr>
</thead>
</table>
| Week 1-3  | --Information seeking (great proportion)  
--Elaborating  
--Challenging (focus on the procedure, process, and the accuracy of a claim)  
--Rejecting, supporting, and defending (simple)  

--Focus on the accuracy of a claim  
--Audience is the teacher  
--The reason to change ideas is because of teacher's hint  

--Talk or writing alone (writing is a product)  
--Use talk and writing in sequence (writing is a product, then becomes a process) | --Combination of sequence and simultaneity | --Elaborating, organizing, challenging, comparing, reflecting, stimulating alternative ideas, defending, multi-model representing, and audience awareness | --Transition from teacher-directed to student-directed |
| Week 4-12 | --Information seeking (small proportion)  
--Elaborating  
--Challenging (focus on the structure of an argument: question, claims, and evidence)  
--Rejecting, supporting, and defending (more evidence-based)  

--Focus on the relationship between question, claims and evidence  
--Awareness of audience shifting from teacher to peers | --Combination of sequence and simultaneity | --Elaborating, organizing, challenging, comparing, reflecting, stimulating alternative ideas, defending, multi-model representing, and audience awareness | --Negotiation is to explain ideas and to revise them |
| Week 13-16 | --Information seeking (small proportion)  
--Elaborating  
--Challenging (focus on the quality of evidence: sufficiency, validity, and reasoning)  
--Rejecting, supporting, and defending (evidence-based)  

--Focus on the sufficiency and reasoning of evidence  
--Audience is both teacher and peers  
--Willing to change or shift ideas based on peers’ feedback | --Use talk and writing simultaneously in a whole class setting or a small group (writing is both product and process in this context) | --Elaborating, organizing, challenging, comparing, reflecting, stimulating alternative ideas, defending, multi-model representing, audience awareness, and analogizing | --Student-directed  
--Negotiation is to explain ideas and reach a consensus; provide evidence to support claim  
--Effective dialogue: students realized the importance of critiquing, constructing, and listening |

The analysis of this study led us to rethink the value of the combination of talk and writing to promote students’ construction of science, as it appears to help students engage in more productive arguments than when using talk or writing alone. This kind of talk associated with writing, as Galbraith noted (1999), required an oscillation between disposition (targeted topic) and linguistic (writing task) knowledge, which led to clarification of conceptual understanding and may lead to the formation of new knowledge. Talk alone simply
deposits ideas that are not recorded. It is difficult to go back to check an idea generated 10 minutes ago. By contrast, the form of talk associated with writing for sharing, challenging and defending is an interaction between students and texts which is represented by someone. Talk associated with writing encourages students to “freeze” their ideas on paper, which records them. Students can frequently collaboratively reflect on their ideas based upon their writing. The role of writing in this case “serves learning uniquely because writing as process-and-product possesses a cluster of attributes that correspond uniquely to certain powerful learning strategies” (Emig, 1977, p. 122).

Importantly, this study also found that students engaged in higher-order and more complex cognitive processes when talk and writing were used together either in sequence or simultaneously, rather than when they were used alone. It is clear that teachers have a responsibility to “design a sequence of instruction that provides opportunities” for student growth (Duschl & Ellenbogen, 2002, p.3). More importantly, the teacher should create a discourse space in which students can construct an argument as part of an investigation with their peers, clarify their thinking by using the six core argumentation components, monitor their conceptual understandings, as well as learn and use the criteria by which these arguments will be judged or evaluated. Talk and writing can be powerful means by which to foster students to engage in higher cognitive reasoning. Especially, the simultaneous use of talk and writing can be an effective way to help students develop ownership of their learning, participate in more productive argumentative practices, and advance their conceptual growth.

References