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Characterizing the changes in teaching practice during first semester implementation of an argument-based inquiry approach in a middle school science classroom

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CHARACTERIZING THE CHANGES IN TEACHING PRACTICE DURING FIRST SEMESTER IMPLEMENTATION OF AN ARGUMENT-BASED INQUIRY APPROACH IN A MIDDLE SCHOOL SCIENCE CLASSROOM

by

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CERTIFICATE OF APPROVAL

PH.D. THESIS

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To my family and friends whose
love and support made this possible

Don't judge each day by the harvest you reap but by the seeds that you plant.

Robert Louis Stevenson

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ABSTRACT

The purpose of this study was to characterize ways in which teaching practice in a classroom undergoing first semester implementation of an argument-based inquiry approach changes in whole-class discussion. Being that argument is explicitly called for in the Next Generation Science Standards and is currently a rare practice in teaching, many teachers will have to transform their teaching practice for inclusion of this feature. Most studies on argument-based Inquiry (ABI) agree that development of argument does not come easily and is only acquired through practice.

Few studies have examined the ways in which teaching practice changes in relation to the big idea or disciplinary core idea (NGSS), the development of dialogue, and/or the development of argument during first semester implementation of an argument-based inquiry approach. To explore these areas, this study posed three primary research questions: (1) How does a teacher in his first semester of Science Writing Heuristic professional development make use of the "big idea"?, (1a) Is the indicated big idea consistent with NGSS core concepts?, (2) How did the dialogue in whole-class discussion change during the first semester of argument-based inquiry professional development?, (3) How did the argument in whole-class discussion change during the first semester of argument-based inquiry professional development?

This semester-long study that took place in a middle school in a rural Midwestern city was grounded in interactive constructivism, and utilized a qualitative design to identify the ways in which the teacher utilized big ideas and how dialogue and argumentative dialogue developed over time. The purposefully selected teacher in this study provided a unique situation where he was in his first semester of professional development using the Science Writing Heuristic approach to argument-based inquiry with 19 students who had two prior years' experience in ABI. Multiple sources of data were collected, including classroom video with transcripts, teacher interview, researcher field notes, student journals, teacher lesson plans from previous years, and a student questionnaire. Data analysis used a basic qualitative approach.

The results showed (1) only the first time period had a true big idea, while the other two units contained topics, (2) each semester contained a similar use for the given big idea, though its role in the class was reduced after the opening activity, (3) the types of teacher questions shifted toward students explaining their comprehension of ideas and more students were involved in discussing each idea and for more turns of talk than in earlier time periods, (4) understanding science term definitions became more prominent later in the semester, with more stating science terms occurring earlier in the semester, (5) no significant changes were seen to the use of argument or claims and evidence throughout the study.

The findings have informed theory and practice about science argumentation, the practice of whole-class dialogue, and the understanding of practice along four aspects: (1) apparent lack of understanding about big ideas and how to utilize them as the central organizing feature of a unit, (2) independent development of dialogue and argument, (3) apparent lack of understanding about the structure of argument and use of basic terminology with argument and big ideas, (4) challenges of ABI implementation. This study provides insight into the importance of prolonged and persistent professional development with ABI in teaching practice.

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CHAPTER ONE

GENERAL OVERVIEW AND PURPOSE OF STUDY

Introduction

The recently released Next Generation Science Standards (National Research Council, 2012) call for the inclusion of eight essential practices for K-12 science classrooms including engaging in argument from evidence, among others. A goal of the use of these practices is to increase the science literacy of students. This study was an exploration into the pedagogical changes that occurred in one middle school classroom undergoing first semester implementation of an argument-based inquiry approach. This study provides a small but important view into how classroom dialogue changes while working towards inclusion of one of the eight essential practices (NRC, 2012).

Science Argumentation

Science argumentation can be defined as a dialogical process of making knowledge claims, providing evidence for those claims, and critiquing claims and evidence through listening, writing, and talking (Duschl, Schweingruber, & Shouse, 2007). Scientific argumentation is primarily a social discipline without any one person or even group of people having access to "truth". Argumentation can be thought of as an iterative process that works to refine knowledge claims as new evidence is brought forward supporting or refuting previous knowledge claims (Berland & Reiser, 2011; Chin & Osborne, 2010; Kuhn, 1992; Lawson, 2003; Wellington & Osborne, 2001). Norris and Phillips (2003) would argue that without understanding this structure, students cannot be considered scientifically literate. Ford (2008) states that a "proper understanding of a scientific idea requires that one also know something about the architecture of that knowledge – that is, how it is constructed" (p. 404). This sentiment is also expressed by the National Research Council (NRC) (1996) in that the learning process should, in some way, parallel the process by which science knowledge is constructed.

Unfortunately, engaging students in argumentation rarely occurs in science classrooms (Driver, Newton, & Osbourne, 2000; Lemke, 1990). Most of the classrooms that do exhibit argument in their discourse "were affiliated with a research-based program or with intervention from one or more of the study authors (e.g. Clark & Sampson, 2008; Martin & Hand, 2009; McNeill & Krajcik, 2008; Simon, Erduran, & Osborne, 2006; von Aufschnatier, Erduran, Osborne, & Simon, 2008)" (Benus, 2011, p.13). Ultimately this means that this practice is rarely seen in classrooms not connected to these programs or interventions with many teachers needing to develop pedagogy for inclusion of argument as a practice of their science classrooms as called for in the Next Generation Science Standards (NRC, 2012).

Dialogue

Dialogue is a critical component of any classroom using argument-based inquiry because to reach meaningful consensus, one must engage in the exchange and understanding of the ideas of others. Dialogue is a generative practice where people can think together about their own ideas in light of others' thinking (Benus, 2011; Schein, 1993). When people engage in dialogue, they speak in ways that seek to contribute to each other (Isaacs, 1999). Dialogue is a "way of thinking and reflecting together. It is not something you do to another person. It is something you do with people" (Isaacs, 1999, p.9). Dialogue is the expansion or clarification of taken-as-shared ideas (Scardamalia & Bereiter, 2006). However, feedback is only encouraged as it relates to individual behavior that might threaten the natural flow of conversation, not as a goal of the dialogic process (Schein, 1993). Dialogue can help one see ideas differently through shared experiences (Schein, 1993). Dialogue is not concerned with persuasion as argument is, but rather the exchange of what one knows and how they know it. A critical component of the ideas presented during a dialogue is that the ideas of others are not only included but also acknowledge during this process (Scott, Mortimer, & Aguiar, 2006).

Nystrand et al. (1997) found the quality of student learning was closely linked to the quality of the classroom talk when examining the dynamics of language and learning. In a dialogue-based class discussion, the students spend time probing the thinking of their peers as the class works toward constructing a common understanding (Varelas & Pineda, 1999). Dialogue goes much further than the common stereotype of "two people talking" (Burbles & Bruce, 2001). A classroom engaging in dialogue cannot be a classroom of "passive recipients of knowledge and instruction" (Benus, 2011, p. 21).

Unfortunately, the dialogue as described above does not often happen in science classrooms (Macbeth, 2003). Normal classroom discourse is predominantly monologic (Duschl & Osborne, 2002). A part of this is due to traditional science classroom discourse being dominated by teacher talk (Crawford, 2005). Additionally, of the discussion that does occur, it usually follows an Initiate, Response, Evaluate (IRE) or Initiate, Response, Feedback (IRF) pattern (Macbeth, 2003; Mehan, 1979). In these situations, the teacher takes a leader role by asking the question (Initiate), the student responds to the question (Response), and the teacher evaluates or provides feedback to the response (Evaluate/Feedback).

Purpose of Study

The purpose of this study was to characterize the ways in which teaching practice in a classroom undergoing first semester implementation of an argument-based inquiry approach changes in whole-class discussion. Being that argument is a rare practice currently in teaching and that it is explicitly called for in the NGSS, many teachers will have to transform their teaching practice for inclusion of this feature. As addressed previously, dialogue is a critical component to an argument-based inquiry classroom. This study seeks to explore changes that occur in dialogue as well as argument in a classroom explicitly focused on inclusion of this practice through the Science Writing Heuristic (SWH) approach to argument-based inquiry.

This study builds off a previous study by Benus (2011) in which he examines how a teacher experienced with an argument-based inquiry approach supports the development of dialogue in his classrooms with students that have not previously had argument-based inquiry instruction. In essence, this study is a reverse situation in that the teacher has not previously worked to implement argument into his classroom but the students have prior experience with the approach. This study also examines whether the units of instruction are oriented around core concepts in science, called "big ideas". Given big ideas will be compared to the Next Generation Science Standards as well as the *Questions, Claims, and Evidence* (Norton-Meier et al., 2008) book teachers receive during SWH professional development to determine if the indicated big ideas are consistent with core concepts.

The goal of this study is to provide insight into areas of whole-class discussion that changed during the first semester of professional development as well as the areas that may not have changed. These insights can inform future research and professional development about the successes or difficulties in classroom practice that come with implementation of the SWH approach. They also offer potential comparisons to previous studies with teachers that have more experience with argument-based inquiry.

Research Questions of the Study

There are three primary questions that guide this study. These questions are designed to explore three areas including: the big idea, whole-class dialogue changes, and argument changes. The overarching purpose of these questions is to explore how whole-class discussion changes while a middle school teacher undergoes first semester implementation of an argument-based inquiry approach.

1. How does a teacher in his first semester of Science Writing Heuristic professional development make use of the "big idea"?
   a. Is the indicated big idea consistent with NGSS core concepts?
2. How did the dialogue in whole-class discussion change during the first semester of argument-based inquiry professional development?
3. How did the argument in whole-class discussion change during the first semester of argument-based inquiry professional development?

Significance of the Study

The Next Generation Science Standards explicitly call for inclusion of argument from evidence as an essential practice in K-12 science classrooms. As a result of the scarcity of this practice currently in classrooms not involved with research programs with this as their focus, many teachers will have to modify their practice for inclusion of argument. This study examines potential changes and challenges teachers may face while working on inclusion of this practice.

Kuhn (1991) suggests sustaining argument in classrooms requires practice; most certainly developing one's abilities to use argument as a pedagogical tool must also require practice. Sustained professional development can help teachers better use ways to approach and practice scientific argumentation. Unfortunately, this sustained professional development promoting scientific argumentation is infrequently noted in the literature and is likely uncommon in practice (Benus et al., 2013). According to Newton et al. (1999), the 14 experienced science teachers they surveyed indicated that they needed more professional development time to manage and facilitate elements of argumentation. Professional development work in Iowa (e.g. Martin & Hand, 2009) has shown that shifting teaching practice to include scientific argumentation takes time (at least 18 months) as well as practice and that teachers need to understand that student learning occurs through engagement in scientific argumentation (Chen, 2011). This study explores the changes that occur at the onset of professional development to explore early challenges and successes teachers may see during inclusion of argument.

Overview of the Study

There are five chapters to this dissertation that will provide the details of this study. This chapter provided an introduction to this dissertation, highlighting key ideas from literature that support the significance of this study and the rationale for studying whole-class dialogue, argument, and the use of core concepts in argument-based inquiry by a middle school science teacher has been addressed. Finally, the research questions that drive this study were introduced.

Chapter Two discusses the relevant literature that lays the groundwork for the significance of argumentation in the science classroom starting with national standards. Argument and dialogue are defined as well as their role in scientific literacy explained. Chapter Three provides rationale for the use of qualitative methods to answer the research questions. A detailed description of teacher selection, the methodology used to gather and analyze data, and establish trustworthiness for the study is provided.

Chapter Four discusses the findings from the research questions for this study. Five major findings are identified from this study: (1) The comparison of given big ideas to the NGSS core concepts indicated only the first time period contained a big idea, (2) The indicated big ideas were used in activities meant to elicit student prior knowledge but served less purpose after the opening discussion, (3) The types of teacher questions shifted toward students explaining their comprehension of ideas and more students were involved in discussing each idea than in earlier time periods, (4) Understanding science term definitions became more prominent later in the semester, (5) No significant changes were seen to the use of argument or claims and evidence throughout the study. Overall, the findings suggest changes in dialogue across the semester as the teacher more frequently stressed student understanding of ideas and terms without a corresponding change to argument or use of the big idea. Finally, Chapter Five discusses the findings of this study in terms of recent literature on argumentation, implications for argument-based professional development, and implications for the use of core concepts in teaching.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter will start with inquiry and the national standards as a vehicle to improve students' scientific literacy. Argumentation will be discussed as specialized dialogue that is evidence-based and produces tentative but stable knowledge. An argument-based inquiry approach, the Science Writing Heuristic, will be explained in terms of structure. Dialogue will be examined as it relates to classroom norms and argumentation. Lastly, the typical role of the teacher in the classroom will be compared to the role expected of an argument-based inquiry teacher.

Inquiry

Science education does not have a single unified definition of inquiry. Instead, inquiry has widely differing definitions to teachers, researchers, and science educators (Crawford, 2007). Inquiry is an approach to teaching science involving students generating questions, designing experiments, gathering evidence, making claims, and justifying claims about science concepts (AAAS, 1993; NRC, 1996). There are many types of inquiry that may be implemented in a classroom, resulting from different approaches to reach the previously mentioned goals (model-based inquiry, argument-based inquiry, 5E model, etc). Each of these approaches stress different parts of what is considered "inquiry". Inquiry also varies along a continuum of teacher-directed to student-directed (NRC, 2000), though some researchers argue that truly open (completely student-directed) inquiry is impossible and may set teachers up for failure (Settlage, 2007). Ultimately, inquiry attempts to engage students in authentic scientific practice

(Duschl & Grandy, 2008). The researcher would stress at this point that while this is the goal of inquiry, significant differences exist between authentic science and inquiry. Several popular inquiry approaches are elaborated below.

5E Model of Inquiry

The 5E model is designed to assist teachers in developing more inquiry-based lesson plans (Bybee et al., 2006). In the 5E model, teachers work to engage students in a task that allows assessment of students' prior knowledge and help establish connections between prior knowledge and current learning experiences. Students are given the opportunity to explore the topic through a series of activities meant to challenge their current understanding. Students construct explanations to demonstrate their understanding of a learning objective, though these explanations may come from a knowledge authority. The student understanding is challenged through elaboration by application of what they have learned to a new situation. Lastly, student understanding is evaluated (Bybee et al., 2006). The 5E model is an approach to inquiry made of five elements that may occur in any order throughout a cycle including:

- Engagement
- Exploration
- Explanation
- Elaboration
- Evaluation

Five Essential Features of Inquiry

The Five Essential Features of Inquiry (NRC, 2000) indicated features that should be found in inquiry somewhat independent of the approach taken, i.e. model-based inquiry should have the same five essential features as argument-based inquiry even though the specifics of how those features are used are expected to differ. Many approaches to inquiry that make use of these Five Essential Features tend to do so by prioritizing certain functions of the features. An example of this is given below. The Five Essential Features of Inquiry (NRC, 2000) framework includes five features that are believed to promote inquiry in the classroom. They are:

- Engage students in scientifically oriented questions
- Students give priority to evidence when developing and evaluating explanations
- Students formulate explanations from evidence
- Students evaluate their explanations in light of alternative explanations (including science explanation)
- Students communicate and justify their explanations (NRC, 2000)

Argument-based inquiry stresses the justification of claims using evidence derived from experimental data in light of competing explanations. The difference between many other approaches to inquiry and argument-based inquiry is the explicit focus on utilizing alternative explanations especially as it relates to justification of explanations. As can be seen in the five features, the classroom discourse is very important involving four of the features. Additionally, evidence plays an explicit role in two of the features (giving priority to evidence and formulating explanations) and implicit roles in two others (evaluating explanations and justifying explanations). This also shapes the classroom discourse to include elements of dialogue, argument, and especially claims backed by evidence.

Next Generation Science Standards

The transition into the Next Generation Science Standards (NGSS) moved away from "features of inquiry" into specific practices that should be seen in classrooms (NRC, 2012). In this approach, argument-based inquiry has an obvious home in the seventh practice (engaging in argument from evidence). Though, just like with the Five Essential Features model, all of the other practices could be used with argument-based inquiry. Some of these practices are embedded in what it means to do argument. As a student, you may be challenged on how you interpreted your data, how you have constructed your explanation from evidence, whether you have gathered appropriate supporting evidence from "expert" sources, etc. These practices include features for both engineering and science, as given below:

Eight Essential Practices for K-12 Classrooms

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information (NRC, 2012)

Many of the Five Essential Features of Inquiry given above can be seen in the Eight Essential Practices (asking questions, constructing explanations, communicating information, for example). Engaging students in argument is given as an explicit essential practice in these standards though it was previously not explicitly given in the Five Essential Features of Inquiry. An important note is that though argument from evidence is given as an essential practice for K-12 science classroom, the NGSS does not state that teachers must teach using an argument-based inquiry approach. The NGSS state the goal is not to limit instruction to a single science and engineering approach but to provide a framework a teacher can adopt their teaching practice around (NRC, 2012). These Essential Practices further elaborate on practices of science especially those related to how science develops explanations, for example: planning investigations, developing models, analyzing data, engaging in argument all play roles in the development of explanations. A critical component of understanding the practices of science includes the development of scientific literacy (Norris & Phillips, 2003).

Inquiry As a Means to Scientific Literacy

Science education research has recently focused on the use of inquiry approaches to improve students' scientific literacy (Fang, 2005; Prain, 2009). Traditionally, "literacy" means the ability to read and write. While this is certainly important to science, it is not inclusive of all that is meant by "scientific literacy". Norris and Phillips (2003) expand on this by including "knowledgeability, learning, and education" (P. 224). Put another way, scientific literacy also includes understanding how knowledge claims are made and supported in science. These two separate but connected senses of literacy are called the fundamental sense, the ability to read and write when the content is science, and the derived sense, being knowledgeable, learned, and educated in the ways of science (Norris & Phillips, 2003). The derived sense allows students to recognize science from nonscience, understand science and its applications, knowledge of what counts as science, the ability to use scientific knowledge in problem solving, knowledge needed to participate in intelligent discussion in science-based social issues, understanding the nature of science, and the knowledge of the benefits and risks of science (Norris & Phillips, 2003).

Inquiry approaches engage students in activities and thinking practices scientists use to develop their understanding of the natural world (Akkus, Gunel, & Hand, 2007; Bliss, 2008; Chinn & Malhotra, 2002; Jiménez-Aleixandre & Erduran, 2008; Kuhn, Black, Keselman, & Kaplan, 2000; Ruiz-Primo et al., 2010; Sandoval, 2005). The National Research Council (NRC) has stated that the central goal of scientific teaching and learning is students learning "scientific knowledge with understanding" (NRC, 1996, p. 21). Engaging students in science as inquiry promotes student learning (NRC, 2000) by encouraging students to think like scientists (Duschl, 2008). Critically, this means that scientific inquiry is more than the procedural aspects of experimenting, i.e. using instruments, recording data, transforming data into graphs or tables. It also includes thinking like a scientist; the evaluation and analysis of data in construction of claims that are backed by sound evidence that may be debated with peers (NRC, 2012).

These additional criteria encourage a change from traditional science instruction from experimental verification of already known knowledge to an understanding of science that produces tentative, but stable, knowledge through argument to produce the best explanation given the current evidence (Bricker & Bell, 2008; Zembal-Saul, 2009). The notion that science education should encourage students to engage in the same meaning making activities scientists use is not trivial as will be discussed below.

Argument

Science argumentation can be defined as a dialogical process of making knowledge claims, providing evidence for those claims, and critiquing claims and evidence through listening, writing, and talking (Duschl, Schweingruber, & Shouse, 2007). Argument has an inherent reasoning component where a new mental representation (or conclusion) is consciously produced while previously held conceptions are also consciously engaged (Mercier & Sperber, 2011). Mercier and Sperber (2011) continue by stating that "humans reason rather poorly, failing at simple logical tasks (Evans, 2002), committing egregious mistakes in probabilistic reasoning (Kahneman & Tversky, 1972; Tversky & Kahneman, 1983), and being subject to sundry irrational biases in decision making (Kahneman et al., 1982)" (p.58). As a result of arguments being formed both consciously and subconsciously students may be aware of reaching a conclusion, the output of an inferential process, but may not be aware of the inferential process itself (Mercier & Sperber, 2011). Importantly, the intuitive inferences made by students need not be about ordinary objects; they may also be about representations of objects or phenomena and must be distinguished from true "argument" (Mercier & Sperber, 2011).

While both argument and inferences have a conclusion, they differ in the processes undergone to reach that conclusion. For Mercier and Sperber (2011), arguments are complex representations that have a conclusion based on premises that have been laid out unlike an inference in which the input justifies the output; in other words, argument is a process by which a supported conclusion is reached using explicit premises. In science argumentation, "truth" is neither a necessary condition nor desired outcome. Science knowledge is tentative, though stable, and carries evidentiary support that has been evaluated by the scientific community which establishes its trustworthiness (Gross, 1990).

Therefore, scientific argumentation is primarily a social discipline without any one person or even group of people having access to "truth". Argumentation can be thought of as an iterative process that works to refine knowledge claims as new evidence is brought forward supporting or refuting previous knowledge claims (Berland & Reiser, 2011; Chin & Osborne, 2010; Kuhn, 1992; Lawson, 2003; Wellington & Osborne, 2001). Science argumentation is the principle method by which scientific knowledge is developed (Kitcher, 1988) and is the majority of scientific discourse (Kuhn, 1993; Lemke, 1990). The root of argument is built around interacting with one's own ideas and the ideas of others using logic, empirical evidence, and counter arguments mediated through written and oral discourse (Benus, 2011; McNeill, 2009; Vygotsky, 1978).

Norris and Phillips (2003) would argue that without understanding this structure, students cannot be considered scientifically literate. Ford (2008) states that a "proper understanding of a scientific idea requires that one also know something about the architecture of that knowledge – that is, how it is constructed" (P. 404). This sentiment is also expressed by the National Research Council (1996), stating that the learning process should, in some way, parallel the process by which science knowledge is constructed. Scientists understand that science knowledge is not fixed and the processes behind the production and revision of science knowledge. While learning about and using the processes scientists use to construct knowledge is important, "students cannot come to know all scientific ideas as scientists originally came to know them, but students can and should *understand* these ideas as scientists *understand* them" (Ford, 2008, P. 406).

Personal and Social Construction of Knowledge

Knowledge, in an argument setting, is created in a social context set around justification of beliefs through reasoning, conjecture, evaluation of evidence, and consideration of counter arguments (Osborne, 2005). Science contains both cognitive and social processes that are critical epistemic practices that allow the articulation of alternative, often competing, viewpoints (Sandoval & Millwood, 2005; Schwarz, 2009). These alternative viewpoints can encourage cognitive dissonance and make explicit the reasoning behind the viewpoints. The act of publicly negotiating claims with evidence can foster the construction of knowledge and learning for all participants (Sandoval & Millwood, 2005; Schwarz, 2009).

Argument as a Personal and Social Process

Argumentation is ultimately a specialized discourse that is inherently persuasive. Science is a social process that constructs knowledge as the result of interactions between and within people (Kuhn, 1993; Newton, Driver, & Osborne, 1999; Westrum, 1989). These social interactions offer a way to externalize the otherwise internal thinking that is critical for argumentation. The construction of knowledge in argumentation, being a social negotiation, leads to deeper and more meaningful knowledge construction (Driver et al., 1994; Driver & Oldham, 1986).

The social process of argumentation and negotiation with others is also a powerful tool for developing personal conceptual understandings. However, each person entering an argument also undergoes a personal aspect of argument. He/She personally considers and justifies his/her claim based on the evidence he/she has available to him/her; evidence that may come from listening to others, personal reasoning, empirical evidence, claims or counter claims by others, and reading from "expert" sources (Benus, 2011). Each individual person has an internal argument to construct their own understanding based on what they believe supports their thinking (Benus, 2011; Driver et al., 2000; McNeill, 2009). A critical note here is brought to us by Wertsch (1979) who states students cannot internalize this argumentative practice until they can make counter arguments to their own claims. As counter arguments are an important component of argumentation; a failure to be able to posit a counter argument to one's own claim would prevent argumentative discourse from occurring on a purely internally basis.

Not all researchers would agree with all of the features of the above definitions of argument. Some researchers view argumentation as a verbal, social, and rational activity with a goal of convincing a reasonable critic of the acceptability of the proposed argument by the offered justifying evidence or refutation of another's argument (Eemeren & Grootendorst, 2004). While there is significant overlap, there is also a significant reduction in what counts as argumentation. For example, this definition ignores written argumentation as well as overshadows the knowledge generation component addressed previously. Instead, this definition posits that the primary goal of argumentation is persuasion. While this is surely a component of argumentation, it alone would render the practice much less valuable for use in a classroom where learning science concepts and improving science literacy are the ultimate goals.

This study acknowledges the writing components and individual reasoning aspects of argument without restricting argument to only verbal communications.

However, this study mainly focuses on the oral components presented by participants in the classroom discussion. Additionally, this study makes use of McNeill's (2009) approach to argument to include both the individual levels (consistent with individual reasoning component) as well as the more broad social aspects of argument (consistent with public negotiation of ideas in both written and oral presentations).

Argument as a Core Feature of Science Education

Consistent with above, contemporary science education reform advocates approaches to science instruction that support and encourage students' inquiry and engagement in science practices, including articulation of explanations that are advanced through dispute and argumentation rather than general agreement or consensus (Erduran & Dagher, 2007; NRC, 2012; 2000). This goal sets argumentation as an important practice in teaching and learning of science practices. This goal was initially encoded in the Five Essential Features of Inquiry framework (NRC, 2000). These features include engaging students in scientifically-oriented questions; giving priority to evidence; formulating explanations from evidence; evaluating explanations in light of alternative explanations; and communicating and justifying explanations (NRC, 2000).

The use of argumentation in the classroom incorporates a cyclic reasoning process where students make claims, generate evidence from data that is used to support or refute claims, by critiquing or challenging claims, and evaluate the arguments for or against these claims to determine their validity (Choi et al., 2010; Kelly & Bazerman, 2003; McNeill, 2009; Peker & Wallace, 2009; Berland & Reiser, 2011; Chin & Osborne, 2010). Studies focusing on argumentation in the science classroom indicate that students develop their conceptual understanding through dialogical interactions with their peers and teacher (Promyod, 2013). In addition to other possible benefits that will be discussed later, argument can be seen primarily as a social process and therefore an essential social skill that students should engage in during their schooling (Benus, 2011).

Because science literacy is seen as a desirable outcome of learning science (American Association for the Advancement of Science, 1993; Hand, Yore, Jagger, & Prain, 2010; Howes, Lim, & Campos, 2009; Klein, 2006; Millar, 2006; Moje, 2007; Norris & Phillips, 2003; Sadler & Zeidle, 2009; Wallace, 2004) and because argument is a core component of science, in order to develop scientific literacy argument must also be an important component of science classrooms. An argument-based inquiry approach leads to a better understanding of the epistemology of scientific knowledge (a primary goal of scientific literacy) as well as improved social skills (Driver et al., 2000; Driver et al., 1994; Duschl, 2008; Cavagnetto, 2010). Unfortunately, argumentation as seen in science rarely occurs in classroom discourse (Benus, 2011; Driver, Newton, & Osborne, 2000; Lemke, 1990; Mehan, 1979; Weiss et al., 2003).

As Benus (2011) reports, most of the classrooms that do exhibit argument in their discourse “were affiliated with a research-based program or with intervention from one or more of the study authors (e.g. Clark & Sampson, 2008; Martin & Hand, 2009; McNeill & Krajcik, 2008; Simon, Erduran, & Osborne, 2006; von Aufschnatier, Erduran, Osborne, & Simon, 2008).” He continues by reinforcing the point that finding a classroom with this practice without ties to recent professional development models is scarce. Ultimately this means that this practice is rarely seen in classrooms not connected to these programs or interventions with many teachers needing to develop pedagogy for inclusion of argument as a practice of their science classrooms as called for in the Next Generation Science Standards (NRC, 2012).

Argument as a Core Feature for Scientific Literacy

Science education research has recently focused on the use of inquiry approaches to improve students' scientific literacy (Fang, 2005; Prain, 2009). As reported above, "literacy" can refer to the ability to read and write and while this is certainly important to science, it is not inclusive of all that is meant by "scientific literacy". Scientific literacy also includes understanding how knowledge claims are made and supported in science. These two separate but connected senses of literacy are called the fundamental sense, the ability to read and write when the content is science, and the derived sense, being knowledgeable, learned, and educated in the ways of science (Norris & Phillips, 2003). The derived sense allows students to recognize science from non-science, understand science and its applications, knowledge of what counts as science, the ability to use scientific knowledge in problem solving, knowledge needed to participate in intelligent discussion in science-based social issues, understanding the nature of science, and the knowledge of the benefits and risks of science (Norris & Phillips, 2003).

Language is the vehicle by which science, and all other disciplines, is practiced, communicated, and understood. Therefore, language is a critical component of becoming literate in science (Jiménez-Aleixandre & Erduran, 2008). The use of evidence and theory to support or refute a claim, explanation, prediction, or model is a critically important epistemic practice and discourse process in science (Erduran, Osborne & Simon, 2005; Pinney, 2010). When used in classrooms, argumentation sets tasks for students that include explaining and justifying their understanding, arguing from data and defending their conclusions, and critically assessing and challenging the scientific explanations of one another (NRC, 1996). Being that science proceeds through argumentative discourse and a significant component of scientific literacy is understanding the discourse of science, "learning science means learning to talk science" (Lemke, 1990, p.1).

Argument-Based Inquiry

Argument-based inquiry approaches are based on science being an argument-based discipline (Erduran, Osborne & Simon, 2005). Science uses argumentation as a tool; using argument in the science classroom engages learners the opportunity to engage in the discourse of science (Kelly & Chen, 1999). By extension, instruction that is more aligned to authentic science should include some form of argument especially to help promote scientific literacy. Argument-based inquiry offers students the opportunity to engage in authentic science discourse where their own ideas can be challenged on the merits of argument addressed above (Newton, Driver, and Osborne, 1999). In this type of setting, students are to articulate their reasons for supporting their understanding as well as justification of their claims; their peers will challenge these claims and are expected to offer alternative claims which can be negotiated using evidence so that a more clear conceptual understanding results (Driver, Newton, & Osborne, 2000).

Many scholars strongly advocate students constructing arguments, explanations, models, and providing the environments that foster them so that students are engaged in authentic scientific practices (Albe, 2008; Bennett et al., 2010; Chin & Osborne, 2010; Hogan, Nastasi, & Pressley, 2000; Maloney & Simon, 2006; Martin & Hand, 2009; McNeill & Pimentel, 2010; Scott, Mortimer, & Aguiar, 2006; Sherrod & Wilhelm, 2009).

While this study focuses on the oral components of the science classroom, Yore and Treagust (2006) remind us that while talk is necessary for argumentation, it is "not sufficient to do and learn science" (p. 296).

The Science Writing Heuristic Approach

The Science Writing Heuristic (SWH) approach is a writing-to-learn approach (Keys, Hand, Prain & Collins, 1999) that consists of a framework designed to guide science inquiry activities, embed science argumentation as a core component of students' inquiry experiences, and provide metacognitive support to prompt student reasoning about data. Through using the SWH approach, students participate in "science disciplines in ways that resemble the thoughtful methods employed by 'real' scientists" (Hand, 2008, p. 2). The SWH approach has a framework designed to support opportunities for knowledge construction that immerse students in using language to express their ideas. In this way, the SWH approach works to develop a "grasp of practice" (Ford, 2008) which does not separate learning science from learning argumentation.

When using the SWH approach, students frame their own questions, propose methods to address those questions, and carry out appropriate investigations. The SWH approach is designed to promote classroom discussions during which students' personal explanations and observations are tested against the perceptions and contributions of other students in the class. Students are encouraged to make explicit and defensible connections between questions, observations, data, claims, and evidence. The teacher and student template are given in Table 2.1 below.

Table 2.1 Structure of the Science Writing Heuristic

SWH Template for Teacher and Student	
Teacher Template Activities to promote laboratory understanding.	*Student Template*
1. Exploration of pre-instruction understanding through individual or group concept mapping or working through a computer simulation.	1. Beginning ideas - What are my questions?
2. Pre-laboratory activities including informal writing, making observations, brainstorming, and posing questions.	2. Tests - What did I do?
3. Participation in laboratory activity.	3. Observations - What did I see?
4. Negotiation phase I - writing personal meanings for laboratory activity. (For example, writing journals).	4. Claims - What can I claim?
5. Negotiation phase II - sharing and comparing data interpretations in small groups. (For example, making a graph based on data contributed by all students in the class.)	5. Evidence - How do I know? Why am I making these claims?
6. Negotiation phase III - comparing science ideas to textbooks for other printed resources. (For example, writing group notes in response to focus questions.)	6. Reading - How do my ideas compare with other ideas?
7. Negotiation phase IV - individual reflection and writing. (For example, creating a presentation such as a poster or report for a larger audience.)	7. Reflection - How have my ideas changed?
8. Exploration of post-instruction understanding through concept mapping, group discussion, or writing a clear explanation.	8. Writing - What is the best explanation that explains what I have learned?

Source: Hand, B. (2008). Introducing the science writing heuristic approach. In B. Hand (Ed.), *Science inquiry, argument and language: A case for the science writing heuristic*. Rotterdam, The Netherlands: Sense Publishers.

The SWH approach embeds scientific argument as a feature of instruction in typical science inquiry lessons (NRC, 2012). Students are encouraged to make explicit connections between data, claims and evidence which are typically in the form of a defensible argument. This act encourages students to maintain the process of knowledge creation connected to the knowledge as a product of that process in a similar fashion to authentic science (Ford, 2008). This type of instruction stresses the epistemology of science as one that is more aligned to a nature of science view of scientific epistemology than traditional science instruction (NRC, 2012). This approach encourages student discussion as a primary feature of developing argument skills involving claims and evidence in students.

The SWH approach is also well aligned to national and state standards, which "center learning on the big ideas of the science discipline area" (Norton-Meier et al., 2008, P. 20). For teachers, determining the "big ideas" that are to be dealt with in the unit can be considered their "single most important task" (Norton-Meier et al., 2008, P. 20). Conceptualizing a big idea can be difficult, but it should at least contain the major concept(s) the students should leave the classroom with at the end of the unit; an organizing idea that frames the concepts present in the unit. Big ideas are well aligned to national and state standards because they are constructed from the core concepts in these standards (for examples see Norton-Meier et al. (2008) P. 160). This delineates big ideas from simple topics because big ideas have core concepts embedded into them. Ultimately, big ideas are the central organizing feature of a unit around which other activities are built. The disciplinary core ideas presented in the NGSS were designed to prepare students with sufficient core knowledge so they might later be able to acquire additional information on their own, empowering them to continue development after K-12 (NRC, 2012) The NGSS (NRC, 2012, p.xvi) states "a core idea for K-12 science instruction should:

1) Have broad importance across multiple science or engineering disciplines or be a key organizing principle of a single discipline.

2) Provide a key tool for understanding or investigating more complex ideas and solving problems.

3) Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technological knowledge.

4) Be teachable and learnable over multiple grades at increasing levels of depth and sophistication. That is, the idea can be made accessible to younger students but is broad enough to sustain continued investigation over years."

Dialogue

Dialogue is oriented around an exchange of ideas. Dialogue is a generative practice where people can think together about their own ideas in light of others' thinking (Benus, 2011; Schein, 1993). When people engage in dialogue, they speak in ways that seek to contribute to each other (Isaacs, 1999). Dialogue can be a powerful tool for clarifying one's ideas as it stimulates additional thinking (Fosnot, 1996) as participants' ideas and thinking interact with one another (Isaacs, 1993; Nystrand, et al, 1997). The ideas presented in dialogue "interpenetrate each other and thereby constitute and change one another" (Baxter, 2004, p.186). Dialogue is a "way of thinking and reflecting together. It is not something you do to another person. It is something you do with people" (Isaacs, 1999, p.9). Critically, dialogue is the expansion or clarification of taken-as-shared ideas (Scardamalia & Bereiter, 2006). However, feedback is only encouraged as it relates to individual behavior that might threaten the natural flow of conversation, not as a goal of the dialogic process (Schein, 1993).

Dialogue can help individuals see ideas differently through shared experiences, as Schein (1993) suggests "As we listen to ourselves and others… we begin to see the bias and subtleties of how each member thinks and expresses meanings. In this process, we do not convince each other but build a common experience base that allows us to learn collectively" (Schein, 1993, p. 34). In this way, dialogue in a general sense is not concerned with persuasion in the same manner as argument is, but rather the exchange of what one knows and how they know it.

Whole-Class Dialogue in the Classroom

Dialogue is a critical component of any classroom using argument-based inquiry because to reach meaningful consensus, one must engage in the exchange and understanding of the ideas of others. Nystrand et al. (1997) found the quality of student learning was closely linked to the quality of the classroom talk when examining the dynamics of language and learning. In his current study the researcher examines whole-class dialogue as a vehicle to look at how the teacher's practice is changing as a result of implantation of an argument-based inquiry approach. In a dialogue-based class discussion, the students spend time probing the thinking of their peers as the class works toward constructing a common understanding (Varelas & Pineda, 1999). A critical component of the ideas present during a dialogue is that the ideas of others are not only included but also acknowledge during this process (Scott, Mortimer, & Aguiar, 2006). This means that all ideas are given time in the classroom discourse.

As reported by Benus (2011), "(p)roponents of dialogic instruction (e.g. Alexander, 2005; Boyd & Rubin, 2006; Christoph & Nystrand, 2001; Gambrell & Almasi, 1996; Wells, 1996; Wells & Chang Wells; 1992) suggest that eight keys factors are needed in order to set up dialogic instruction". These eight factors are presented in Table 2.2 below:

Table 2.2 Eight Key Factors Needed to Establish Dialogic Instruction

1. Classroom environment promotes collectively engaging and learning tasks together.	Alexander, 2005; Boyd & Rubin, 2006
2. Classroom environment is reciprocal with all listening to each other and considering alternative viewpoints.	Alexander, 2005; Osborne 2007
3. As ideas are articulated there is ample support for helping each other to reach common understandings.	Alexander, 2005; Osborne 2007
4. Dialogic instruction is cumulative and collective as all build on their own and each other's ideas.	Alexander, 2005; Mercer, 2000; Osborne 2007
5. Classroom environment is relatively unpredictable because it is negotiated as teachers and students pick up on, elaborate, and question what students say.	Boyd & Rubin, 2006; Harris, Phillips, Penuel 2011; Nystrand et al., 1997, p. 7
6. Dialogical interactions involve fewer teacher questions and more conversational turns.	Boyd & Rubin, 2006
7. The teacher's voice is one of many voices, though likely a "critically important one"	Nystrand et al., 2003, p.187
8. Decisions are purposeful in that teachers plan well-defined educational goals in support of dialogue	Alexander, 2005; Osborne 2007

Source: Benus (2011) p. 20

As can be seen from Table 2.2, dialogue goes much further than the common stereotype of "two people talking" (Burbles & Bruce, 2001). A classroom engaging in dialogue cannot be a classroom of "passive recipients of knowledge and instruction" (Benus, 2011, p. 21). In dialogue, no one person has ownership; it is a collective experience where people construct understanding after a having a shared experience (Klein, 2006). All members of this experience participate and collectively work to build understanding with others.

Dialogue Verse Monologue

Unfortunately, the dialogue as described above does not often happen in science classrooms (Macbeth, 2003). Normal classroom discourse is predominantly monologic (Duschl & Osborne, 2002). A part of this is due to traditional science classroom discourse being dominated by teacher talk (Crawford, 2005). Additionally, of the discussion that does occur, it usually follows an Initiate, Response, Evaluate (IRE) or Initiate, Response, Feedback (IRF) pattern (Macbeth, 2003; Mehan, 1979). In these situations, the teacher takes a leader role by asking the question (Initiate), the student responds to the question (Response), and the teacher evaluates or provides feedback to the response (Evaluate/Feedback). Benus and colleges report (2013) in classrooms that tended toward being monologue-based they "… saw many textbook descriptions of IRE or IRF cycles (Mehan, 1979) or what Isaacs (1999) calls a 'back-and-forth volley' (p. 365)…" (p. 238). The issue is actually further compounded by most of the questions in these classrooms being knowledge level questions that did not sustain further turns of talk beyond these simple cycles unlike the classrooms that had more dialogue-based discussions (Benus et al., 2013). In their work with implementation of an SWH approach, Benus et al. (2013) noted that Medium implementation classrooms tended to not be monologic in nature. The Low implementation still retained notions of monologic speech. Trying to extract something from someone (such as seeking an explicit answer instead of an explanation) moves away from dialogue (Isaacs, 1993).

Teacher's Role in the Classroom

Traditional Verse Argument-Based Inquiry

As a result of this, traditional science instruction and perhaps other inquiry settings that do not stress dialogue or argument likely fail to offer students the opportunity to critically evaluate ideas or engage in authentic discourse. Additionally, these settings largely prevent students from engaging in student-student discussions (Kuhn, Kenyon & Reiser, 2006). Traditional science instruction usually represents science as a set of knowledge that has been separated from the processes used to create that knowledge (Osborne, 2005). When this occurs, students are left with the impression of science as a collection of unquestionable facts (Driver, Newton & Osborne, 2000). However, current philosophy of science views emphasize that science is not merely a collection of facts of nature; science offers evidentiary explanations that attempt to explain the way the world may be as a result of the construction of claims that are advanced through dispute, conflict with competing ideas, and argumentation built around evidence rather than general agreement (Erduran & Dagher, 2007). Critically, the knowledge produced from this process can be viewed as trustworthy and tentative, but stable.

Tasks that merely require following the teacher instructions to completion do not offer a real scientific nature to the task or significant student understanding of the concepts behind the activity; encouraging students to learn from what is already known instead of having students construct this knowledge for themselves (Jiménez-Aleixandre et al., 2000). Teaching science as inquiry must focus on how science knowledge is generated, how science knowledge is supported, what evidence may be anomalous to that knowledge, why science knowledge has applicable ranges (Newtonian physics vs. Quantum Mechanics for instance), and how that science knowledge fits with other knowledge (Duschl & Osborne, 2002).

The ability to generate persuasive evidence-based arguments and explanations to support or refute a claim is a critical feature of inquiry classrooms (Sampson & Clark, 2008). Students must be given ample opportunities to formulate their own ideas about science concepts, to infer relationships between these concepts, and to combine them into increasingly more complex networks of conceptual understanding (Chin and Osborne, 2008).

A critical feature of science is the use of data in constructing evidence to support a claim. This practice must also be supported and encouraged by teachers. The evidence is then used to help support or challenge student claims. These explanations, while frequently left out of classroom practice, can change a student's view of science and enhance their learning of content (Lizotte, McNeill, & Krajcik, 2004; Pinney, 2010). This stresses the importance of evidence-based argument in science and is central to those that utilize this approach. Science literacy requires that teachers make available to their students the opportunity to engage in scientific argument (Osborne, 2005).

In a study by Benus and colleagues (2013), they found that for classrooms where high levels of dialogue were found that the teacher acted as both the navigator for discussion as well as the lynchpin that held together the overall classroom discourse. A critical component of the navigator role was to insure that the conversation was developed and maintained around a "big idea" of science. These "big ideas" are core conceptual points that are broad enough to allow the classroom to negotiate a unit (NRC, 2012). This keeps the discourse focused on the important concepts to the unit. They also found that in high level implementing classrooms that a major difference as compared to lower level implementing classrooms was seen in the persistent evidence-based whole-class dialogue present as compared to dialogue that emerged and faded. The teacher in this setting also acted as a lynchpin by assuring that the five factors of whole-class dialogue they analyzed were ground in the conversation (Benus et al., 2013). These factors included complexity of question, depth of idea exchange, classroom interactions, evidence-based ideas, and conversational patterns.

Teacher Questioning as a Core Feature of Classroom Discourse

Questioning is an essential practice to scientific argumentation. Teacher questions are a frequent component of a classroom and therefore play a critical role in the classroom discourse (Chin, 2007; van Zee et al., 2001). Questions can take students from where they are and launch them further (Boyd & Rubin, 2006). Teachers can guide discussion through their questioning and their questions may give insight into the classroom environment. These types of questions are generally authentic (Nystrand, Gamoran, Kachur, & Prendergast, 1997) and stay within the student's zone of proximal development (Vygotsky, 1986). These questions may be voiced by all participants in the classroom to further clarify, elaborate, and/or extend ideas (Boyd & Rubin, 2006). It is thought that the teacher in classrooms with dialogical instruction asks fewer questions and encourages more talk among the class (Boyd & Rubin, 2006). This does not remove questions from the classroom but rather places some of the expectation for posing questions to the students instead of on the teacher.

Unfortunately, teacher questions are also typically associated with evaluating what students know; not what students think (van Zee et al., 1997). Eliciting what students think provides opportunities for negotiation of student ideas. Through making student ideas explicit in the classroom discourse, alternative conceptions are made known and meaningful discourse can be used in resolution of these conceptions. This also allows students to see how alternative conceptions may arise from similar data and to develop argument skills while reaching consensus. Benus et al. (2013) reported the largest change between Low-implementation and Medium-implementation of argument occurred in teacher questioning, frequently replacing knowledge recall questions with more complex questions that cannot be responded to with one turn of talk.

Pedagogical Work Needed for Argument-Based Inquiry

An argument-based inquiry approach does require some special attention. Teachers that do not have a mastery of dialogue and negotiation in their classes must develop this skill (Hand, 2008). An area that is especially challenging comes in helping students understand how to construct and support claims. Many students are frequently unaware of what counts as evidence; often they cite their data as evidence and have difficulty differentiating their claims from their supporting evidence (Kuhn et al., 2006). Developing the ability to differentiate claims and evidence and better understanding the constituents of evidence can only occur in a context where there is evidence to evaluate and that this evidence forms the basis of scientific argument (Kuhn et al., 2006; Osborne, 2005). Fortunately for teachers, even young children can engage in this specialized discourse. They can learn to explain natural phenomena, design and conduct empirical investigations, and engage in meaningful evidence-based argumentation (Duschl, 2008; Pinney, 2010).

The primary difference between argument-based inquiry and the other forms of inquiry is the degree of stress placed on students evaluating not only their own explanations but others' explanations as well. This is a critical feature that establishes the "argument" part of the inquiry experience. It also adds an additional complexity to the classroom as a result of fostering the development of additional forms of specialized discourse.

While this study is primarily interested in the oral components of argumentation in the classroom, several researchers have reported the students that use only talk as a learning tool in the science classroom tend to process information on a surface level (Hogan, 1999; Kelly, Druker, & Chen, 1998; McNeill & Pimentel, 2010). Additionally, even though young students are capable of these activities it does not come without work by the teacher. Kelly et al. (1998) found that even though students usually challenged each other during discussions, the students usually did not provide sound evidence for claims they made. On a less positive note, McNeill & Pimentel (2010) found that most of the time, students simply sought the correct answers to respond to teachers' or peers' questions instead of using claims, evidence, and reasoning. This reduces the effectiveness of the activity in terms of being a knowledge generating practice. Benus and colleagues (2013) also found even students in classrooms that experience dialogue that students struggle to reason through how to use evidence or even what counts as evidence, consistent with Kelly et al. (1998) and Kuhn et al. (2006).

A number of researchers have also proposed that students may not fully understand the intent of using argumentation in the classroom, noting that students have great difficulty revising ideas through argumentative discourse. They suggest that the students may have been too focused on the persuasion component of argument (the inherent nature of argument addressed earlier) rather than the knowledge generating activities including reflecting and revising their own ideas (Berland & Reiser, 2011; D. Kuhn, Black, Keselman, & Kaplan, 2000).

Students also have difficulty differentiating and connecting everyday language and scientific language (Yore & Treagust, 2006). While this does highlight some potential challenges, Prain (2009) also states that student talk is an important resource for learning new science concepts and practices and is valuable for engaging in argumentative practices. Additionally, Prain (2009) points out that the meanings of some words differ between scientific and everyday language (e.g. weight, matter, mass, force, energy, etc) and that these differences can cause difficulties when talking about and learning about science concepts.

If we expect the classroom community to be aligned to the social practices of scientists, justification of a claim requires evidence (Kuhn & Reiser, 2006). However, Kuhn (1991) suggests that some do not feel that claims need to be justified with evidence and Sadler (2004) tells us that some do not understand what counts as evidence, consistent with the student notions from above. However, scientific argumentation requires that claims and evidence not only be presented, but subjected to ongoing discussion and critique (Kuhn & Reiser, 2006).

Factors that Prevent Implementation

Several researchers have noted that teachers rarely link both oral and written argument components to their instruction (Nystrand, Gamoran, & Carbonaro, 2001; Rivard, 2004), though few studies explore this interaction in the classroom (Chen, 2011). Kuhn (1991) tells us sustaining argument in classrooms requires practice; most certainly developing one's abilities to use argument as a pedagogical tool must also require practice. Transformation of schools and classrooms toward implementation of scientific argumentation occurs slowly because the science curriculum is frequently built around predetermined investigations that serve to verify knowledge that is already known (Duschl, 1990; Lemke, 1990).

In order for successful implementation of argument in the science classroom, teachers need to understand the nature of argumentation in a science context as well as the role it serves in knowledge production (Driver et al., 1994; Osborne et al., 2004). Argument-based inquiry, as a process of negotiation and argumentation, students are immersed in the process of claim generation, deriving evidence from data, and negotiating their ideas with peers during the learning process (Milar & Osborne, 1998; Siegel, 1995). When the proper context is provided, students have shown a natural tendency to engage in forms of argument (Duschl, Ellengoben, & Erduran, 1999).

Teacher Change Takes Time and Occurs Incrementally

Sustained professional development can help teachers better use ways to approach and practice scientific argumentation. Teachers also need reassurance that the strength of what one knows comes not from the ability to answer rote memory questions but rather in the ability to coherently construct and critique one's understanding with others and self

(Benus et al., 2013). Unfortunately, this sustained professional development promoting scientific argumentation is infrequently noted in the literature and is likely uncommon in practice (Benus et al., 2013). According to Newton et al. (1999), the 14 experienced science teachers they surveyed indicated that they needed more professional development time to manage and facilitate elements of argumentation. This goes beyond the teacher merely trying to implement argumentation in their classroom.

Professional development work in Iowa (e.g. Martin & Hand, 2009) has shown that shifting teaching practice to include scientific argumentation takes time (at least 18 months) as well as practice and that teachers need to understand that student learning occurs through engagement in scientific argumentation (Chen, 2011). Professional development work in London (Osborne, Erduran, & Simon, 2004) tell us the strength of the teacher's initial understanding of argumentation determined their short term development. Additionally, they found that an extended period of professional development helped adapt classroom practice toward the use of argument (Simon, Erduran, & Osborne, 2006).

Further work by Benus et al. (2013) looked at the implementation level of argument in classes ranked by their modified RTOP (Martin & Hand, 2009) score. They found teachers at all three levels (Low, Medium, High) indicating a gradient of implementation. They claim that the existence of a Medium implementation provides "recognition that inquiry-based approaches are part of a dynamic process for the teacher and student…" (Benus et al., 2013, p.239). They continue that these Medium implementation classrooms could indicate practices in transition or classrooms that have settled into a stable form of practice (Benus et al., 2013). These types of classrooms saw change in both the structure of the activities of the classroom and the goals that underlain them (Duschl & Osborne, 2002). These types of classrooms saw an increasing likelihood of student-student dialogue and more complex questioning with less teacher feedback, evaluation, or forced directions (Benus et al., 2013).

Theoretical Framework of the Study

People interact and learn through their use of language (Vygotski, 1986). Ultimately then, the learning opportunities are shaped by the patterns of talk produced through social interaction, with learning happening through interactions among individuals. This interaction between peers is one of the ways students learn to make sense of their world (Wells, 1999). Like participating in authentic scientific discourse, students participating in whole-class dialogue means assuming a role within a community of practice (Wenger, 1993). This highlights an important role for the teacher; enculturation of students into this practice through social interaction. For teachers new to argument-based inquiry, this role adds another layer of complexity to their implementation.

Interactive-Constructivist Approach

The interactive-constructivist approach is situated between social and radical constructivism (Henriques, 1997). This view stresses both an individual's interpretation of the world around them and the sociocultural context underlying how these experiences reflect the lived experiences and cultural beliefs of the knowers (Yore, 2001). Important to this view are the limitations that learners have in the ways that they are able to interpret the world around them. In this perspective, as with argument, all knowledge claims should be valued and evaluated on the basis of the evidence that supports or refutes those claims especially as it relates to nature. Knowledge in these settings moves between public, socially shared and understood knowledge (social constructivism), and private, unique and personal knowledge only held by the individual (radical constructivism). Consensus making, then, occurs when individuals work together to come to a common shared understanding, though each individual brings their own unique understanding to the discussion.

The goals of this paradigm include describing meaning and examining how "objective" realities are produced. The epistemological assumptions of this approach embrace abstract definitions of meaning and definitions of settings produced in a natural context and are constructed by individuals through social interaction (Hatch, 2002; Creswell, 2007). Put another way, students construct meaning about the reality around them which ultimately refines their vision of their reality.

The ontological assumptions of this approach are based out of a social, yet personal, construction of reality; where regardless of an objective reality existing, students have only a subjective means of knowing it. This means that multiple realities exist and even though an objective reality may exist, it is inaccessible to individuals except by interpretation of perceptions via construction of paradigms to create meaning (Hatch, 2002). Individual understanding is crafted out of social interaction especially as it relates to negotiation of ideas, as negotiation is an interactive social process.

Summary

In this chapter, the researcher has presented existing literature that explains and supports the use of whole-class dialogue, science argumentation, and scientific literacy that grounds this study. It is well noted in the literature that a teacher's ability to engage his or her science classroom in productive dialogues is a skill that takes time to develop for all members of the classroom. The Next Generation Science Standards (NRC, 2012) explicitly call for argumentation in the science classroom, a practice rarely seen in current science classrooms. Therefore, this is a pedagogical practice that current teachers will have to develop in order to have inclusion of argumentation in their classrooms. The present literature base for science argumentation offers little insight into how teacher practice relating to inclusion of argument is changed as a result of implementing an argument-based inquiry approach. The current research that does exist for whole-class dialogue in science classrooms using argument-based inquiry approaches is limited and fragmented, existing within studies with other loci than development of whole-class dialogue. Finally, data collection and analysis used interactive constructivism as a framework, because in science argumentation, dialogue, and the derived sense of scientific literacy, meaning is negotiated through shared interactions that highlight how individual understanding can be collectively critiqued, developed, and/or agreed/disagreed within a community of peers.

CHAPTER THREE

METHODOLOGY

Introduction

The purpose of this chapter is to establish the methodological framework for the study as well as to identify data collection, data analysis procedures, and trustworthiness. This chapter first discusses the rationale behind using a qualitative approach to examine the potential changes in this classroom during the first semester of argument-based inquiry professional development. The context under which the study was conducted will be described. Lastly, four criteria for establishing the trustworthiness of the findings are reviewed: credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985).

Research Design

There are three primary questions that guide this study. These questions are designed to explore three areas including: the big idea, whole-class dialogue changes, and argument changes. The overarching purpose of these questions is to explore how pedagogy in whole-class discussion changes while a middle school classroom undergoes first semester implementation of an argument-based inquiry approach.

1. How does a teacher in his first semester of Science Writing Heuristic professional development make use of the "big idea"?
    a. Is the indicated big idea consistent with NGSS core concepts?
2. How did the dialogue in whole-class discussion change during the first semester of argument-based inquiry professional development?

3. How did the argument in whole-class discussion change during the first semester of argument-based inquiry professional development?

A basic qualitative approach was used to answer each research question (Merriam, 1998). This approach is used to identify recurrent patterns of themes or categories which seek "to discover and understand a phenomena or process" and not to focus on culture or build substantive theory as in grounded theory studies (Merriam, 1998, p. 11). The basic qualitative approach is appropriate for identifying common patterns of developing discourse over the course of the first semester of argument-based inquiry professional development. This study sought to characterize and better understand the changes that occurred in teaching practice in a classroom with a teacher that underwent his first semester of argument-based inquiry professional development and did not seek to establish a causal explanation as to how an argument-based inquiry approach (SWH) impacted the classroom.

The basic qualitative approach provided several advantages given the research questions. First, it allowed for the extraction of patterns of discourse in the whole-class discussion rather than focusing on a specific case. Secondly, it allowed for examination of potentially subtle changes in the classroom across varied data sources and in greater detail than is typically feasible in quantitative studies with larger sample sizes. Lastly, it aided in an examination of the changes to classroom practice across a semester.

Research Tradition

Qualitative studies require that the researcher become intimately familiar with the subjects of their study (Creswell, 2007). To perform good qualitative research, Creswell (2007) suggested that it is necessary to explicitly define the assumptions, paradigm, and framework that are used in the study. Several epistemological, ontological, and methodological assumptions form the basis of this research study. The goals and subject matter of this study put limits on the appropriate methods available for use. The constructivist-interpretative approach is the research paradigm used in this study (Hatch, 2002). Goals of this paradigm include describing meaning and examining how "objective" realities are produced. The epistemological assumptions of this approach embrace abstract definitions of meaning and definitions of settings produced in a natural context and are constructed by individuals through social interaction (Hatch, 2002; Creswell, 2007). Put another way, students construct meaning about the reality around them which ultimately refines their vision of their reality. In this way, each individual has his or her own "reality". This study is primarily concerned with the teacher though these multiple realities highlight the importance toward negotiation toward a common understanding in the classroom.

The ontological assumptions of this approach are based out of a social, yet personal construction of reality; where regardless of an objective reality existing, students have only a subjective means of knowing it. This means that multiple realities exist and even though an objective reality may exist, it is inaccessible to individuals except by interpretation of perceptions via construction of paradigms to create meaning (Hatch, 2002). Individual understanding, then, is crafted out of social interaction especially as it relates to negotiation of ideas, as negotiation is an interactive social process.

Research Context

School

This study was set in a public school district with a population of approximately 2,500 located in a rural city of less than 1,500 in the Midwestern United States. The district population is approximately 91% white and 9% Hispanic (Information obtained from city website). Around 17% of students are eligible for free or reduced price lunch. This school has less than 500 K-12 students with 19 students in the sixth grade class section under study. This site was selected based on proximity to researcher, willingness of teacher to participate, and the unique set of circumstances present in the grade under study. This school was also recently identified as a school in need of assistance for reading and writing. The teacher under study was selected as a purposeful sample due to his first year of argument-based inquiry while his students had undergone two previous years of argument-based inquiry. This represented a unique situation for study.

Classroom and Students

The sixth grade classroom under study was located on the second floor on the corner of two converging hallways. The square-shaped room had one exit along the right side wall and a window on the left side wall on opposite corners. A large chalk board spanning most of the wall was present at the front of the room with a SmartBoard on the left side of the wall connected to the teacher’s desktop. The teacher’s desk was situated at the front left of the room with a lab table positioned in the center of the front of the room. At the back of the classroom were five computers, though a cart full of laptops was available for use throughout the semester. The students sat around five rectangular tables typically in groups of four. The room was usually lit with fluorescent lighting and heated by a radiator under the window on the left wall. Laboratory work supplies were along the right side wall behind a curtain with a thigh-high bookshelf along the left side.

Nineteen students comprise the class under study, 10 girls and 9 boys of those students 18 were white and 1 was Hispanic. Science instruction took place every day for 45 minutes in a single time block and met immediately following Physical Education, their first class of the day. The class period was reduced to less than 25 minutes in the case of a scheduled early out.

Also important to this study as mentioned earlier, this sixth grade class had two previous years of experience with SWH instruction with different teachers, their fourth and fifth grade teacher who started the SWH implementation two years earlier than the teacher in this study. This class is under the instruction of a teacher that is undergoing professional development for implementing the SWH approach and is in his first year of the approach. The researcher is working with this instructor to help him develop as an inquiry-based teacher as addressed below. This is an important consideration because these students have significant prior history with this approach. This means that many of the changes seen are more likely to be the result of the teacher developing with the approach rather than the students. That is not to suggest that the students do not change as a result of teacher implementation under any approach.

Professional Development Role Verse Researcher Role

The researcher served a dual role throughout the semester under study: both researcher and professional developer. This dual role complicates the study due to potential biases and the professional development offered by the researcher. Several steps were taken to minimize the impact of this. First, the initial “cycle” of SWH for each unit had no professional development. This first cycle included the start of the unit through the student presentation of their claims and evidence for their first round of experimentation when possible. In this way, the research data collected during each initial cycle for each unit was not directly influenced by professional development. However, it is hoped that the professional development after the initial cycle and beyond influenced the classroom's development of science argumentation. It is undeniable that elements of professional development likely did impact the classroom dynamics. However, by isolating the professional development to outside of data collection and removing fore-planning as discussed below, any collected elements impacted by professional development occurred not as a result of the professional development directly but rather as a decision by the teacher.

Secondly, at no point during the semester did the researcher help the teacher plan or prepare for any class period that was part of the study data. This means any carry over from professional development occurred as the result of decision-making and planning for inclusion that the teacher made himself. The researcher did not work with the teacher during the four-day workshop prior to the study nor did he work with the teacher during lesson plan development, both of which are components of the SWH workshop. The summer professional development workshop was conducted by professional developers not connected to this study. Elements from this workshop are expected to carry over into at least first unit implementation as an activity at the end of the workshop includes planning unit "big ideas".

Though many class periods were not part of the study, the vast majority of class periods (81) over the semester were recorded. These class periods include conversations between the teacher and researcher during the professional development and were examined prior to selection of the emergent themes. It is critical to note here that themes that demonstrate change may be areas that were discussed with the teacher as part of the professional development, but at no point were these stressed over any other professional development area. Finally, the first research question focused on the teacher's orientation to the unit which was not addressed by the researcher in professional development as it entailed future planning. The second and third research questions focused on complex classroom dynamics including the development of dialogue and features of argument across the time periods of the semester. As a final note, the professional development was not tailored to impact instruction right before or after that instruction occurred. The professional development focused on the approach of using SWH in the classroom rather than *how* to teach or prepare the lesson.

The Teacher

The teacher in this study was 35 years of age, held a Bachelor's of Arts Degree in elementary education (2006), a Master's in Athletic Administration (2012), and a 5-12 teaching license in science with an addition of reading (2006) and middle school (2008) endorsements. He has taught five years of middle school science and one year of seventh grade geography within the same school district. During the academic year of this study he was the only middle school science teacher. He taught science for a total of two sections of sixth graders, two sections of seventh graders, and two sections of eighth graders. This study examined only one section of sixth grade students. This teacher was selected for this study because he had just started implementing the Science Writing Heuristic approach (Hand, 2008; Keys et al., 1999) to promote student-centered approaches to learning at the onset of this study, undergoing training just prior to the semester starting. Additionally, he was willing to participate in the study and the school was located such that the researcher could have substantial in-class time. Prior to the SWH professional development, this teacher had not participated in any argument-based inquiry professional development.

The Summer workshop he attended consisted of five key features; discussing alignment of one's teaching practice with learning theory, participating in a SWH lesson allowing the participants to experience the lesson as students would, examining the role of language in learning science, practical and pedagogical issues relating to implementation, and assisting teachers to design instructional units built around a "big idea" in science that are consistent with the SWH approach and NGSS standards. Through this workshop, teachers go through the argument-based inquiry process as students. His workshop had several sessions where strategies for forming questions, the difference between data and evidence, and the relationship between questions, claims, and evidence were discussed. Each day, teachers were encourages to share their feelings and questions relating to the SWH process. A session was specifically tailored to adapting the SWH approach for students with special needs and participants engaged in a discussion of language use in a dialogic environment. The Summer workshop entailed approximately 24 hours of intensive professional development.

Typically, a teacher in the professional development would receive offsite and onsite professional development where elements emphasized in the workshop could be discussed in the context of actual classroom experiences though onsite visits are typically isolated to one or two visits per week. Teachers are required to submit one classroom video per year to researchers involved with the professional development project, typically of "claims and evidence" presentation by students. A teacher in the typical professional development would receive offsite and onsite professional development. This was done by the researcher during non-data collection times. The vast majority of class periods were recorded during the first semester instead of the one video per year requirement of the traditional professional development as a result of participation in this study.

Three Instructional Units

Prior to the instructional units beginning, the teacher had the students do a pre-instructional activity called "mystery tubes" which is an activity that is frequently done in the professional development workshop. These tubes are PVC tubes with secured end caps and ropes that interact with each other. Students work in groups to model the way they think the tubes work, supporting their claims with evidence. These students reported their findings in an electronic format on Edmodo and then engaged each other with critiques of their models and presentation of models. This introductory set of lessons to argument-based inquiry took one week (five days). The researcher would like to restate at this point that these students had two previous years of SWH instruction so it is not expected that they were unfamiliar with argument-based inquiry and perhaps this activity due to their previous teachers undergoing the same workshop.

Table 3.1 Unit Dates and Big Idea

Time Period	Given Big Idea	Dates Spanned	Time Spanned
1	Force Affects Motion	September 4 – October 16	7 weeks
2	Electricity	October 17 – December 6	6 weeks
3	Light	December 7 – January 15	4 weeks

The data set was constrained by the dual role of the researcher from the unit dates given in Table 3.1 above as a result of him being both researcher and professional developer. The teacher was free to plan and implement the first portion of the units without explicit researcher guidance, though the researcher was available if questions arose. These portions were defined by the onset of the unit through the presentation of the first round of experimentation. This typically limited the available data for those units to around ten instructional days depending on the unit. After the students had concluded the first portion of the unit, there was increased researcher involvement in terms of professional development.

A typical class period consisted of 45 minutes, and was equally represented each week day. In each of the units there were typical breaks in instruction due to holidays or scheduled field trips that interfered with class time. The class would have reduced hours on early out, only meeting for around 25 minutes on these days.

The instructional unit big ideas given by the teacher were aligned to the Next Generation Science Standards, presented in Table 3.2 below. Though this alignment varied in strength, each unit has explicit connections to the Standards. Where appropriate, connections to other units in the relevant standard are included in the table. For example, the motion of an object being related to the amount of energy it possesses can be related to electricity (all part of PS3.A).

Table 3.2 Big Ideas Aligned With NGSS Standards

Unit Big Idea	Disciplinary Core Idea
Force affects motion.	**PS2.A Forces and Motion (P. 215)** For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's Third Law). The motion of an object is determined by the sum of forces acting on it; if the total force on the object is not zero, its motion will change… For any given object, a larger force causes a larger change in motion. All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared. (Later in unit.) **PS2.B Types of Interactions (2) (P. 216)** Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass (e.g., Earth and the sun).
Electricity	**PS3.A Definitions of Energy (P. 193)** The faster an object is moving, the more energy it possesses. Energy can be moved from place to place by moving objects or through sound, light, or electrical currents. **PS3.B Conservation of Energy and Energy Transfer (P. 193)** Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion… Light also transfers energy from place to place.
Light	**PS4.B Electromagnetic Radiation (P. 219)** When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

The units began with some activity that helped show the students' pre-existing knowledge: sematic webs for the first two units; compare and contrast t-charts for the third unit. Students then wrote questions they wanted to explore in their student journals. Frequently, a classroom discussion would follow about whether these questions were testable or researchable. Students would be assigned to start designing experiments that allowed them to answer their research questions. After experimenting, students usually reported their findings in some manner, though during the available data set no oral presentation of claims and evidence was seen. Throughout these activities, whole-class discussion, group discussion, individual and group writing, note-taking, and student journaling was done to reinforce learning goals and skills.

Data Collection

Data were collected from several sources during the three instructional units of this study, including classroom videos, non-participant observations, student journals, student classroom work, teacher interview, informal conversations audio recorded with teacher and students, teacher planning notes from previous years, researcher reflective notes, and a written questionnaire given to the students all isolated to the first portion of each unit. Planning notes and teacher written reflections from the current year were requested, but were not made available to the researcher. The coding scheme for these data sources is given in Appendix A. These data sources helped to provide a more comprehensive perspective (Patton, 2001) regarding the classroom dialogue. While these data sources share similarities, they are all distinct in their own way and helped with the triangulation of data (Stake, 1995). Table 3.3 below provides a summary of the type of data, data source, and purpose of the data collection.

Table 3.3 Data Type, Data Source, and Purpose for this Study

Data Type	Data Source	Purpose	Items Collected
Classroom video	Whole-class video of lessons	To assess for further analysis the ways in which classroom dialogue changed over time and overall classroom interaction, transcribed.	30 videos, 11 transcripts
Non-Participant observation	Whole-class	To assess, on-site, the ways in which the teacher worked to establish dialogue in whole-class discussions and overall classroom interactions.	22 entries over the three units
Student journals, assignments	Individual, Group	To assess the student way students understood and executed assigned tasks	19 student journals, roughly 25 pages each
Student questionnaire	Individual	To assess how the students interpreted the big ideas of the units and the experiments of the unit	18 student replies
Teacher interview	After the end of the school year	To understand the teacher's approach to the units, to assess changes in teaching practice with teacher, to member check with teacher	One 2 hour interview
Informal conversation	Before/After lessons	To understand why elements of the SWH approach were used the way they were	15 instances lasting 2-7 minutes
Field notes, reflective field notes	Journal from classroom observations	To capture researcher thoughts from being in-person in the classroom and help illustrate what may not be well captured by video	22 entries from observation and reflection after visits
Teacher lesson plans (previous years')	Lesson plans e-mailed to the researcher from before SWH implementation	To understand teaching approaches prior to SWH implementation	2 PowerPoint files (Electricity and Light)

Video

The three units were observed over the first semester through non-participant observations. This method allowed the researcher to see and hear the majority of the aspects of the classroom. This included student-student interactions as well was teacher-student interactions during all classroom activities including, but not limited to, the eight aspects of the SWH approach (Hand, 2008, p. 6): beginning ideas, tests, observations, claims, evidence, reading, reflection, and writing. All class periods attended by the researcher were video recorded. It was not possible for the researcher to be present at each lesson, though the teacher recorded most of these class periods. The digital camera was placed in the back of the classroom near the window to capture most of the classroom activity. All of the teacher talk was captured in the video recording without difficulty. The student audio in the video was dependent upon where the students were sitting, how loudly and clearly they spoke, and if someone was talking at the same time largely determined the quality of the recorded student talk.

Semi-Structured Interview and Informal Conversations

Interviewing is an important research tool to help researchers understand the research participant's point of view. Interviewing can be considered having a purposeful conversation (Kahn & Cannell, 1957). A 2-hour interview was conducted at the conclusion of the study to member check preliminary findings, to elicit teacher input and reflection on selected lessons across the units, to ascertain the ways in which he would change his approach now after his first year of implementation. Informal conversations took place before and after lessons distributed across the semester lasting between 2 and 7 minutes and often took place at the back of the classroom. If conversations occurred during the lesson, they took place while students were working individually or in groups.

These conversations focused on elements of his classroom practice as they relate to the elements of SWH implementation. Notes were taken after these conversations and some were captured by audio or video recording.

Researcher's Field Notes and Reflective Notes

Field notes are used to record the reactions to research settings by the researcher, and to record quotes and actions from participants (Patton, 2001). For this study, a non-participant observer role (Bogdan & Biklen, 2007; Marshall & Rossman, 2011) was not possible throughout the semester due to the dual nature of the researcher but was maintained throughout the study time periods. Field notes were recorded for each observation and generally included noteworthy student-teacher interactions, missed teacher opportunities, strengths and weakness of implementation, and how students and teacher responded during whole-class discussion. The field notes were hand written in a field journal and dated. The researcher also audio recorded reflections on the class period and the teacher implementation of the SWH approach within the hour after the class period ended.

Student Journals and Student Questionnaire

The student journals were used to capture individual and group work that resulted from the interactions of students within the class. This type of data provided insight into how students conceptualized assignments they were given as well as their understanding of content. In addition to student journals, the students were given a questionnaire (Appendix B) on March 7, 2012 that explicitly asked them to answer questions relevant for this study. This element was important as students are critical players in the classroom. This questionnaire was given well after the conclusion of the third time period as it was given outside of the science class period in the students' writing class. The questionnaire date was selected to help limit bias toward the last unit due to it being more recent. These data provide insight into how the students viewed their classroom experiences.

Previous Years' Teacher Lesson Plans

Both current and prior lesson plans were requested from the teacher in this study. Only two past unit lesson plans, including the electricity and light units, were made available to the researcher. These lesson plans were compared to elements of the current classrooms he taught and provided insight into potential changes or lack thereof that were made to be more in line with SWH implementation. This was especially important as a result of the teacher stating he had some reversion to prior teaching approaches within the study.

Data Analysis

In order to answer each research question a "basic qualitative approach" was used (Merriam, 1998, p.11). This approach to analysis was used to define and identify "recurrent patterns in the form of themes or categories" (Merriam, 1998, p. 12). The research questions are best answered by looking at how the classroom discourse changes over time. For the first research question, the researcher looked for ways in which the big idea served a role in the units across the first semester of implementation and clarified this question by comparing the given big idea to national standard core concepts to determine if the two were in alignment. The second and third research questions examined over these same time periods looked at the process and pattern in the ways in which the dialogue and features of argument in the classroom changed over the course of the first semester of implementation of an argument-based inquiry approach to science education.

Table 3.4 Example of Level One Coding

Date and Time Stamp	Classroom Activity
09-04-2012	
00:00 – 05:13	Assigning [Assigning students to concept map] [NOT TRANSCRIBED]
05:13 – 11:26	Small group work [Students working on concept maps together] [NOT TRANSCRIBED]
11:26 – 12:20	Assigning [Giving students demonstration – spinning globe] [NOT TRANSCRIBED]
12:20 – 14:29	Small group work [Students discussing demonstration – concept maps] [NOT TRANSCRIBED]
14:29 – 20:14	Whole-class discussion [Discussion of demonstration] [TRANSCRIBED]
20:14 – 30:54	Small group work [Students working on concept maps together] [NOT TRANSCRIBED]
30:54 – 32:35	Whole-class discussion [Discussion of demonstrations] [TRANSCRIBED]
32:35 – 42:08	Small-group work [Students discussing demonstrations together] [NOT TRANSCRIBED]
42:08 – 46:05	Assigning [Assigning groups experimental goals – get balloon to go as far as possible] [NOT TRANSCRIBED]

Level One Analysis (For All Research Questions)

All the potential video data for the study included video of 30 days of instruction. As mentioned above, the dual role of the researcher limits the available data from the 81 days of class attended by the researcher over the first semester. All videos were viewed and spreadsheet summaries of the activities of the classes were coded. The overall nature of the activities was time stamped on the summary sheets for each video.

The given notation included time stamp of the event, small-group work/discussion, whole-class discussion, individual work, experimenting, assigning, and a summary of the topic present. Table 3.4 above represents an example of this Level One coding for the September 4, 2012 video. In the given examples, "whole-class discussion" was later transcribed for further analysis. In cases where small-group discussion was interlaced with whole-class discussion, transcription was done when possible. All other videos followed this typical format for this level of analysis.

Level Two Analysis (For All Research Questions)

Level Two analysis began after Level One analysis was completed for the first two units. This analysis first involved transcribing the videos containing "whole-class discussion" code segments. These transcripts were done in Microsoft Excel, with each new turn of talk representing a new cell, and were isolated by video code. A turn of talk captures the entirety of a speaker's utterance. Teacher and student talk was transcribed if at all possible. Each minute of class discussion took the researcher approximately 5 minutes to transcribe. At times, student talk was difficult to transcribe due to students talking at the same time, differences in where the students sat in relation to the camera, the enunciation of students especially when combined with where they were seated, or general inaudibility which may have been caused by other sounds in the classroom.

Every effort was made by the researcher to correctly capture every spoken word for transcription. Transcripts were made with native sound first, and then areas that had presented with difficulty were transcribed again using software to help enhance the clarity of the speaker. VLC Media Player was the software used to both play video for transcription as well as to reduce extraneous classroom noise for clarity in transcription. This was made possible by 10 different "sliders" on a graphic equalizer relating to a range of sound wavelengths including: 60 Hz, 170 Hz, 310 Hz, 600 Hz, 1 KHz, 3 kHz, 6 kHz, 12 kHz, 14 kHz, and 16 kHz. Typically, reduction of frequencies outside the range of 310 Hz to 3 kHz helped make the speaker's voice more clear. This made it possible to essentially eliminate common classroom noise such as high-pitched squeaking chairs or low-pitched fan noises to isolate mostly spoken sound. This software also allows amplification of sounds in the video, useful when student voice was quiet.

When clarity was not reached by any of these methods, it was indicated as "inaudible". No instances of "inaudible" were coded for any of the teacher talk presented in the transcripts for data analysis. This was mostly helped by the teacher speaking in the general direction of the camera and having a clear, loud voice during instruction. Transcripts were checked and revised, if necessary, against the video as needed throughout the coding process. Corrections to the transcripts mostly oriented around spelling, omitted words, or addition of the names of the speaker and became infrequent as analysis progressed.

Data Analyses to Answer Research Questions 1 and 1a

Each question had a unique approach in terms of data analysis after the first two steps presented above. To determine the ways in which the big idea was utilized throughout the units, the researcher developed additional analytic steps to answer the first set of research questions including: 1) identifying the given big idea for a unit; 2) tracing the legacy of the big idea across the time periods to determine how the big idea was used; 3) comparing transcript data to other data sources and to national standards to determine consistency of the given big idea. Each additional step is summarized and discussed in greater detail in Table 3.5 below. Figure 3.1 below summarizes the analytic steps for research question 1:

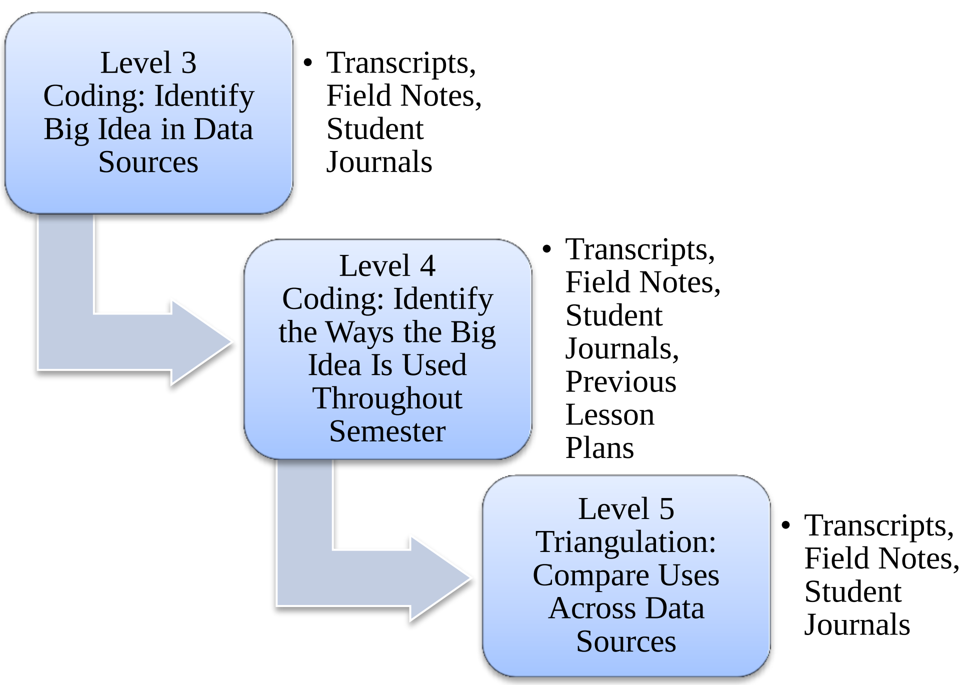


Figure 3.1 Analytic Flow Chart for Research Question 1

Level Three Analysis (For Research Question 1a)

In the third level of analysis, the big idea given to the researcher by the teacher was compared to the Next Generation Science Standard core concepts and the professional development book given to SWH teachers, *Questions, Claims, & Evidence*. This comparison allowed the researcher to determine the appropriateness of the big idea to the unit. As reported in Chapter 2, a big idea represents a core concept. The given big ideas that were compared to the NGSS core concepts were: 1) Force affects motion, 2) Electricity, and 3) Light.

Table 3.5 Five-Step Analysis Procedure for Research Questions 1 and 1a

Type of comparison	Analysis activities	Goal	Questions
Level 3a: Compare to National Standards and *Questions, Claims, & Evidence*	"Evaluating": Determining agreement between given big idea and NGSS core concepts	Establish if the given big idea is consistent with core concepts	Is the big idea reflective of core concepts in NGSS?
Level 3: Identify the big idea of each unit from transcripts, field notes, student journals	Coding: Identifying the location and wording of the big idea in available data	Identify instances of the big idea	What was the nature of the use of the big idea?
Level 4: Identify the Ways the Big Idea Is Used Throughout Semester	Coding: Identifying the context around the use of the big idea in data sources	Understanding how the way the big idea is used over the course of the unit	Does the role of the big idea stable across the unit?
Level 5: Compare transcript data to other data sources	Triangulating: Cross-checking how field notes, interview, & student journals support pattern	Consensus of pattern among other sources of data	What pattern of use could be supported across all data sources?

Level Three Analysis (For Research Question 1)

This step of analysis included coding the transcripts, field notes, and student journals by the big idea given to the researcher by the teacher. These big ideas were as follows: 1) force affects motion, 2) electricity, 3) light. Data sources were coded whenever these terms were present or the term "big idea" was present as "big idea related". These codes provided markers in the data for secondary coding that would be done in step four below.

Level Four Analysis (For Research Question 1)

The next step included coding the transcripts, field notes, and student journals as to whether the discussion or activity oriented around the big idea of the unit. This coding frequently involved multiple utterances instead of individual utterances with the transcripts. For example, an utterance involving an object traveling far could relate to either the outcome of the experiment, not the big idea, or could be tied to the big idea by discussing the reasons why an object might have gone far. This could ultimately be clarified by the resulting discussion as presented in the example coding given in Table 3.6 below. When discussion could not be tied back to the big idea, a notation was made for clarification in later analytic steps. These areas were then coded with a secondary, clarifying code that was explored in Level Five after the primary coding had been finished.

Table 3.6 Example Codes for Relatedness to Big Idea

Example Code: Big idea related		primary code	secondary code
Teacher	Ok, what else? Carson?		
Carson	That when you pushed it, there was motion… which was it spinning. The force was you pushing it.		
Teacher	Ok, what else?	big idea related	N/A
Bruce	Umm. Motion comes from force?		
Teacher	Ok, what else?		
Tyler	I don't know what stopped it, but it stopped.		
Example Coding: Not big idea related			
Teacher	As far as possible, ok? What is the one rule that you have? The balloon has to do what?		
Bruce	The balloon has to go on its own.		
Teacher	It has to go on its own, with its own power.	not big idea related	focus of experiment related
Ann	And as far as it can go.		
Teacher	It has to go as far as it can under its own power. Ok, three minutes, are you ready? …		

Level Five Analysis (For Research Question 1)

In this level of analysis, triangulation was used to provide a more detailed and balanced picture of the analysis (Altrichter et al, 2008). The big idea was carefully looked at across time in other data sources to check that the big idea showed similar, consistent trends across all data sources to determine the stability of the role of the big idea throughout the unit. A student short answer questionnaire was given to all students of this classroom that asked them to state the big idea of each unit along with other questions. This essay was given well after the third time unit had ended and is given in Appendix B. This questionnaire was to determine what the students perceived the big idea of each unit to be.

Table 3.7 Codebook for Interview, Field Notes, Student Journals for Big Idea Patterns

Categories	Description	Example
Big idea	Any response or idea with clear connections to the big idea	Semantic web built around the given big idea. (Appendix C)
Experimental-outcome	Any response or idea with clear connections to only a specific desired experimental outcome	"Which balloon goes farthest, curly or circular?" – Only indication of specific outcome of test.
Student questions	Any response or idea with clear connections to only student questions	"How much mass does the Earth have?", "6,600,000,000,000,000,000,000"
Resolving experimental problems	Any response or idea with clear connections to only resolving an experimental problem	"Zipline needs to be angled" – in reference to how to get balloon to travel farther on a schematic of their experiment.
Not big idea	Any response or idea that is clearly not any of the above	"Transmitted is like transparent because transmitted means light that travels through matter…" in a list of words for students to define from previous year's PowerPoints.

Secondary codes from Level Four Analysis were used to characterize the role of the big idea in other data sources. These codes included: (1) big idea, i.e. use of the big idea as identified in the transcripts, (2) experiment-outcome related, i.e., activity focusing on a desired outcome of the experiment that was not tied into the big idea, (3) student questions (not big idea), i.e., student questions for experimenting that were not tied into the big idea, (4) resolving experimental problems, i.e., fixing experimental design problem such as multiple variables, and (5) not big idea, i.e., given focus that was none of the above, perhaps topic from previous years. Table 3.7 above summarizes the categories and provides examples of coding used in this level of analysis.

Data Analysis to Answer Second and Third Research Questions

Table 3.8 Five-Step Analysis Procedure for First Research Question

Type of comparison	Analysis activities	Goal	Questions
Level 3: Characterize unit transcripts with Benus et al. (2013) framework	Coding: Identifying sections of transcripts relating to features of Dialogue Framework	Characterize features of dialogue present in classroom for each unit	What was the nature of dialogue in the classroom?
Level 4: Score transcripts on m-RTOP	Cross checking: Comparing m-RTOP score against expected profile reported by Benus et al. (2013)	Ensure framework scoring is consistent with what is expected given m-RTOP scores	Are the m-RTOP scores and Dialogue Framework scores consistent?
Level 5: Use Transcript Analyses to Support or Refute Scoring	Case building: Data related to scoring features isolated to compare to scores	Allow some quantification of features for comparison across time	How do differences in scores represent in the transcript data?
Level 6: Identify Dialogue or Argument in Data Sources	Coding: Identifying instances relating to dialogue or argument	Identify instances relating to dialogue or argument	What examples of dialogue or argument are available in other data sources?
Level 7: Compare transcript data and scores to other data sources	Triangulating: Cross-checking how field notes, interview, & student journals support pattern	Consensus of patterns among other sources of data	What patterns could be supported across all data sources?

The second and third research questions dealt with the ways in which dialogue and argument, respectively, changed in the classroom across the first semester. A six-stage analytic procedure was followed to answer the second and third research questions through coding and analysis of transcripts, field notes, teacher interview, and student journals. The first two steps presented earlier related to coding the raw video and transcribing relevant sections of whole-class discussion and were shared among all research questions. The remaining steps are summarized in Table 3.8 with elaboration above.

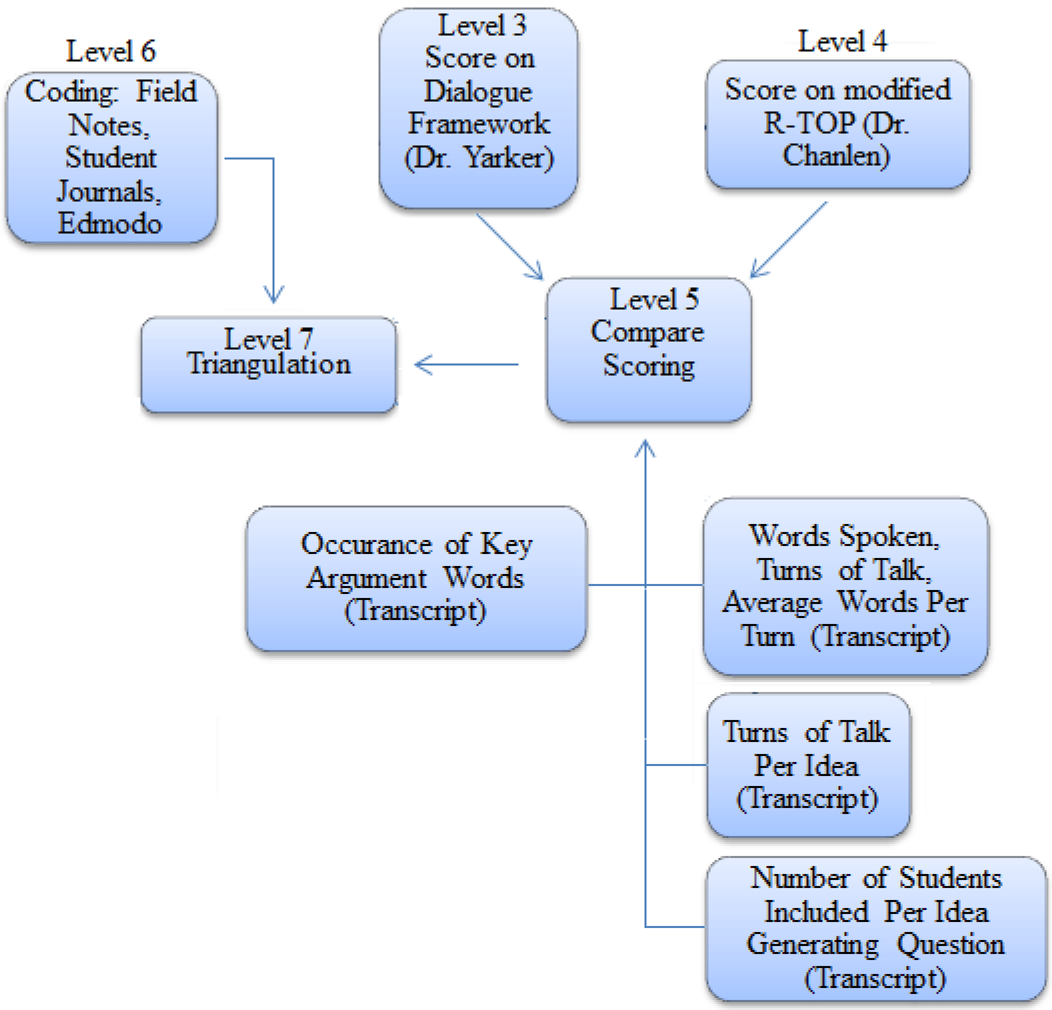


Figure 3.2 Flow Chart for Analysis for Research Questions 2 and 3

A flow chart that pictorially represents this is presented in Figure 3.2 above. Importantly, both the second and third research questions followed the same basic analytic approach. The analytic framework by Benus et al. (2013) was also separated in this same manner to best explain either the dialogue or argument component which is later clarified.

Level Three Analysis (For Research Question 2)

Level Three analysis began by scoring the transcripts according to a Dialogue Framework presented by Benus et al. (2013). This framework, presented in Table 3.9 below, characterizes five areas of classroom dynamics related to the development of dialogue. This framework also characterizes the typical conditions one might expect to see in three different levels of classroom that range from one to three (low to high). A preliminary coding was given for the time periods based on the following framework. The framework used for this level of analysis was co-coded by an author of the framework on the same transcripts to ensure valid coding for each unit. Any disagreements in coding were discussed between researcher and author until an understanding was reached (less than ten minutes each on average, four codes in total).

Additional clarification of some features in the Dialogue Framework was necessary to provide a more detailed picture of the classroom practices. For the "Complexity of Question" feature, the first level has questions that seek explanation as all levels in this feature do. This was not seen as a necessary first level component to the questioning of the classroom and mischaracterized many of the questions seen early in the semester as they appeared to not seek explanations. An additional clarifying feature was added to the Benus et al. (2013) framework to better characterize the time periods that presented with these types of questions to include that the questions asked need not seek explanations, which is typical of IRE type classrooms. Another area that became important for explanation building especially in questioning was the role of science

Table 3.9 Benus et al. (2013) Analytic Framework for Dialogue Development

Factor	Level One	Level Two	Level Three
Complexity of Question	In most cases, questions were asked to explain explicit knowledge.	In most cases, questions ask students to explain their comprehension of ideas.	In many cases, questions challenged students to explain, reason through, and/or justify.
Depth of Idea Exchange	Even if opportunities existed, ideas were rarely discussed beyond initial response.	Ideas were discussed for several turns of talk but were usually limited to comparing/checking/ understanding some smaller element of the "big idea."	Ideas were discussed over many turns of talk to help understand many elements/viewpoints of the "big idea."
Classroom Interaction	Students did not ask a student to justify reasoning or evidence. Teacher may occasionally ask for justification and/or reasoning.	Occasionally student(s), and often the teacher, asked follow-up responses that required student(s) to justify reasoning or evidence.	Students often, and teacher may or may not as often, ask follow-up responses that required students to justify reasoning or evidence.
Evidence-based Ideas	There is little discussion of the claim/evidence presented.	There is some discussion of the claim/evidence presented.	There is extensive discussion of the claim/evidence presented.
Conversational Pattern	Student conversation not well connected to previous turns of talk, with very short conversations about student ideas. Generally Q&A format.	Student conversation at least occasionally is connected to previous turns of talk. Some medium-length conversation occurs about a student idea.	Student conversation was consistently integrated with previous turns of talk. Lengthy discussions occur about a student idea.

terminology. To better display how science terms were used throughout the time periods, another clarifying feature was added to the "Complexity of Question" feature. The new feature explanations can be found in Table 3.10 below.

Table 3.10 Clarifying Features Added to Benus et al. (2013) Framework

Factor	Level One	Level Two	Level Three
What Types of Questions are being asked by the Teacher?	Teacher questions tend to be IRE based. Questions typically short answer, not explanatory in nature.	Teacher questions may elicit student understanding. IRE questions may compete with explanatory questions.	Teacher asks questions that elicit student understanding and challenge student statements. Questions are mostly open ended.
Role of Science Terms	The use of science terms in discussion is preferred. No or little follow up as to what the terms mean or understanding of the terms.	Science terms in discussion preferred but steps are taken to have students give definitions of terms.	Science terms in discussion, but definitions are discussed to ensure that students understand both the term and definition.
Role of Teacher in Discussions	Teacher takes dominant role in discussions. Controls all turns of talk. Provides feedback to student replies and dictates direction of discourse.	May still control turns of talk, but encourages challenge of student ideas either directly or with other students. Seeks to reach consensus of student ideas. Still controlling flow of discussion and ideas.	Teacher acts to moderate the discussion, ensuring that the "rules" of appropriate discourse are followed. Students tend to engage the ideas of others. Students tend to dictate flow of discussion.

A final clarifying feature was added to the "Conversational Pattern" feature to further explain how student ideas might be developed in the classroom discourse. In the original framework, the requirement was that student conversation be connected to previous turns of talk. This left the control of the connection of student ideas ambiguous. A clarifying feature that addressed this control was added to better describe the player in the classroom that utilized this control. Coding schemes are presented in Table 3.10 above.

Level Four Analysis (For Research Questions 2 and 3)

Each time period was scored on the modified RTOP (Reformed Teacher Observation Protocol) (Martin & Hand, 2009) as used by Benus et al. (2013) in construction of their framework and implementation profiles. The original RTOP (Sawada et al., 2002) consists of 25 Likert-type scales within five subscales, including: lesson design and implementation, propositional knowledge, procedural knowledge, communicative interaction, and student/teacher relationships. The reliability of RTOP was tested by inter-rater reliability, i.e., $r^2 = 0.954$, $p < 0.01$, and internal consistency, i.e., Cronbach's $\alpha = 0.97$. The authors of the RTOP describe it as consistent with the nature of scientific inquiry (AAAS, 1989) and aligned to the National Science Education Standards (NRC, 1996), noting that in "reformed classrooms" students "explain and justify their work to themselves and to one another" (NRC, 1996, p.33).

The modified RTOP consists of a 13 item subset of the 25 original RTOP items. Like the original RTOP, each item in the modified RTOP subset may receive a score from 0 – 4 to indicate the range of representation in the classroom from "never occurring" in a classroom to "very descriptive of the class". The modified protocol consists of four subscales that are closely aligned to the SWH including: teacher questioning, teacher role, student voice, and science argument. The alignment of these 13 items is described by Martin and Hand (2009) in Table 3.11 below. This modified

Table 3.11 Comparison of Modified RTOP and SWH Categories

RTOP	SWH
Student voice	
1. Instructional strategies respected students' prior knowledge/preconceptions.	**Connections:** There is an emphasis on determining student knowledge and building teacher plans based on this knowledge.
5. Focus and direction of lesson determined by ideas from students.	**Connections:** Teacher builds or activates students' prior knowledge with some evidence of using it to make instructional decisions.
16. Students communicated their ideas to others.	**Focus on learning:** Student sharing with argumentation/connections in either small group, group to group, or whole group.
	Connections: Language activities flow naturally throughout the SWH.
	Science argument: Teacher promotes linkages to big ideas and begins to promote debate on these ideas.
18. High proportion of student talk and a significant amount was student to student.	**Focus on learning:** Student sharing with argumentation/connections in either small group, group to group, or whole group.
	Dialogical interaction: Communication effectively varies from teacher to student and from student to student according to the situation.
19. Students' questions and comments determined focus and direction of classroom discourse.	**Connections:** Teacher effectively builds or activates student prior knowledge with evidence of using this to make instructional decisions.
	Dialogical interaction: Teacher is not compelled to give right answer shifting focus to the big idea. Teacher uses all levels of questioning, and adjusts levels to individual students.
Teacher role	
24. Teacher acted as resource person, supporting, and enhancing student investigations.	**Focus on learning:** Teacher effectively plans for teacher and student instruction as needed and appropriate.
25. The metaphor "teacher as listener" was very characteristic of this classroom.	**Dialogical interaction:** Teacher used questions to explore student thinking. Teacher's response to student answers is probing, connects, and extends, questions.
Science argument	

Table 3.11 Continued

13. Students were actively engaged in thought provoking activities that involved critical assessment of procedures.	**Connections:** Science activities promote big ideas clearly and extend students learning. Connections can be seen from beginning to end and are articulated by students.
14. Students were reflective about their learning.	**Science argumentation:** Teacher demands connections between question, claims, evidence, and reflection.
15. Intellectual rigor, constructive criticism, and the challenging of ideas was valued.	**Focus on learning:** Student sharing with argumentation/connections in either small group, group to group, or whole group.
	Science argumentation: Teacher promotes linkage to big ideas and promotes debate on these ideas.
21. Active participation was encouraged and valued.	**Science argument:** Teacher requires students to link claims and evidence. Teacher scaffolds questions, claims, evidence, and reflection. Promotes linkages to big ideas, and promotes debate of these ideas.
22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.	**Science argumentation:** Teacher scaffolds questions, claims, evidence, and reflection. Promotes reflection to big ideas and promotes debate of these ideas.
Questioning	
17. Teacher questioning triggered divergent modes of thinking.	**Dialogical interaction:** Students are asked to explain and challenge each others' responses rather than the teacher passing judgment. Teacher asks many layered questions (i.e. Bloom's Taxonomy). Teacher is not compelled to give "right" answer shifting focus to the big idea.

Source: Martin, A. M. & Hand, B. (2009). Factors affecting the implementation of argument in the elementary science classroom. A longitudinal case study. Research in Science Education. 39(1), 17-38.

RTOP has also been shown to have a positive relationship between the teacher's level of implementation of the SWH and higher modified RTOP scores (Cavagnetto, Hand, & Norton-Meier, 2010; Martin & Hand, 2009).

The modified RTOP is preferred in this study for two reasons. First, it is the same scoring framework used to determine the level of implementation of the teachers by Benus et al. (2013) which allowed this case to be more easily compared to the profiles they reported. Secondly, it allows for a comparison of the Dialogue Framework scoring results in this study to be compared to the modified RTOP scores as a check for alignment. The modified RTOP scoring was performed by an independent researcher with more than 60 videos scored with this scoring protocol.

Level Five Analysis (For Research Questions 2 and 3)

Level Five analysis included comparing the scores between the Dialogue Framework and modified R-TOP scores. These scores were also compared to transcript data when possible to help quantify differences between time periods. For this step, specific data that highlighted features of the frameworks was used for comparison. After the initial scoring of the time periods on the above framework, additional analyses were used to help support the codes made in the fourth level of analysis. These additional analyses are summarized in Table 3.12 below. These values were calculated using the filter feature of Microsoft Office Excel to filter based on who was speaking and then performing a word count using Microsoft Office. For counting turns of talk, ideas were tracked through the discussion until the idea changed and the number of turns of talk per idea was then counted. Examples of these analyses can be found in Appendix D. These analyses are reported in either tables or graphs in the Results.

Table 3.12 Clarification Analysis - Step Four

Framework Characteristic	What was done?	Reasoning
Depth of Idea Exchange	Counted turns of talk per idea	The number of turns of talk per idea gives an indication the extent of idea development.
Classroom Interaction	Word counts for various terms	Certain terms should appear in the transcript for certain activities. For example, when discussing claims and evidence, one would expect terms like "claim", "evidence", "data", etc. to appear.
Conversational Pattern	Counted number of students included in discussion per idea	This gives an indication of whether students' ideas were being brought in individually or at the same time.
	Counted number of words spoken by teacher and students.	This gives an indication of the amount of teacher and student talk in the room.
	Counted number of turns of talk taken by teacher and students	This gives an indication of the amount of teacher and student talk in the room.

Level Six Analysis (For Research Questions 2 and 3)

Level Six analysis included coding of field notes, student journals, transcripts, and Edmodo data as it related to dialogue or argument. This coding served to provide instances that could support or refute the scoring in the Dialogue Framework and modified R-TOP in the triangulation step that followed. For this level of analysis, several codes were used including: dialogue, argument, and lack of dialogue. The primary role of this analysis was to provide context and examples of the scoring given in the other two frameworks. An example of "Argument" coding is given in Table 3.13 below. This example is coded as Argument because clarification of the ideas is being expressed as a result of a challenge to the claim. The class provides an additional set of challenges to the teacher challenge. This is aligned to aspects of argument. In the example in Table 3.14 below, students provide ideas about why water is a conductor. Multiple ideas are taken as shared without challenge or critique of the evidence provided, consistent with dialogue.

Table 3.13 Example of Argument Coding

Speaker	Transcript	Code
Carson	I can always see in my room… when the lights are all off.	Argument
Teacher	You can see in your room with the lights all off? 100% darkness?	
Carson	Yeah.	
Teacher	Ok, close your eyes. How many fingers am I holding up? (holds up none)	
Carson	I don't know.	
Taylor	Because you're blocking your eye sight.	
Teacher	You're in 100% darkness.	
David	Yeah, but it's blocking his eye sight, it's not really dark.	

Note: TRN-101-021/030 – (025/026 omitted)

Table 3.14 Example of Dialogue Coding

Speaker	Transcript	Code
Tyler	Because all water is a conductor.	Dialogue
Teacher	Ok, all water is a conductor. What do you think?	
David	I think it's a conductor too because in the movies they stick a wire in water and then the lightning strikes it and it electrocutes the water and all the fish die.	
Teacher	Ok. What do you think? Greg?	
Greg	Yes, water is a conductor of electricity because if you go to a swimming pool and there's lightning they ask you to get out.	
Teacher	Yeah, they tell you to get out immediately right? Ok so, you know something's going on with water…	

Note: TRN-060-061/066

Level Seven Analysis (For Research Questions 2 and 3)

The seventh step of analysis for the second research question, triangulation was used to provide a more descriptive and balanced picture of the analysis (Altrichter et al., 2008). Teacher interview, field notes, and student journals were analyzed to gather further understanding of the changes in dialogue over time. Student journals and Edmodo, the electronic forum where written presentations were occasionally given, were examined for the use of claims and evidence structure during experimentation. All of these data sources were compared against the framework results for consistency of trend. The features from the above Dialogue Framework were used to code alternative data sources. Splitting Argument and Dialogue in Dialogue Framework

While the Dialogue Framework presented by Benus et al. (2013) is useful for this study, it can be divided into two distinct groups. While Benus et al. (2013) did not make the distinction between generalized dialogue verse specialized argument, this study does seek this distinction where possible. As a result of the framework not being designed to carry this distinction, there are some areas of caution when grouping the features. The grouping decisions are presented below in Table 3.15 and include areas of caution with explanations as to grouping. Grouping the features in this way allows a more focused discussion of the differences seen between developing dialogue features or developing argument features. The primary difference between these areas for the Dialogue Framework is in the use of claims and evidence through the discussion. The researcher would like to restate at this point that argument in this study is seen as a specialized form of dialogue.

Table 3.15 Grouping Decisions of Benus et al. (2013) Framework

Feature	Dialogue or Argument?	Reasoning
Complexity of Question	Dialogue	Much of this feature relates to students explaining their ideas or comprehension of ideas. This does not require argument. Level 3 contains more argument elements with justification and reasoning components.
Depth of Idea Exchange	Dialogue	This feature relates to discussing ideas over varying turns of talk as well as what the talk is oriented around. This does not require argument.
Classroom Interaction	Argument	Students ask students to justify or provide reasoning, representing specialized discourse consistent with argument.
Evidence-based Ideas	Argument	The claim/evidence structure is, by nature, an argument structure.
Conversational Pattern	Dialogue	This feature is about the connection of student talk and the length of talk associated with student ideas. This does not require argument.

Trustworthiness

The research of a study should provide a picture that is comprehensive as well as comprehensible (Stake & Mabry, 1995). The findings of a study should also be "sufficiently authentic" to the point where one may trust acting on the implications of the study (Lincoln & Guba, 2000, p. 178). The trustworthiness of this study was established through credibility, transferability, and dependability (Marshall & Rossman, 2011). Table 3.16 below shows a summary of the ways in which these were achieved with a more detailed description of the three factors that follow.

Table 3.16 Description and Strategies for Establishing Trustworthiness

	Credibility	**Transferability**	**Dependability**
Description	Level of confidence in the findings	Degree to which the findings apply in other contexts	Repeatability of findings if the study could be replicated
Strategy Used	Observing over a semester	Selecting the research site and teacher in a purposeful way	Providing detailed description of data collection processes
	Non-participant observation	Providing a detailed description of the context of study and data analysis	Using video to capture conversation and activities of the classroom
	Collecting multiple sources of data		Utilization of other researchers to examine the findings
	Building trust with both teacher and student participants		Coding of transcripts by author of framework, RTOP scoring by researcher familiar with RTOP framework
	Discussing findings with the participant (member checking)		
	3rd Party Review of Coding (RTOP, Benus et al., 2013 Framework)		

Credibility

Qualitative studies require that the researcher become intimately familiar with the subjects of their study (Creswell, 2007). The researcher was present for 81 days of instruction over the first semester. This helps ensure that the researcher is more than a "stranger in a strange land" (Lincoln & Guba, 1985, p. 290). The length of engagement in the classroom and the recordings of the classroom for each class period provide an element of prolonged engagement. For any class periods where the researcher was unable to attend, the teacher willingly recorded the class period providing a nearly unbroken course of instruction over the study. These recordings, though infrequent, allowed the researcher to see if there were changes apparent that may have occurred as a result of the researcher not being present. No major differences were detected by this researcher or by two other researchers scoring video and transcripts during these segments. When the researcher was present in the classroom, it was not uncommon for him to chat with the researcher in the back of the room if the students were working in small groups. These interactions suggest a level of trust between the researcher and the teacher. The teacher also freely offered past years' lesson plans. In summary, the 81 in person visits over the semester, extensive video, and conversations both inside and outside the classroom provided persistent observation of the "scope" and "depth" (Lincoln & Guba, 1985) of the research.

All of the data had at least one other corresponding data source. Video and transcripts, teacher conversations, interview, field notes, and student essay were data sources with overlap for investigator triangulation. Member checking, which has been described as "… the most important technique for establishing credibility" (Lincoln & Guba, 1985, p. 316) was done with the teacher in a post study interview to help the researcher understand the classroom dynamics as the teacher saw them and to check that he agreed that the preliminary results were an accurate representation of his classroom practice. Several quotes used in the results section come from the interview member checking conversations.

Transferability

Transferability references the ability of the research results to transfer to situations with similar context parameters as the study. This research contains "thick descriptions" (Geertz, 1973; Creswell & Miller, 2000) of the study rationale, the background of the teacher, data collection methods, and analytic methods. Of careful note in this study is the use of the Science Writing Heuristic (SWH), an argument-based inquiry approach. This approach or other argument-based inquiry approaches should be carefully noted in future research endeavors. Efforts should be made in future research to report both the experiences using argument-based inquiry but also the modified RTOP scoring as explained in this chapter. Comparisons between teachers not utilizing the SWH approach and this study should be made with caution between the two practices to aid in interpreting and comparing the settings and results.

Dependability

Dependability is an account of the ways in which the research is maintained as a stable process overtime so it can be replicated. Within this study, the teacher's credentials, classroom setting, location of camera, and intervals of recordings did not change during the length of the study which might make the process appear unstable. While the number of days' worth of data available for study for each unit and the student grouping did change at every unit change, these were the only notable change throughout the semester. The available data for this study (which excludes class periods after the conclusion of claims and evidence from the first round of experimentation) was minimally impacted by early outs.

In an effort to insure dependability, the transcripts used by the researcher for scoring on the Benus et al. (2013) framework were also scored by an author of the framework that is independent of this research. Most scoring differences, initially 3 of 15 total scores, were resolved through conversations with this researcher. Additionally, the researcher engaged in weekly peer debriefings (Marshall & Rossman, 2011) with Dr. Benus, another author of the framework at use in this study who did not provide transcript scores due to his involvement in peer debriefings. The modified RTOP (Martin & Hand, 2009) scoring was also performed by an independent researcher with more than 60 hours scoring experience with this framework.

Summary

This study attempts to understand the changes in whole-class dialogue patterns and use of the big idea that occur and develop in the first semester of a sixth grade classroom undergoing professional development in the Science Writing Heuristic approach to inquiry. Qualitative methods were used to understand how these patterns occur and develop overtime. Sources of data used in this study include classroom video, teacher interview, students' written essays, student journals, non-participant observation, and the researcher's field notes. Strategies of purposeful selection of the teacher, long periods of observation, extensive video recording, member checking with the teacher, and scoring by outside researchers on RTOP scoring and the primary analytic framework used in the study all help to enhance the credibility, transferability, and dependability of the study.

CHAPTER FOUR

RESULTS

Introduction

This chapter will report the findings of the data analysis procedures discussed in Chapter Three for the three research questions of this study, which are:

1. How does a teacher in his first semester of Science Writing Heuristic professional development make use of the "big idea"?
    a. Is the indicated big idea consistent with NGSS core concepts?
2. How did the dialogue in whole-class discussion change during the first semester of argument-based inquiry professional development?
3. How did the argument in whole-class discussion change during the first semester of argument-based inquiry professional development?

Each research question will be addressed independently within each time period and then will be compared across time periods. Summaries of each area including the big idea, dialogue, and argument are given at the end of each section.

The First Research Question

The first research question explores the use of the big idea throughout the three units during the first semester of argument-based inquiry implementation. In order to better capture this research question, a clarifying question (1a) was asked that compares the given big idea to the NGSS core concepts. Each time period will be discussed below as they relate to these research questions and has been divided into smaller questions that help explore the areas of "use". To do this, each time period will start with a comparison of the given big idea to the NGSS disciplinary core ideas to determine the appropriateness of the given big idea. After this, the way the big idea was used through the unit will be explored both in terms of the use present as well as the consistency of that use across time. Lastly, the student questionnaire is used to determine what students thought the big idea of the unit was.

The First Time Period – Force Affects Motion

What is the big idea and is it consistent with a "big idea"?

The big idea, "force affects motion", was presented early in the unit and was used in a semantic webbing activity (similar to concept mapping but without linking words between the nodes) to make prior student understanding explicit. Force affects motion captures a core concept dealing with force and motion and therefore is consistent with a "big idea". This big idea as presented to the class is represented in an assignment given by the teacher:

> We're starting off with the big idea brought up by Adam. Force affects motion… We're going to be working in groups today and I want you to come up with one single concept map about force affecting motion… (Taylor, TRN-006-002).

How is the big idea used?

The students started their semantic webs with the big idea at the center. The collected student work all showed this singular big idea at the center of the semantic webs consistent with the assigned task presented above (SJ02-01, for example) and is identified in the researcher field notes: big idea: Force affects motion, brought up by student (RFN-0904-02). The students engaged in a discussion where they connected observations from an in class demonstration about forces and motion (TRN-006-005/028).

While the big idea was used both for the writing task given to the students and also for the discussion that followed, in subsequent observed class periods not only does the term “big idea” not reappear in classroom video, “Force affects motion” is also absent under any context (TRN-009, VID-011/039). A note was made by the researcher during student experimentation of the lack of a big idea being apparent (RFN-0906-10).

There were opportunities to make use of the big idea during this time period that were missed; one such interaction is given below. Students had started designing tests to explore force and motion at this time with a goal of getting a balloon to travel as far as possible (RFN-0905-08). In the transcript, this desired outcome was repeated three more times by the teacher just before releasing the students to work without explicit mention of the big idea (TRN-009-13, 17, 19).

Table 4.1 Changing Classroom Priorities

Person	Classroom Transcript
Teacher	... You are going to design a test. What does a test have to do with?
Kale	Uhh…. Force and motion?
Teacher	Force and motion. What is your objective? What are you trying to do with this test?
Class	Get a balloon to go.

Note: TRN-009-009/012

The researcher made note of this to the teacher while the students were developing their experiments. In a private exchange with the teacher while students were working, the researcher commented that students had multiple variables in most of the experimental designs (TRN-009-091), the teacher replied about minimizing variables, and the researcher commented "…as long as they can connect it back to force and motion" (TRN-009-095). It appears that the big idea was initially used for semantic webs and an opening discussion on "force affects motion" but already appears to be diminishing in use by the second class period.

Is the use of the big idea consistent across the unit?

As mentioned above, the big idea served a clear purpose at the start of the unit. However, as the unit continued, the big idea became scarce. Throughout the class period following the opening discussion, "force" appears four times in total (two presented in the above transcript (TRN-009-009/012), one at the onset of the class period (TRN-009-001), and the notation by the researcher to the teacher (TRN-009-095)). The term "motion" appears in these same places connected to "force" ("force and motion"). "Far" appears 12 times, "furthest" appears 5 times, and "test" appears 49 times in 116 turns of talk (TRN-009). Neither "big idea" nor "force affects motion" reappear in any collected data after the opening discussion. There are also no notations in the field notes about the big idea being used after this point. Throughout the unit, there are many examples referring back to this objective but none observed referencing the big idea. Therefore, it appears as though the utility of the big idea changes across the unit from being the central feature of the semantic web activity to make student understanding explicit to being not present as the unit moved into experimenting.

What do students think about the big idea?

The students indicated what they thought the big ideas of the different time periods were in a student written questionnaire (SWA). As highlighted above (TRN-006-

002), the big idea was explicitly stated for the students and they made semantic webs with the big idea. Yet, when asked, only seven students were able to identify either "Force affects motion" or "Force and motion" as the big idea. In fact, more students (nine) referenced the objective given in the transcript above (TRN-009-009/012).

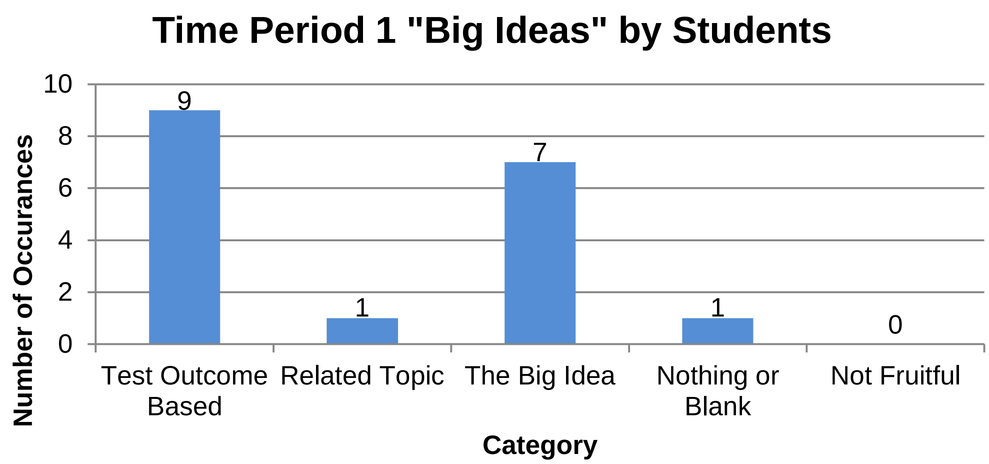


Figure 4.1 Time Period 1 Big Ideas by Students

Table 4.2 Big Ideas Identified by Students in Time Period 1

Time Period 1	
Make balloon/rockets fly/go far	9
Force and motion*	6
Air Pressure	1
Force affects motion	1
Nothing	1

As can be seen in Table 4.2 above, many students identified either an idea close to the big idea or the desired outcome stated by the teacher at the onset of experimentation (TRN-009-013). Only two students did not identify the big idea directly, an idea close to the big idea, or the experimental outcome. Of these students, one of them identified air pressure which is related to the big idea. This suggests that many students connected well enough to the big idea to remember it at the time of the questionnaire, though roughly half the class identified the outcome of an experiment as the core concept of the unit even though a big idea was explicitly stated in the transcript. Important to note is the relatively few categories of ideas identified by students.

Summary – Role of Big Idea in First Time Period

The big idea appears to be present initially. The teacher brought it up to the students as part of a semantic webbing activity (TRN-006-002). The students appeared to follow the directions given as all of the student journals have "force effects motion" at the center of their semantic webs (SJ). After this discussion, both "big idea" and "force affects motion" were not seen in the collected data. After the first semester had concluded fewer students identified the stated big idea (force affects motion) than the outcome of the experiments (to get an object to go far) (TRN-009-009/012). However, of the 18 student replies, all but one student failed to represent something close to the big idea or near the topic of the big idea. This student left the question blank. Therefore, many students were able to connect to either an experimental outcome stressed in transcript 009 or the big idea presented to the students during the initial semantic webbing activity.

The Second Time Period – Electricity

What is the big idea and is it consistent with a "big idea"?

The given big idea, "electricity", was presented early in the unit and used in a semantic webbing activity to make prior student understanding explicit as with the first unit (RFN-1018). Electricity does not capture a core concept and therefore is not consistent with a "big idea". "Electricity" is a topic; there are no inherent ideas or concepts, much less a core concept, embedded into it. Two possible big ideas for an electricity unit are given in the *Questions, Claims, and Evidence* book given to teachers during professional development including: "Electricity in circuits can produce light, heat, sound, and magnetic effects" or "Electrical circuits require a complete loop through which an electrical current can pass" (Norton-Meier et al., 2008, p.160). As presented in Chapter 3, the NGSS core standards for this grade level indicate a core concept dealing with energy with a minor component of electricity: "Energy can be moved from place to place by moving objects or through sound, light, or electrical currents." (NRC, 2012, p.193).

How is the big idea used?

The student journals (SJ-11-10, for example) all contain semantic webs with "Electricity" as the central focus as in the first unit. When the teacher was asked privately why "electricity" was selected for a big idea, he was not sure (RFN-1018). The teacher lesson plan notes given to the researcher were versions of lessons he taught in previous years and as such do not indicate a "big idea" for this unit though they are labeled "Electricity" (TP2-01). The PowerPoints were e-mailed to the researcher with the note from the teacher: "I have attached some of the PowerPoint notes I have gone over. I don't really give notes anymore but use them to help illustrate some of my points." (TEM-0421-02/03). These notes cannot be SWH notes because they existed prior to his implementation of SWH. In fact, the curriculum rotation of units in this school's middle school is on a two-year cycle, meaning these notes were made at least two years prior to the onset of SWH implementation.

During the end of study interview, the teacher remarked that he, at the time of the interview, was still uncomfortable with implementation though maintained optimism at the thought of progressing with his implementation (TIN-0935). He also noted that "there was some stuff I struggled through last year, and I just didn't want to do it anymore" and that there were areas where he had recession to the past describing his struggling as "difficult" for a subject he loved (TIN-1025). When probed, he clarified by talking about the big idea stating that he felt some of the big ideas were "too big" (TIN-1212) and a general lack of comfort with the approach, comparing it to his coaching students that were not comfortable with something they had been taught (TIN-0945).

Is the use of the big idea consistent across the unit?

Table 4.3 Discussion Aligned to Previous Lesson Plans

Person	Classroom Transcript
Teacher	Ok, there are three. There's a black one, a white one, and then there's a copper one. Are these all copper? (Holding up electric cord)
Class	Yeah… no… (some agree, some disagree)
Teacher	They're all copper. Why would they use copper for electrical wires? Why do you think? David why?
David	Because copper… because it's a good conductor.

TRN-060-030/035

This unit showed examples of reversion to previous teaching approaches consistent with the teacher comments above. Following the student experiments, the teacher had indicated frustration with the student experiments as far as their ability to explore the concepts of the unit (RFN-1022-10).The transcript sections above in Table 4.3 are from whole-class discussion held by the instructor following the student experiments as he used common objects to try to stir a discussion (RFN-1022).

The researcher compared the activities of the classroom discussion and student notes to the previous years' lecture slides. The following image is a slide from the teacher lesson plans related to electricity. The slides presented below are the unmodified slides from semesters previous to SWH implementation and represent colored copper wire exactly as described in Table 4.4 above with the exception of a red wire instead of a white wire.

Figure 4.2 Conductor Slide from PowerPoint (TLP-02-10)

The section above is followed shortly by another example offered by the teacher. Again, during this section of transcript, the teacher is still using the wire sample to lead a discussion with students. The previous years' lesson plan notes are given below the transcript selection.

Table 4.4 Class Discussion Aligned to Notes

Person	Classroom Transcript
Teacher	What is it David?
David	It's insulated wire.
Teacher	Insulated wire, why do you say insulated?
David	Because it has a cover on the outside.
Teacher	Ok, so if I'm touching this and there's current going through, will I get shocked?

TRN-060-039/043

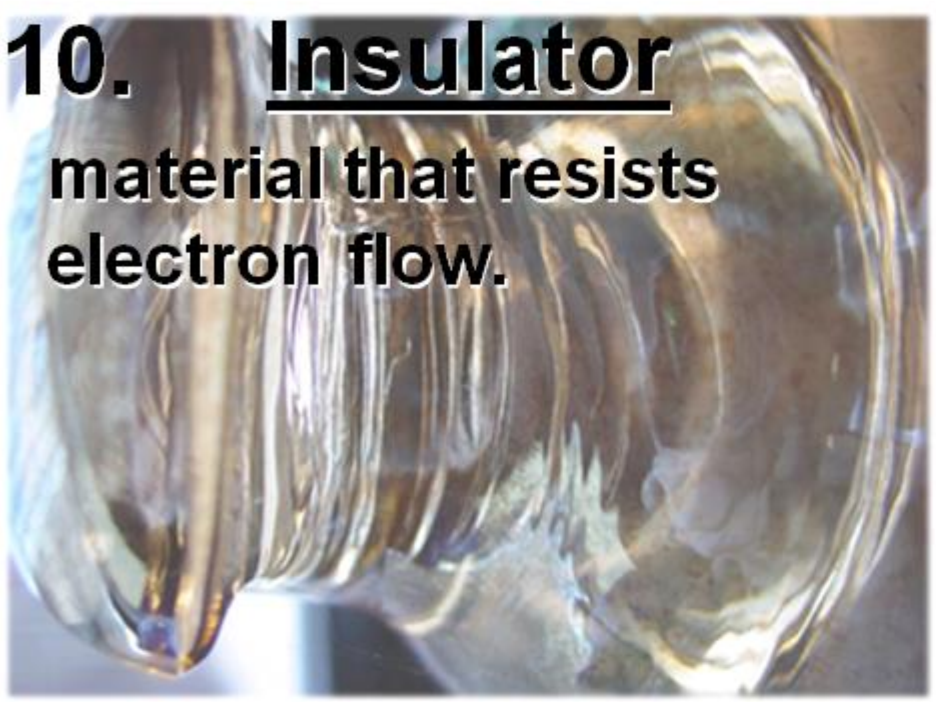


Figure 4.3 Insulator Slide from Teacher Lesson Plans (TLP-02-011)

Of critical importance here is the order in which these occur. The discussion order, which is being dictated by the teacher as a result of him presenting objects for discussion, follows the same order as the previous years' lecture notes and has a given big idea that matches the unit topic of previous years. The above transcript selection does not show Tracy's reply to his question: Cord (TRN-060-038). It is not clear as to why he did not follow up with Tracy's answer but did follow up with David's answer. Taylor did indicate that he felt frustration struggling through teaching a subject matter he loved and had reverted to some degree to prior teaching approaches that seemed to work for him (TIN-1025). This is consistent with the given big idea matching previous years' unit topics as well as guiding the discussion in the same order as those previous lesson plans. Ultimately, if this were the case, then the given big idea cannot be an SWH big idea unless Taylor had already been teaching with big ideas prior to undergoing SWH professional development. With electricity as the given big idea, this is unlikely.

What do students think about the big idea?

The students were also asked about the big idea for this unit during their written questionnaires. Figure 4.4 below summarizes the individual responses in Table 4.5 also below. As can be seen in the graph, many students were able to identify a related topic. It is important to restate here that this unit only had a topic present so the big idea was not possible to identify. It is also noteworthy that more students either left this question blank or wrote “nothing” for the big idea.

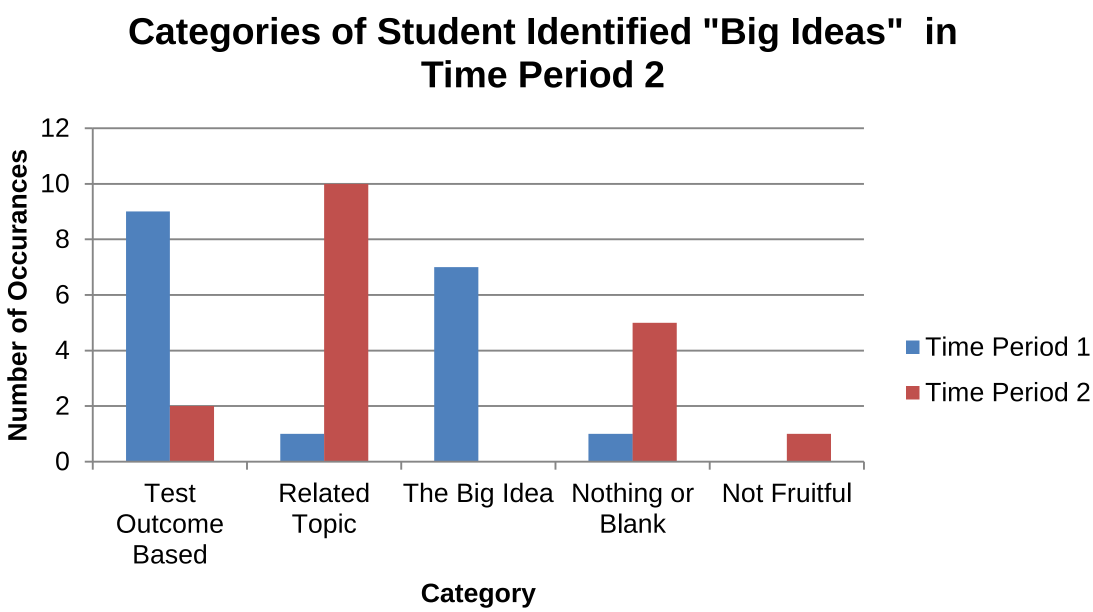


Figure 4.4 Time Period 2 "Big Ideas" by Students (SWA)

In Table 4.5 below, most students indicated something about how electricity works, wrote nothing, or indicated that they did not remember. In the first time period one student had written nothing while most students had indicated either to make an object go far (9 students) or force and/affects motion

(7 students). In time period two, seven students expressed ideas that were different than their classmates (with the exception of using a battery to light a light where two students had indicated that as the big idea). In the first time period, only two students indicated answers that were unique to their classmates and one of those did not write in an answer. This represents an increase in variability over the first time period. Figure 4.4 above does have a large proportion of students with a related topic, but the actual student responses that were grouped into that related topic were much more varied than in the first time period. This suggests students were less able to identify a consistent idea as the central concept to this unit.

Table 4.5 Big Ideas Identified by Students Between First Two Time Periods

Time Period 1		Time Period 2	
Make balloon/rockets fly/go far	9	How electricity works	6
Force and motion*	6	Nothing/Don't remember	5
Air Pressure	1	Get battery to light a light	2
Force effects motion	1	Do potatoes make electricity?	1
Nothing	1	Electricity: protons, electrons	1
		How electricity is made	1
		Makes objects work	1
		What has energy	1

Summary – Role of Big Idea in Second Time Period

This time period is initially oriented around a topic: “electricity”. This topic was used in a similar fashion to the big idea in the first time period, both serving as the central feature of student semantic webs. However, “electricity” is a topic without an embedded core concept to orient a unit around. This unit also showed overlap to lesson notes from years previous to SWH implementation with statements from the teacher indicating frustration and a lack of comfort with the approach. Students were much more varied in their responses in identifying what the big idea of this unit was. More students left this question blank on the questionnaire than in the first time period.

The Third Time Period – Light

What is the big idea and is it consistent with a “big idea”?

The big idea, “light”, was given to the students at the end of the second unit and they were instructed to compare and contrast light and electricity (SJ04-086). “Light” does not capture a core concept and therefore is not consistent with a “big idea”. “Light” is a topic; there are no inherent ideas or concepts, much less a core concept, embedded into it. Two possible big ideas for a unit on light are given in the *Questions, Claims, and Evidence* book given to teachers during professional development including: “Objects can be described by their properties and the materials they are made from” or “Objects (things) have properties (stuff) that you can see and feel” (Norton-Meier et al., 2008, p.160). While these do not explicitly focus on light, much of this unit oriented around the outcome of light striking matter and characterizing that matter based on the effect of light striking it. “Light” also appears as the title of the previous years’ PowerPoints as “electricity” had in the previous unit (TLP-03-02).

How is the big idea used?

This unit began with “light” being given as the big idea and students being asked to write down their initial ideas about light in a narrative comparison between light and electricity, their previous unit (SJ04-086). Following this, there is a discussion that comes after the students making a t-table as a class to compare light and electricity (TRN-101, RFN-1209-08). Unlike the second time period, this discussion was led almost exclusively by student ideas that were given during the t-charting exercise (RFN-1209-11). There were no demonstrations at this time; all of the ideas presented came from the student or from challenges to the student ideas (RFN-1209-13).

Is the use of the big idea consistent across the unit?

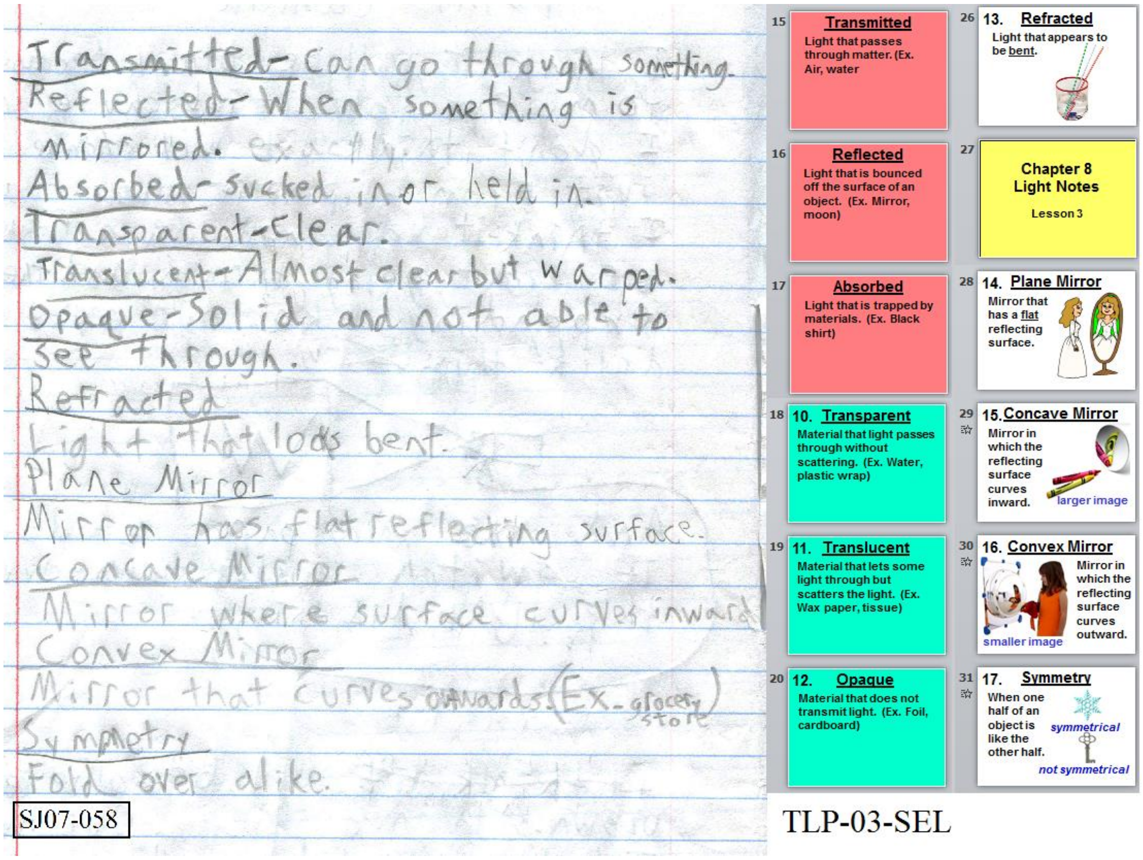


Figure 4.5 Student Notes Aligned to Previous Lesson Plans

As mentioned in the previous time period, there was an indication during the teacher interview that there was a return to prior teaching methods (TIN-1025). In the above example, a student journal (SJ07-58) was aligned to teaching lesson plans that had been used in years previous to SWH implementation (TLP-03). In Figure 4.5, the last component of coding indicates the slide number of the planning notes. Each slide has its slide number to the upper left of its image. The important note behind this alignment is that the order of terms in the student journal exactly matches the order of the slides presented in the Light unit lesson plan notes. There is also similarity in the wording used for many of the definitions (most notably slides 26 – 31). In addition to the alignment of the student journal and teacher slides, we also see this order presented to the students in the transcript after this activity had occurred in Table 4.6 below. This is compelling evidence of a return to previous, more comfortable lesson plans.

Table 4.6 Comparing In-Class Talk to Lesson Plan Notes

Speaker	Transcript
Teacher	The rest of you, what are the six things we talked about?
Students	Giving answers (lines 005 – 012)
Teacher	Ok, transmitted, reflected, absorbed, transparent, translucent, opaque.

TRN-105-004/013

What do students think about the big idea?

Students were also asked to indicate what they felt the big idea of this time period was in the student questionnaire. The results of this time period were rather similar to the second time period and are shown in Figure 4.6 below. Also like the second time period, no students were able to identify a big idea in this time period because there was no big idea given; light is a topic.

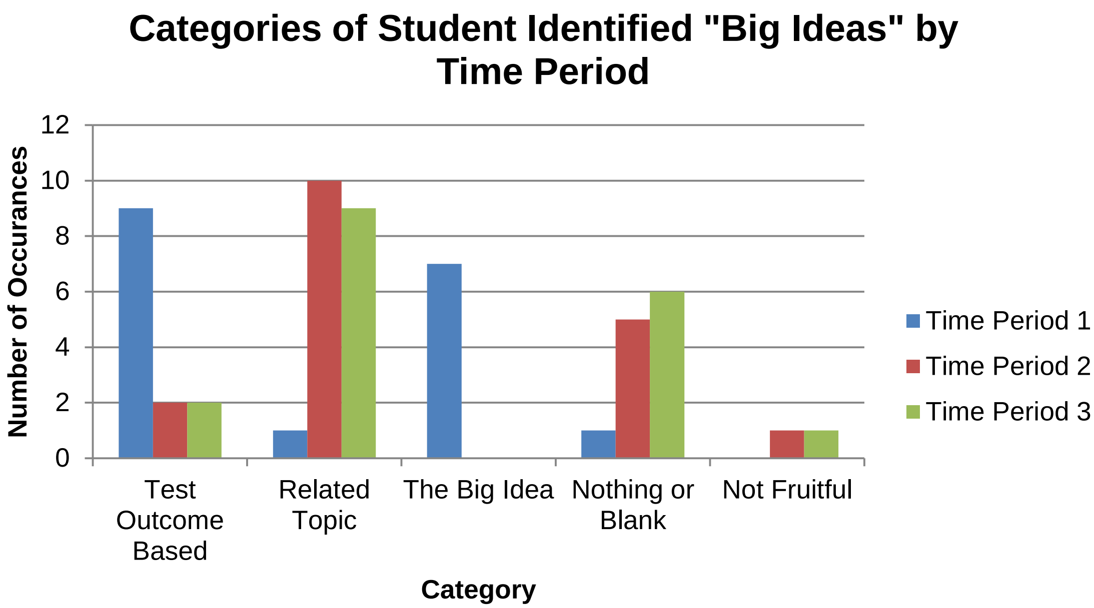


Figure 4.6 Time Period 3 "Big Ideas" by Students (SWA)

Table 4.7 Big Ideas Identified by Students

Time Period 1		Time Period 2		Time Period 3	
Make balloon/rockets fly/go far	9	How electricity works	6	Nothing/Don't remember	6
Force and motion*	6	Nothing/Don't remember	5	How light works	4
Air Pressure	1	Get battery to light a light	2	Learning about light	2
Force effects motion	1	Do potatoes make electricity?	1	What is light?	2
Nothing	1	Electricity: protons, electrons	1	Impacts of light	1
		How electricity is made	1	Light up a light	1
		Makes objects work	1	Power town with windmill	1
		What has energy	1	Where do we get light?	1

As can be seen in Table 4.7 above, many students left this question blank or indicated that they did not remember. In fact, this was the most represented category in this time period. Much like the second time period, there was an increased variability in responses as compared to the first time period. Also like the second time period, while many students identified a related topic, there was large variability inside that category. This indicates that, like the second time period, students were unable to connect to a single idea as the core of this unit.

Summary – Role of Big Idea in Third Time Period

This time period is initially oriented around a topic: "light". This topic was used in a novel fashion to the big idea in the first time period, by being compared and contrasted to the previous unit's topic: "electricity". However, "light" is a topic without an embedded core concept to orient a unit around. This unit also showed overlap to lesson notes from years previous to SWH implementation with statements from the teacher indicating frustration and a lack of comfort with the approach. Students were much more varied in their responses in identifying what the big idea of this unit was than the first time period. More students left this question blank on the questionnaire than in the first time period.

Overall Summary and Findings for Research Question One

The findings relating to the first research question are as follows: (1) The comparison of given big ideas to the NGSS core concepts indicated only the first time period contained a big idea and (2) The indicated big ideas were used in activities meant to elicit student prior knowledge but served less purpose after the opening activity and discussion. These are further elaborated below.

When asked what role the Big Idea should play in a unit, Taylor responded in a hesitant manner, saying:

> "I think, umm, well I guess you know getting the kids… hmm, how do I say it. Umm, I don't even know what I'm trying to say here. I mean, the kids need to learn and kids need to understand using life skills and science to guide them through whatever vehicle they're using to get there. So the big idea is a learning tool or a stepping stone to use to learn all that encompasses that, which is the standards that we're trying to teach them. Whatever that theme or big idea is, is the vehicle for them to take to get there. I'm not sure if that makes sense, it's spinning in my head but not really coming out." Taylor (TIN-1700).

In this way, the big idea is made somewhat comparable to the Iowa Core or National Standards in his view. The teacher noted a possible reason for some of his difficulty making use of big ideas was that they may have been too big stating: "I'm going to make those big ideas even smaller this year. I think it's going to help me…" (TIN-1215). He later clarified this point by stating: "…Earth is always changing (a big idea he used in his 7th grade classes) that's great but wow, where is that going to take us? Because it was so big, I didn't know where to start from there. We need to start with something smaller." (TIN-1550). This exchange provides insight into what happened with using big ideas during the semester. Taylor noted that he felt overwhelmed with big ideas and felt the students may also have been at times (TIN-1645). He also showed resolve in wanting to modify the way he had used the big ideas by making them smaller:

> "… Or if we did do 'Earth is Always Changing' as our big idea, but we're going to put it over here for a bit and drop off a leg here and talk about this smaller idea of this leg and how it relates back to the big idea but only focus on this leg right now and then come back to that and then come off another one for a little while." (Taylor, TIN-1625)

Of the three units, only the first unit presented with an actual big idea. Both of the other units presented a topic to the students. The first two time periods contained similar activities for eliciting prior student knowledge: semantic webbing of the given big idea. The third time period had a novel approach consisting of a t-chart comparison of the new unit, light, to the last unit, electricity. The first unit showed a lack of using the big idea throughout the unit. Both the second and third time periods showed significant overlap to instruction that had been given prior to SWH implementation. When combined with the teacher comments indicating a lack of comfort with the approach and stating some reversion to previous teaching approaches, compelling evidence of prior unit organization is offered. Students also had less success identifying a core unifying concept across the units after the first unit. In order to rule out the difference between the distinction of “topic” verse “big idea” from artificially amplifying differences, Figure 4.7 below groups the responses consistent with the big idea from the first unit into the category “related topic” to have a more direct comparison.

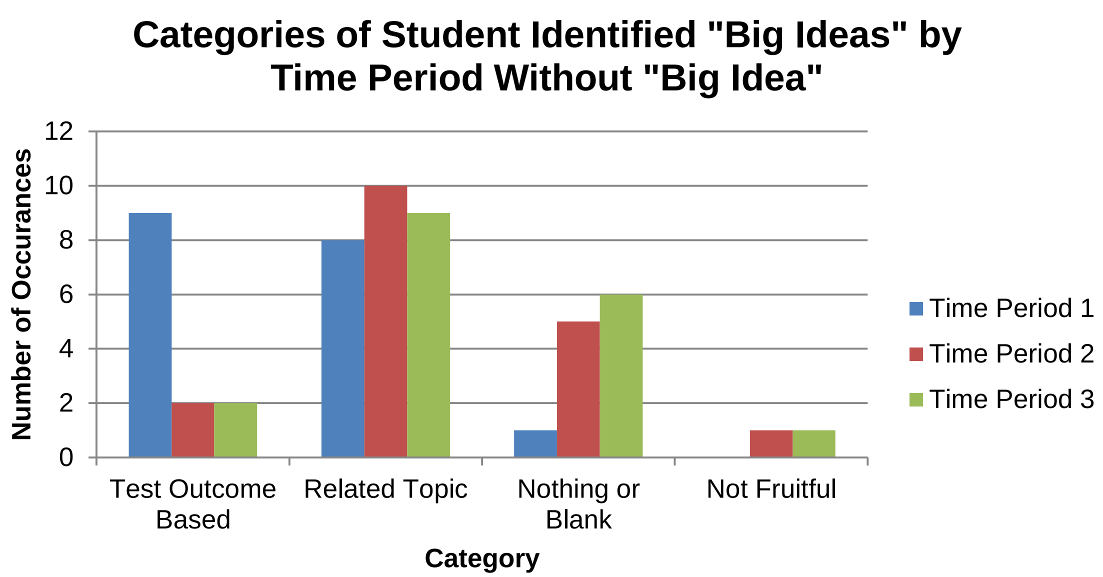


Figure 4.7 Categories of Student Identified "Big Ideas" by Time Period Without "Big Idea"

In this graph, many students indicate a related topic to the unit. What is interesting is the change in students no longer indicating the outcome of tests though they had previously done so as well as leaving time periods two and three blank or indicating "nothing". Some of this may be explainable by time period three containing demonstrations instead of experiments, though experimentation was seen in time period two.

The Second and Third Research Questions

As mentioned in Chapter 2, argument is a specialized form of dialogue. The results presented below have been grouped based on whether they better relate to argument or dialogue. This section is oriented around characterizing the discourse present in the classroom. As mentioned previously, this section will use a dialogue framework by Benus and colleagues (2013) as a starting point to exploring this classroom across the semester. Some features of this analytical framework have additional features that were explored to elaborate the individual categories, though the feature in the Benus et al. (2013) framework is bolded. This section will explore how argument and dialogue changed over the course of the semester.

The Development of Dialogue

The second research question asks: How did the dialogue in whole-class discussion change during the first semester of argument-based inquiry professional development? This question examines dialogue features independently to argument features which will be discussed later. The researcher would restate at this point that dialogue in a general sense is concerned with the exchange of ideas.

The First Time Period – Force Affects Motion

Table 4.8 Complexity of Question Scoring Time Period One

Feature	Time Period 1
Complexity of Question	1 (1)
What Types of Questions are being asked by the Teacher?	1
Role of Science Terms	1

Table 4.9 Sample Transcript for Complexity of Question

Speaker	Transcript
Context	Teacher releases inflated balloon. It moves across classroom. Students are experimenting during this discussion.
Teacher	Ok, is there a force there?
Class	Yeah
Teacher	Is there motion?
Class	Yeah
Teacher	Where? When the balloon is blown up, where's the force?
Class	In the balloon
Teacher	And when you let go, where does it go? It's shooting out of the balloon.
Bryce	Air pressure
Teacher	Air pressure is a force, is that… what happened to the balloon?
Class	It flew

Note: TRN-015-004/013

In this transcript selection presented above in Table 4.9, there are examples of questions that seek explicit knowledge from the students even though the opportunity exists to ask follow up questions that call for justification or evidence. These student statements stand devoid of supporting evidence. Especially during this opening discussion, there is an abundance of "what else?" questions, representing 9 questions out of 83 total class utterances. “What else” is not a question consistent with challenging student ideas. The researcher noted a lack of explanation building questions during this time period (RFN-0904-10, RFN-0910-08). There were a total of 11 “why” questions asked throughout all transcript data for this time period, six of these being asked in the same utterance (TRN-006, TRN-009, TRN-015, TRN-019).

The science terms used by students do not have definitions attached to them during this time period and teacher questions do not seek students’ explanations of those terms. Outside of the transcript segment presented below, no questions were asked that encouraged students to explain a force they had stated through the first two experimental periods (TRN-006, TRN-009, TRN-015, TRN-019). Additionally, what friction meant was only explore this far during those transcripts as well. The student journals have force diagrams relating to their balloon tests, but most are lacking explanations for how the forces impact the balloons under test (SJ05-184, for example).

Table 4.10 Sample Section Seeking Friction Explanation

Speaker	Transcript
Teacher	Me? Ok, what else? … (student mumbles) Say that word out loud.
Stan	Friction?
	Friction… what's friction? When two people are screaming at each other?
Teacher	What is it?
Tyler	When two things rub together they cause a type of electricity.
Bruce	Static!
	What does that mean? You guys are all rubbing your hands together or
Teacher	some of you are rubbing your hands together. What does that cause?
Bruce	Heat
Teacher	Ok heat. Why?

Note: TRN-006-064/070

Perhaps the best example in this time period of the importance of the science term verse the understanding of the science term occurred in the opening discussion. The teacher and Ann are engaged in a discussion about why a constant force was necessary to keep the globe spinning. They had seven exchanges back and forth without settling out that friction was a force that would stop the globe if it were not given “a constant force” (Ann, TRN-006-024). Another student utters the term “gravity” and this conversation is abandoned by the teacher without returning. This provides evidence that the priority of the teacher at this time was not on explaining the science terms as evidenced by the shifting away from Ann, who had given no science terms in her explanation though she was highlighting a core part of “force affects motion”. Definitions for science terms were not seen in the data until eight class days after this opening discussion, after the students had been experimenting for a full week (ED-01).

Table 4.11 Idea Exchange and Conversational Pattern of First Time Period

Feature	Time Period 1
Depth of Idea Exchange	2* (2*)
Conversational Pattern	1 (1)
Role of Teacher in Discussions	1

For this time period, a special notation was made for the scoring of Depth of Idea Exchange. Both the researcher and an author of the framework noted that there were few occasions where ideas were discussed beyond their initial utterance but the teacher did frequently provide a summary of previous ideas which was counted as comparing or checking a smaller element of the big idea. Many elements of the opening discussion were consistent with a scoring of “1” at the beginning of the class period, though some “2” elements appeared as the class went on. An example of summarizing student ideas is given in Table 4.12 below:

Table 4.12 Example of Summarizing Student Ideas

Speaker	Transcript
Tyler	You pushed it
Teacher	Ok, what else? Carson?
Carson	That when you pushed it, there was motion… which was it spinning. The force was you pushing it.
Teacher	Ok, what else?
Bruce	Umm. Motion comes from force?
Teacher	Ok, what else?
Tyler	I don't know what stopped it, but it stopped.
Teacher	Ok. So, I pushed it, it moved, and it stopped.

Note: TRN-006-007/014

However, both scorers agree that while summarizing student thinking does occur in this discussion, there are also examples where ideas are not appropriately questioned by the teacher. In the transcript section above, students are not providing explanatory answers, consistent with the previous analysis on types of questions being asked by the teacher. There were also examples of students providing explanatory answers with follow up that fell short of what would typically result in a higher scoring for this feature, as presented in Table 4.13 below. During the teacher interview, this segment of video was played back for the teacher. When asked if there was anything he noticed that he would do differently, he noted that he was looking for specific answers during this discussion but that he was not sure what answers he wanted to hear explaining that he was trying to emulate the conversation he had had during the original professional development (TIN-2828).

Table 4.13 Missed Opportunity to Explore Student Idea

Person	Classroom Transcript
Ann	It wasn't given enough force to keep going.
Teacher	Ok, how much force would it take to keep going?
Ann	Umm, a lot?
Teacher	A lot?
Ann	A constant force.
Teacher	A constant force? Why would it have to be constant?
Ann	Because just one push it would go around a few times and stop cause of the weight of the globe itself pulls it back.
Teacher	Ahh… ok. What was that?
Stan	(mumbles) gravity
Teacher	I haven't heard that word yet. Say it out loud.

Note: TRN-006-020/029

He also noted that in the first time period that he did not keep track of student ideas as well as he should have (TIN-2534). When the researcher specifically targeted the video associated with the transcript selection above for his opinion as to the ideas presented by Ann, Taylor did not note anything different he would do. Therefore it is likely that this follow up would be missed again if this conversation were to occur again.

Conversational Pattern and Role of Teacher in Discussions

The turns of talk per idea are used in this analysis to give an approximate indication of the amount of talk surrounding an idea in discussion. When looking at the number of turns of talk following an idea offered by students or elicited by the teacher in the time periods, the first time period has an abundance of short turns of talk per idea for the first discussion as seen in Figure 4.8 below. This is consistent with a lack of follow up questions to statements.

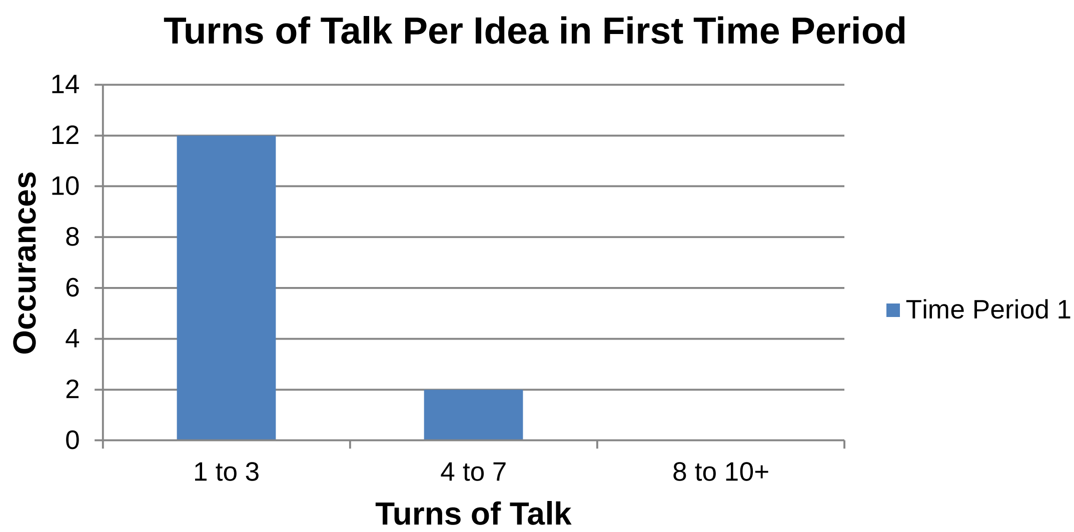


Figure 4.8 Turns of Talk Per Idea in First Time Period

Turns of talk per idea only illuminate part of the picture of a discussion. Another portion of this section involves who is a participant in the discussion. The above analysis focused on counting the total turns of talk by idea per time period which gives an indication of the duration that ideas may have been discussed in the classroom. The following graph looks at how many different students were involved in discussing each idea during these time periods. In Figure 4.9 below, we see that the first time period contained a large amount of individual students involved with the teacher when discussing ideas. This is somewhat expected due to the results given above. If there are only a few utterances per idea, then there are only a limited number of utterances for which students could participate. However, few students per idea and few turns of talk per idea is also consistent with IRE questioning.

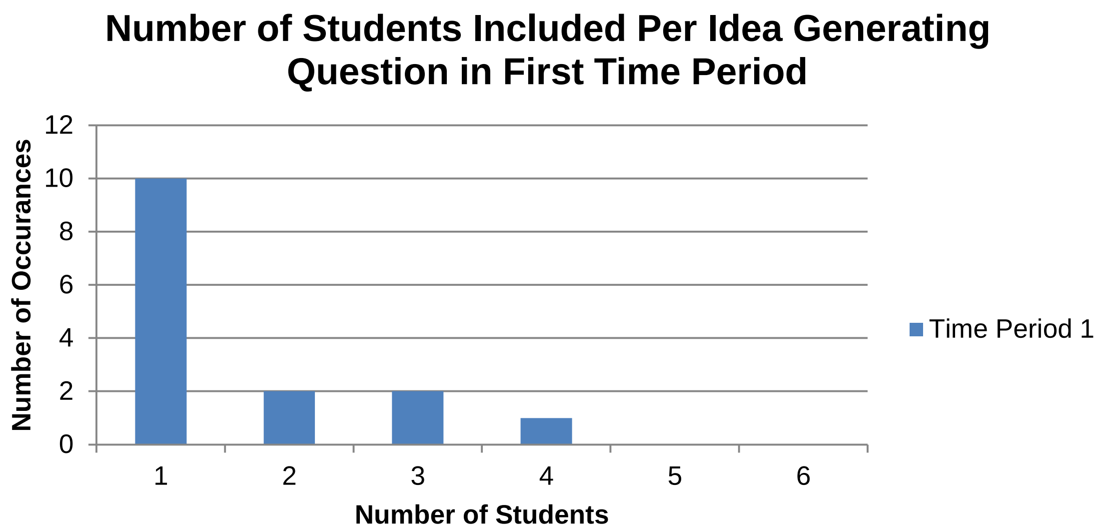


Figure 4.9 Number of Students Included Per Idea Generating Question in First Time Period

Table 4.14 Teachers vs. Students Discourse Data Time Period 1

Speaker	Time Period 1
Total Words Spoken	
Teacher	3243 Words Spoken
Students	570 Words Spoken
Total Turns of Talk	
Teacher	100 Turns of Talk
Students	92 Turns of Talk
Average Words Spoken Per Turn of Talk	
Teacher	32.4 Words per Turn
Students	6.2 Words per Turn

This section of analysis also includes examining who dominates the discussion, in terms of talking. The above analyses look at the talk oriented around ideas whereas the graphs below look at the total talk in the classroom. Table 4.14 above compares the total word count for class discussions, finding that the teacher has many more total words in than all students combined. The teacher also had more turns of talk than all students combined, consistent with IRE questioning. Lastly, the teacher had many more average words per turn of talk than the students. These analyses show a classroom discussion where students rarely talk after other students, and where the teacher maintains the vast majority of the talk in the classroom. When students talk, they tend to have short utterances which are frequently followed by much larger turns of talk by the teacher.

Comparing Dialogue Framework to Modified R-TOP Scores

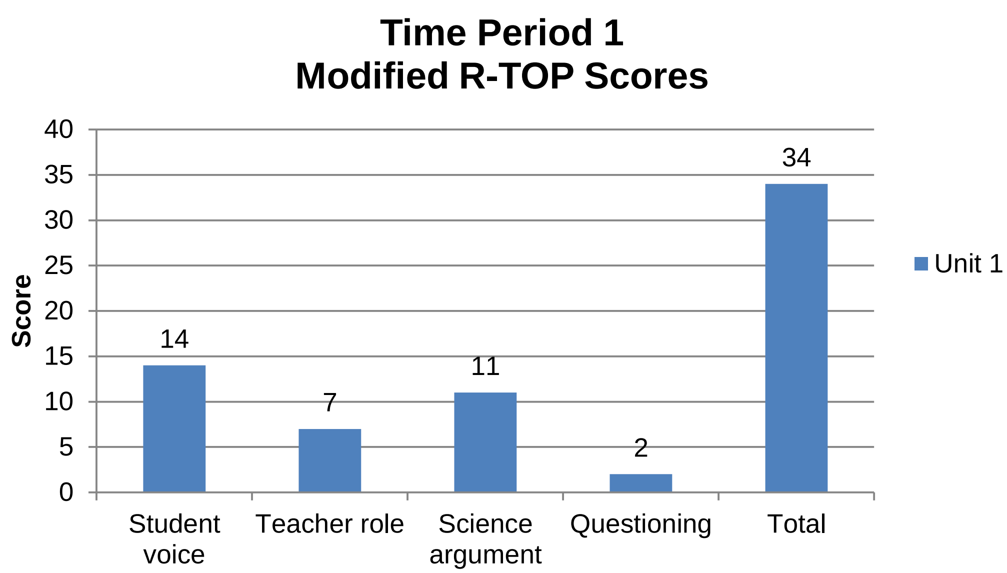


Figure 4.10 Time Period 1 Modified R-TOP Scores

The modified R-TOP scoring for this time period indicated a total score of 34 out of 52 total points, which is indicative of a *medium* (21-39 points) level of implementation as seen in Figure 4.10 above. Within the Student Voice feature, Taylor scored very high on instructional strategies that respected prior knowledge consistent with the semantic webbing activity described in the big idea analysis. He scored low on students communicating their ideas to others and a high amount of student talk with significant amounts of it being student to student talk consistent with the dialogue analysis. Taylor also scored low on asking questions that trigger divergent modes of thinking, consistent with having short conversations with few students per idea. He scored high on planning a lesson that functioned to support student investigations and being a “listener” in the classroom.

Summary of Dialogue in First Time Period

This time period scored low on the Complexity of Question feature, which is characterized by classrooms where students are typically not expected or asked to explain their comprehension of ideas or justify their ideas. This feature also had a clarifying feature associated with the types of questions the teacher was asking. It was found that many examples of IRE type questions that were not explanatory in nature were asked during this time period. A focus on science terms instead of seeking discussion exploring what the science terms mean was found. This is mostly consistent with the Benus et al. (2013) framework with the exception that their level 1 mentions explaining explicit knowledge. There were many examples of a lack of exploring what students meant with the science terms they were using.

This time period also exhibits many characteristics consistent with a teacher dominated classroom with IRE type questioning. This was seen by the sheer number of words spoken, the turns of talk, and the average number of words spoken per turn of talk which were all dominated by the teacher. Few students tended to participate in discussing ideas and few turns of talk were spent on each idea, additional characteristics of IRE questioning. These results were supported by the modified R-TOP scores, which tended to show that questions did not encourage divergent modes of thinking and had students that infrequently talked to other students about their ideas.

The Second Time Period – Electricity

Table 4.15 Complexity of Question Scoring Time Period Two

Feature	Time Period 1	Time Period 2
Complexity of Question	1 (1)	1 (1)
What Types of Questions are being asked by the Teacher?	1	2
Role of Science Terms	1	2

The transcript scored for this time period indicated the classroom was most consistent with questions seeking explicit knowledge. These questions in this time period tended more toward students defining the science terms they were using. This ultimately relates to explaining explicit knowledge as questions on the comprehension of these definitions were not seen in the collected data. There are also examples of questions that elicit student understanding. In Table 4.16 below, we see one such example where the teacher is following up on the assignment he had given in the prior class period to define certain science terms. In this section, after a student provides a definition, he asks whether or not it makes sense to the students. Unfortunately, there is not additional follow up after she indicates that it does not make sense. This type of interaction occurs three times in rapid succession at the start of this class period dealing with electricity, energy, and the interaction between energy and electricity (TRN-060-010/026). This limits the utility of the exercise because while students do look up definitions, they also express that they do not understand them.

Table 4.16 Example Discussion With Science Terms

Person	Classroom Transcript
Ann	We looked up energy and electricity.
Teacher	Ok and what is energy?
Ann	Energy is, uhh, it says the capacity for various activities.
Teacher	Ok, does that make sense to you? Does it make sense? Yes or no? Not really?
Ann	No
Teacher	Ok, that's fine. If it doesn't make sense that's why we keep going…

TRN-060-010/015

However, there are also examples in this same discussion where Taylor challenges students by asking them to draw a logical inference from their statements. In Table 4.17 below, a transcript segment identifying the first collected examples of Taylor asking students to expand or clarify a definition they had given for a science term. Also important is that this discussion of terms is occurring at the start of the unit after students had given questions they wanted to research which included many of the terms they were now struggling to define (RFN-1021-08).

Table 4.17 Example of Students Working With Science Terms

Person	Classroom Transcript
Teacher	Ok, the flow of electric power or charge. Katie?
Katie	We had electricity is a form of energy.
Teacher	Ok, is a form of energy. Alright, so what is energy?
Katie	It… energy is… uhh… it is used to do work.
Teacher	So energy gives us electricity. So, I have energy?
Class	Yeah
Bruce	Yeah, you're making… you're doing work.
Katie	You're doing something.

Note: TRN-060-019/026

Importantly, these are the science definitions, not the students' own definitions of the science words. This is demonstrated by the teacher assigning terms from the opening discussion to groups to look up their definitions prior to the onset of experimentation (RFN-1019) and following up in a class discussion to ensure the definitions are given during the class period (TRN-060). However, most student journals do not have any definitions of these terms; only a few student notebooks actually contain definitions related to these terms (SJ-14-126, SJ-11-013). Students left their journals in the classroom and this was a take home assignment, so only those students that copied over definitions would have them in their journals (RFN-1019).

Table 4.18 Idea Exchange and Conversational Pattern Second Time Period

Feature	Time Period 1	Time Period 2
Depth of Idea Exchange	2* (2*)	2 (2)
Conversational Pattern	1 (1)	2 (2)
Role of Teacher in Discussions	1	1

While there are times during the discussions that Taylor asks his students if definitions made sense to them, there were also times that he follow up to help explore what that definition means to the students. As presented above this was done by drawing a logical conclusion from a student statement: If energy is used to do work, then do I have energy? (TRN-060-023). During this time, he also held a class discussion while demonstrating objects relating to electricity. While looking at Romex wire, a discussion was had as to why cardboard and a plastic insulator were on the wire. This ended up working into talking about conductors and insulators and how cardboard (an insulator) can become a conductor by getting wet (TRN-060-039/066). Unlike the first time period that had students answering individual questions, during this discussion Taylor gathered multiple student ideas on several of the ideas under discussion (TRN-060-052/054/058/062/064, for example). These events were consistent with a classroom that compared ideas against other ideas and even drew out discussions about those ideas for several turns of talk.

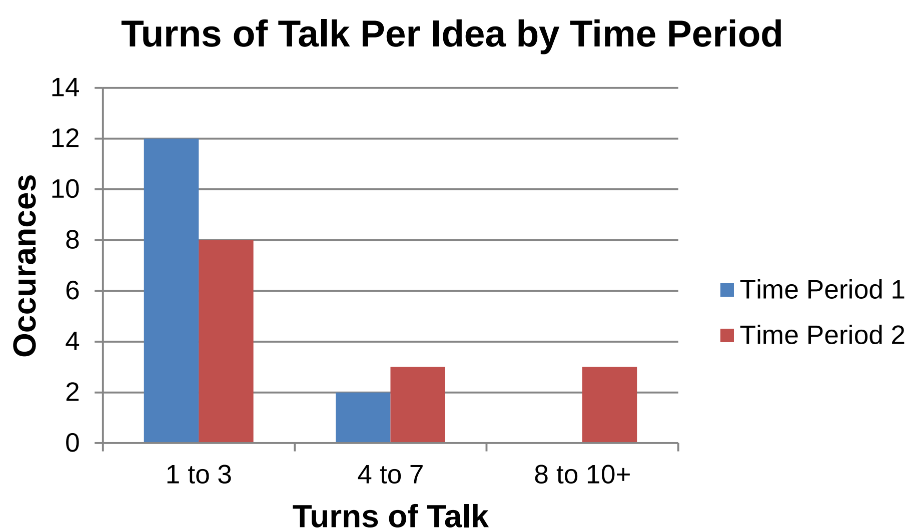


Figure 4.11 Turns of Talk Per Idea Second Time Period

When compared to the first time period, the number of turns of talk per idea was greater on average in the second time period opening discussion. There were a number of instances where ideas were discussed for eight or more turns of talk, something that had not been seen in the first time period. This time period also saw a decrease in the number of 1 to 3 utterances per idea, consistent with an increase in the amount of talk surrounding ideas.

An analysis of the number of students per idea was also done. An important note here relates to Figure 4.11 above: more turns of talk per idea allows more opportunities for additional students to join a discussion because there are more available turns of talk. When comparing the first and second time periods in Figure 4.12 below, there are several ideas that have a relatively large number of students involved in the discussion. However, while there are many more discussions involving four or more students per idea, the most common category is still one student per idea. This relates to the amount of turns of talk spent discussing each idea, an important component to dialogue.

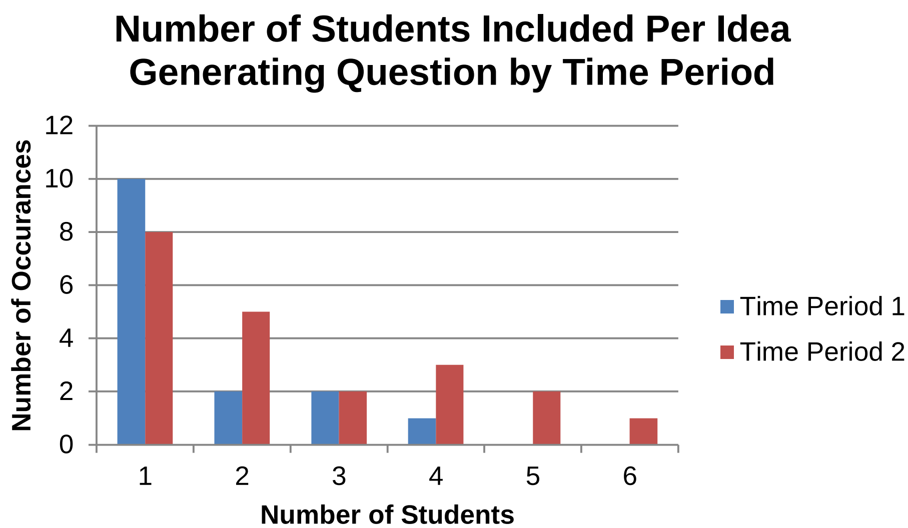


Figure 4.12 Number of Students Per Idea in Second Time Period

Table 4.19 Teachers vs. Students Discourse Data Time Period 2

Speaker	Time Period 1	Time Period 2
	Total Words Spoken	
Teacher	3243 Words Spoken	1579 Words Spoken
Students	570 Words Spoken	693 Words Spoken
	Total Turns of Talk	
Teacher	100 Turns of Talk	133 Turns of Talk
Students	92 Turns of Talk	157 Turns of Talk
	Average Words Spoken Per Turn of Talk	
Teacher	32.4 Words per Turn	11.9 Words per Turn
Students	6.2 Words per Turn	4.4 Words per Turn

In Table 4.19 above, the total words spoken by the teacher is dramatically reduced. However, while the teacher talked less than half as much as the first time period, student talk increased by less than 25%. Another important difference was the larger proportion of student turns of talk to teacher turns of talk as compared to the first time period. Both teacher and student average utterances were shorter in this time period. As reported in the big idea analysis of this chapter, this time period was marked by some reversion to prior teaching oriented around a guided discussion by the teacher. We see multiple examples of the kinds of questions being asked as well as the types of answers being offered by the students.

Comparing Dialogue Framework to Modified R-TOP Scores

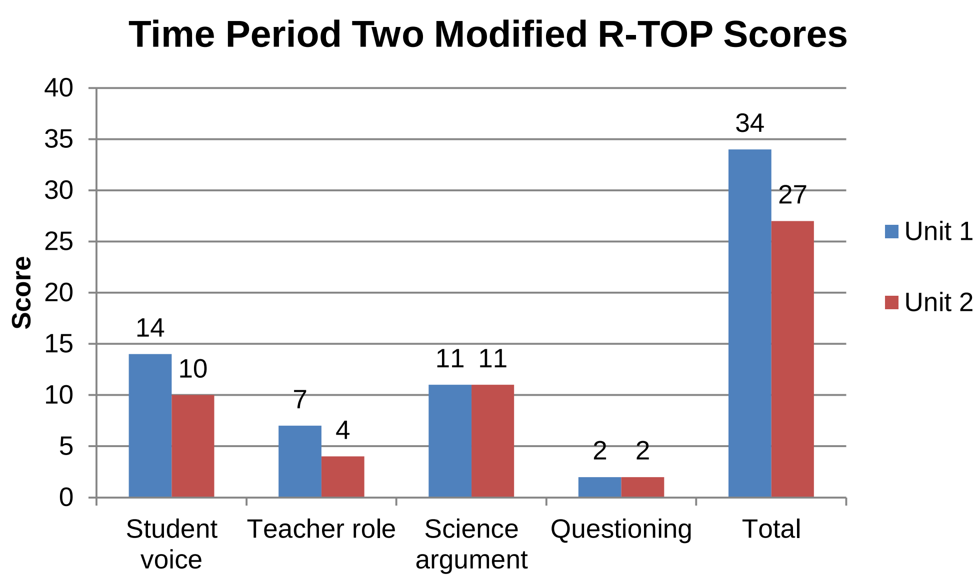


Figure 4.13 Time Period Two Modified R-TOP Scores

Overall, the modified R-TOP scores for this time period were reduced compared to the first time period. This is consistent with the teacher stating he had some reversion to prior teaching approaches because his prior teaching was not likely aligned to argument-based inquiry. A score of 27 is consistent with a low implementing teacher. For the analyzed transcript, Taylor scored low in most categories for Student Voice including the student voice determining the direction of the lesson and the teacher acting as listener, consistent with the lesson plans formed prior to SWH implementation that were aligned to the teacher-led, structured class discussion in this time period. He also scored low on the amount of student talk as well as students communicating their ideas to others. His questions did not appear to trigger divergent modes of thinking often for this scoring.

Summary of Dialogue in Second Time Period

This time period scored similarly to the first time period on the Complexity of Question feature, again characteristic of classrooms where students typically are not asked to explain their comprehension of ideas or justify their ideas. This was supported in the modified R-TOP scoring, indicating low amounts of student talk and students communicating their ideas. However, this unit differed from the first on the types of questions being asked by the teacher as well as the role of science terms. In this unit, examples of teacher questions that elicited student understanding were found. Students were also expected to at least give definitions of the science terms they were using. This time period also saw a reduction in the amount of teacher talk as compared to student talk, though the student talk did not increase much as compared to the first time period. In contrast to the first time period, students had more turns of talk than the teacher. There were also some extended conversations about ideas with more students involved per idea than in the first time period. While this time period saw less discussion orally dominated by the teacher, it is important to remember that this time period also saw discussions oriented around previous teaching approaches. In this way, the discussions were still being controlled by the teacher through the explicit use of objects used to highlight ideas he viewed as important.

The Third Time Period – Light

Table 4.20 Complexity of Question Time Period Three

Feature	Time Period 1	Time Period 2	Time Period 3
Complexity of Question	1 (1)	1 (1)	2 (2)
What Types of Questions are being asked by the Teacher?	1	2	2
Role of Science Terms	1	2	2

In this time period, Taylor held a class discussion unlike others seen in the previously collected data. In this discussion (TRN-101), he started by using student comparisons of the previous unit, electricity, to the new unit, light. This assignment was given to them on Edmodo (ED-06-01) and then they were to discuss what they wrote as a group. This activity was written on the board and served as the focal point of the opening discussion into the light unit (RFN-1209-01). The discussion that occurs is founded on these student ideas and the comparisons they made between electricity and light (TRN-101). These comparisons were completed prior to the discussion are generated in student groups and are written in their student journals (SJ-03-05) unlike the two previous units that contained semantic webs leading into the units. Within this opening discussion, there are a number of examples of the teacher challenging student ideas directly (TRN-102-021/033, TRN-102-048/056, TRN-102-070, for example) as well as working to bring together student ideas into a consensus (TRN-102-048). The questions challenging student statements also encouraged students to elaborate on their ideas, which is consistent with the second level scoring on the Benus et al. (2013) framework. This discussion was not scored a three because no justification was sought throughout (RFN-1209-15).

The questions that challenged students challenged them on their own idea and the words they were using to describe a phenomenon. For example, a student was describing what happens when they get a (static) shock. They stated they were able to see the little light which looked like "blue static". This was challenged by the teacher six turns of talk later in in terms of whether the student was seeing the electricity or the shock (implying that they are different, TRN-102-038/048). In this exchange, not only did the teacher keep track of the student ideas, he also summarized them into one claim to challenge all of the students at once. This meant that the student ideas had time in the classroom discourse prior to challenge or evaluation (RFN-1209-13).

However, in other transcripts, there are examples of students reciting science terms and in essence filling out work sheets elaborating on those science terms (TRN-105-004/017). In the next class period, these definitions are then explored using the students' own words in a given assignment called "Light Striking Matter Posters". In this quote, the teacher has identified that students have not explained what *they* mean when they use a given term and is making explicit the expectation that they do so.

> … I want you to continue with your writing. This writing is for in sixth grade terms and sixth grade words, understanding those six things. Transmitted, reflected, absorbed, ok, translucent, transparent, and... opaque. Ok, those six things. You're not writing definitions, you're writing what they mean to you… What have you learned about those things, and why? I'll give you as much time as needed… (Taylor, TRN-107-005)

For this time period, ideas tended to be discussed for many turns of talk. As can be seen in Figure 4.14 below, few ideas had short discussions while extended discussion of at least eight turns of talk were common. However, this time period did not score higher partially as a result of a lack of a big idea to orient discussion around. Additionally, though these conversations were extended, many related to checking that students were saying comparable things and then challenging the resultant idea.

Table 4.21 Idea Exchange and Conversational Pattern Time Period Three

Feature	Time Period 1	Time Period 2	Time Period 3
Depth of Idea Exchange	1* (2*)	2 (2)	2 (2)
Conversational Pattern	1 (1)	2 (2)	2 (2)
Role of Teacher in Discussions	1	1	2

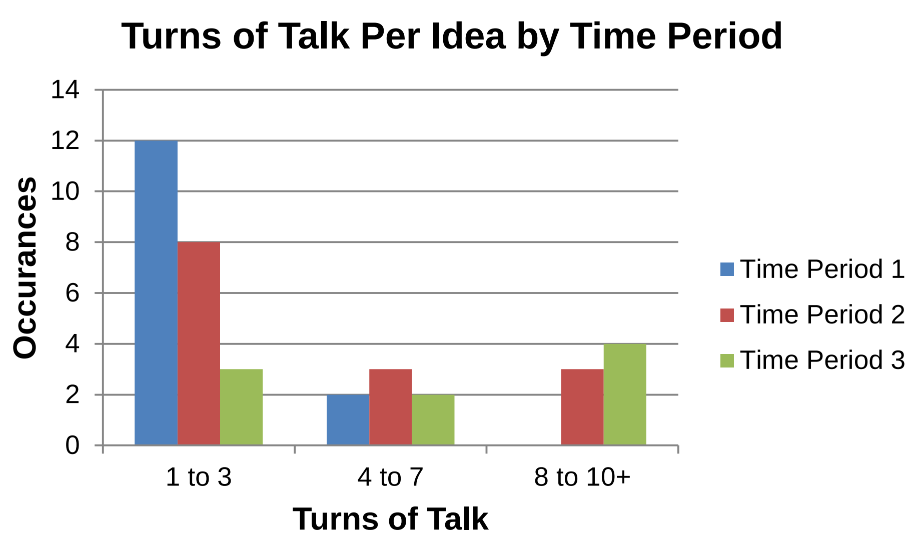


Figure 4.14 Turns of Talk Per Idea by Time Period

When compared to previous units, many more students tended to be involved in idea discussion throughout this time period. In fact, there was only one instance of a single student involved with an idea. Some of this may be the result of extended discussion about an idea allowing additional opportunities for more students but this time period also saw an explicit focus by the teacher to bring in other students to the discussion (RFN-1209-05). This was also the first time period where it was noted that he sought consensus or disagreement in the classroom, stating: "anyone have a problem with that (idea)?" (TRN-101-004) and "does everyone agree with that?" (TRN-101-035). This time period sees the direct challenge of student ideas frequently taking multiple turns of talk to resolve as well as some sense of consensus making (TRN-101-037/057). Also important for this time period is that all of the talking points brought up by the teacher are student ideas that they have placed onto the board (RFN-1209).

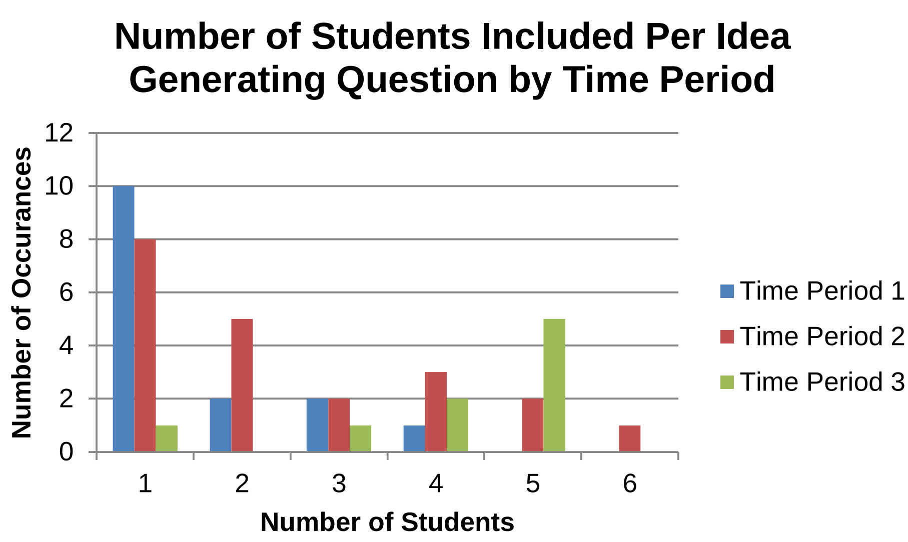


Figure 4.15 Number of Students Per Idea By Time Period

Table 4.22 below summarizes the later graphs comparing these constructs across the three time periods. Each graph will be discussed independently to better highlight the differences in each construct.

Table 4.22 Teachers vs. Students Discourse Data

Speaker	Time Period 1	Time Period 2	Time Period 3
		Total Words Spoken	
Teacher	3243 Words Spoken	1579 Words Spoken	2194 Words Spoken
Students	570 Words Spoken	693 Words Spoken	573 Words Spoken
		Total Turns of Talk	
Teacher	100 Turns of Talk	133 Turns of Talk	104 Turns of Talk
Students	92 Turns of Talk	157 Turns of Talk	112 Turns of Talk
		Average Words Spoken Per Turn of Talk	
Teacher	32.4 Words per Turn	11.9 Words per Turn	21.1 Words per Turn
Students	6.2 Words per Turn	4.4 Words per Turn	5.1 Words per Turn

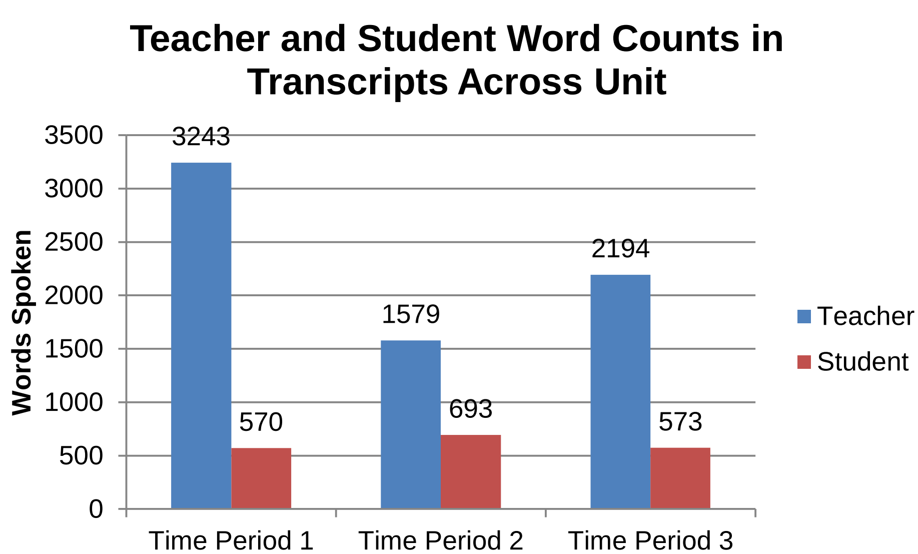


Figure 4.16 Teacher and Student Word Counts Across Units

In time period three, the teacher had slightly more words spoken than in the second time period, while maintaining many less than the first time period. However, the student talk remains rather consistent across all three of these units. This suggests that there is more to increasing student talk than simply decreasing the amount of teacher talk for this classroom. A trend similar across all three units is noted in Figure 4.17 below, the teacher and student turns of talk remain relatively similar for all three units with the largest difference occurring in the second time period. Though it is important to note that this time period also frequently had multiple students joining into discussions, that the teacher and student number of turns of talk is similar suggests that they were being brought into the discussion by the teacher. This data is consistent with the field notes taken during this discussion (RFN-1209-11).

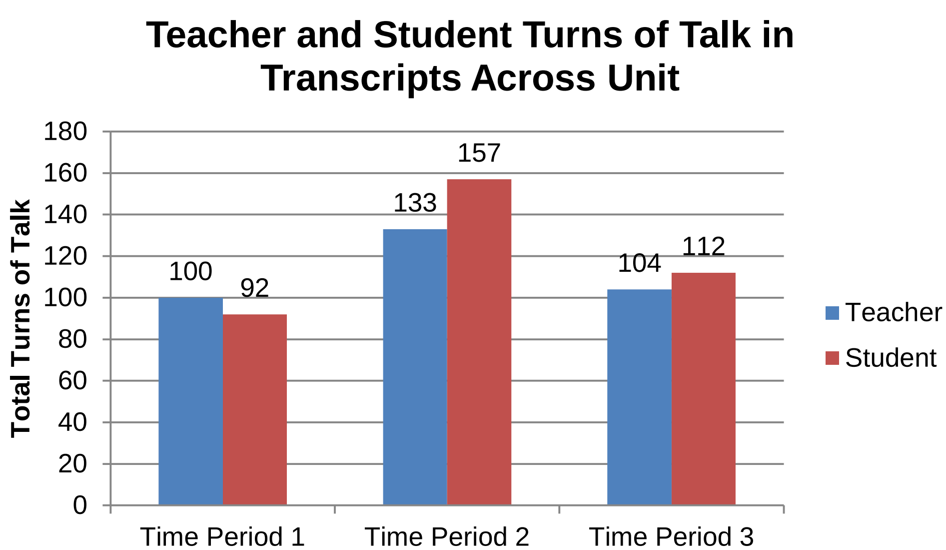


Figure 4.17 Teacher and Student Turns of Talk Across Units

Lastly, there is an increase in the average words spoken by the teacher in this time period. As with the number of words spoken, the student average words per turn of talk is rather consistent across all three time periods. This average of words per turn of talk is still somewhat low if student statements tended to be explanatory in nature as five words in a turn of talk would tend to be insufficient to explain one's thinking. It is possible that student explanations were drawn out over many turns of talk, each consisting of shorter utterances.

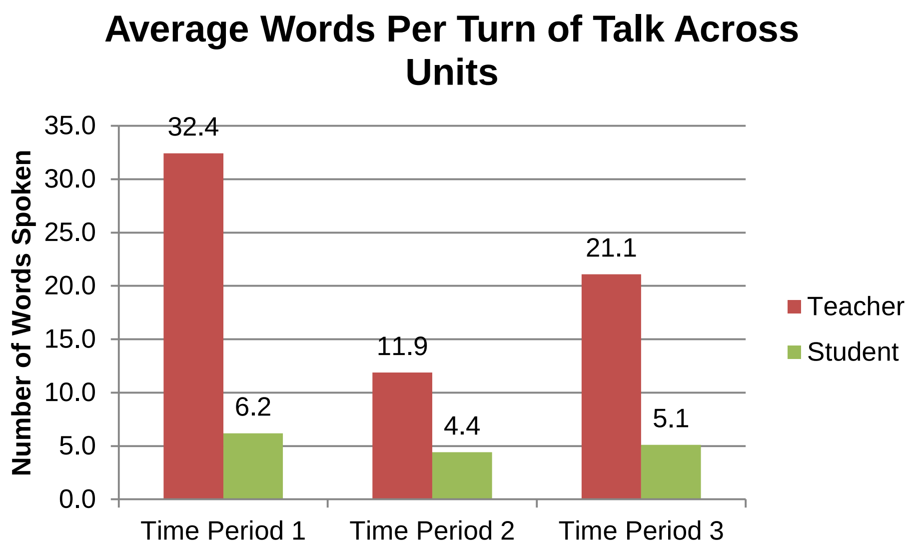


Figure 4.18 Average Word Per Turn of Talk Across Units

Comparing Dialogue Framework to Modified R-TOP Scores

Many of the scores relating to dialogue for the modified R-TOP were highest in this time period. Every feature related to Student Voice increased in this time period as compared to the second time period, indicating more student talk and students communicating their ideas to others. This time period was also the highest score for the teacher triggering divergent modes of thinking. This is consistent with the increases seen for the dialogue component of the Dialogue Framework.

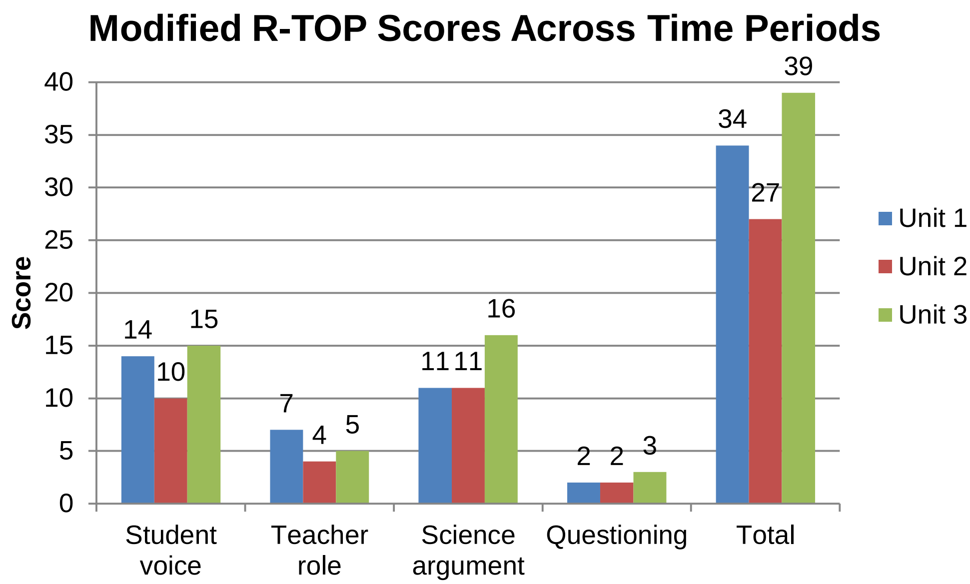


Figure 4.19 Modified R-TOP Scores Across Time Periods

Summary of Dialogue in Third Time Period

This time period was somewhat interesting in terms of idea development. There were a number of novel things observed by the researcher in this time period, such as seeking consensus or integrating student ideas together and challenging them as a whole. The teacher then stated to the students that they must write out science terms in their own sixth grade words. There were evaluative statements by the teacher in this time period, such as “anybody have a problem with that (idea)?... Nobody besides me?” (TRN-101-004). An important note with this utterance is that it occured on the first student idea he introduced for discussion and occurred after no students had entered discussion.

However, in the opening discussion the teacher appeared to disagree with a student claim but refrained from immediate evaluation of the idea (TRN-102-037/057). The teacher challenged student ideas such as the following exchange when challenging a student discussing electrical fires as they relate to appliances: “But does it? If you want a fire, do you go plug something in?" (TRN-102-070). While working through this discussion, Taylor sought consensus in the classroom (TRN-102-035, TRN-102-077) as well as explicitly sought students that disagree with other student statements (TRN-102-037). When no consensus was reached, he made a note of the student idea on the board with a star to revisit it later (TRN-102-035, TRN-102-097). Finally, he worked to integrate different ideas presented by the students into a larger idea (TRN-102-109). At the conclusion of this opening discussion, the teacher noted how successful he felt the discussion was by stating: "Why can't they all be like this?" (TRN-102-124) and "How do I help them do this more?" (TRN-102-126).

Research Question Two Overall Change in Dialogue and Findings

The findings related to this research question are: (3) The types of teacher questions shifted toward students explaining their comprehension of ideas and toward more students being involved in discussing each idea than in earlier time periods and (4) Understanding science term definitions became more prominent later in the semester, with more stating science terms occurring earlier in the semester. Over the three units, the Complexity of Question increased. This is consistent with an increase in questions that sought students to explain their comprehension of ideas instead of stating explicit knowledge. Early in the semester, discourse patterns consistent with IRE questioning was observed. By the third time period, the teacher questions occasionally challenged student statements, something that had not been seen previously.

There was a change in the way science terms were used throughout the semester. Initially, the science terms were given without definitions or explanations. In the second time period, these definitions were given as an explicit assignment to students but there was no check for understanding of the given definitions. In the third time period, both definitions and an explicit assignment to restate science terms in the students' own words was given as well as an assignment that had them correctly apply the terms.

Most ideas had few turns of talk spent discussing them, almost all in the first time period discussion having one to three turns of talk. By the end of the semester, there were lengthy discussions seen spanning more than eight turns of talk per idea. While some short exchanges still occurred, this time period had a large reduction in these short exchanges (three as compared to twelve in the first time period and eight in the second).

Few students initially participated in discussions for each idea, with a vast majority of ideas involving the student and teacher only. The second time period had a variation of few students to many students per idea with the third time period most frequently having four or five students per idea. There was also a large proportion of teacher talk present in all units.

The teacher dominated classroom talk in all time periods, having at least twice the number of spoken student words in every time period and five times at the maximum. The teacher also had similar turns of talk to total student turns of talk. This is consistent with the students talking to or through the teacher instead of talking to other students. This would also indicate a teacher that controls the discourse of the classroom by controlling access to who gets to speak.

The Development of Argument

Both of the features Classroom Interaction and Evidence-based Ideas have an explicit focus on justification, reasoning, or evidence. An important note about the Evidence-based Ideas feature is that it was initially meant to be examined in the presentation of claims and evidence. This study did not have a public presentation of claims and evidence. However, if this practice were common in the classroom, it is unexpected that it would only occur within presentation of claims and evidence and would therefore have elements present during many aspects of classroom instruction.

The third research question asks: How did the argument in whole-class discussion change during the first semester of argument-based inquiry professional development?

The First Time Period – Force Affects Motion

Table 4.23 First Time Period Classroom Interaction and Evidence-Based Ideas

Feature	Time Period 1
Classroom Interaction	1 (1)
Evidence-based Ideas	1 (1)

As mentioned in the dialogue analysis, in time period 1 there are few examples of student utterances following other student utterances. This would also minimize the opportunities for students to be able to ask other students questions, a characteristic of level 1 Classroom Interaction. Few student questions were identified in the transcripts for this time period (TRN-006, TRN-009, TRN-015, TRN-019)., To clarify, if students are not asking questions that call for justification, reasoning, or evidence then this task, if present, must fall on the teacher. In this time period student claims and evidence were not publically presented, though many are present in the student journals (SJ05-181, for example). The student questions asked during this time period are presented below, removed from this list are students guessing at answers with an inflective tone. These questions are also only for whole-class discussion, additional small group questions are expected. Some of the questions presented below, though in whole-class discussion, were asked by a student to their group (TRN-009-058, TRN-009-060, TRN-015-050).

- Are we testing today? (TRN-009-021)
- What's our beginning claim? (TRN-009-058)
- How far will it go? (TRN-009-060)
- Do we need to do our tests? (TRN-009-115)
- Why don't we just put wings on it? (TRN-015-050)

While there are inflections on a host of student utterances, these are almost exclusively students answering a teacher question and being unsure about their answer (TRN-006-22/32/59/61/63/65/85, for example). In subsequent transcripts, students did not tend to ask questions with explanatory answers, for example "what's our beginning claim?" (TRN-009-058). No examples of questions that seek explanatory answers were found in the transcripts (TRN-006, TRN-009, TRN-015, TRN-019). Justification of ideas requested by the teacher was also not well represented in the data. Ultimately, student questions in whole-class discussion were an infrequent component of this unit.

The term "evidence" only appears twice in all of the transcribed classroom talk by any participant in classroom discussion (TRN-006, TRN-009, TRN-015, TRN-019). An interesting note during this time period is the way the teacher uses the word "evidence". When assigning the groups to experiment, the teacher tells the students: "… and you're going to write down all of your evidence?" (TRN-009-077). Being that the context of this discussion was writing down evidence during experimentation that would follow and that later in the class period the three goals indicated by the teacher for the students were: to be able to state the "design, your claim, and how you're going to chart the data that you are doing" (TRN-009-114), it is likely that the teacher was using these terms somewhat interchangeably.

The students during this time period do exhibit claims at the start or conclusions of their tests even though it does not appear to be present in the classroom discussions aside from assigning it to the students (SJ11-003, SJ05-183, SJ07-206, for example). The researcher noted that there was not much development of claims or evidence by the students or discussion during the time when the students were experimenting (RFN-0906). At the end of data collection for this unit, the researcher urged the teacher to encourage explanation building by the formation of force diagrams as a result of what was a perceived lack of explanation building through experimentation and resulting small group discussions (examples: SJ11-005, SJ02-011, SJ05-184, SJ07-209).

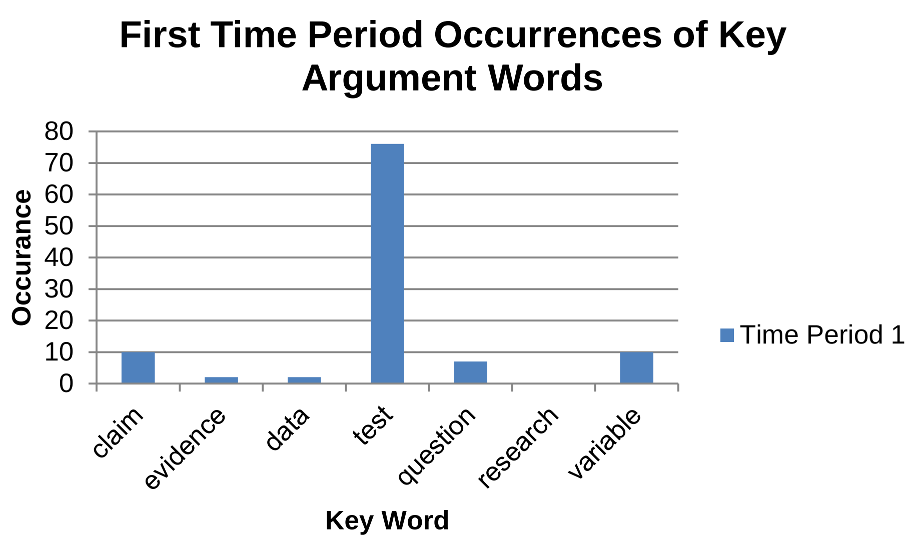


Figure 4.20 First Time Period Occurrence of Key Argument Words

Figure 4.20 above reports terms from all transcripts for the first time period for select terms. In a class making use of a claims and evidence approach to science, both of these terms would be expected to occur in the classroom discourse. While these terms do appear, they are much less frequent than might be expected and more than seven times less frequent than the most common term "test".

Summary of First Time Period Argument

There was little evidence of the use of claims and evidence in the classroom during this time period. A student noted during discussion: "It needs a claim, evidence, how you did it." (TRN-009-030). This indicates students know what is expected of them in classrooms utilizing an SWH approach. However, this was not reflective of the classroom discourse as there were few mentions of claims and even fewer mentions of evidence in the transcripts. The researcher noted a lack of explanation building, especially using evidence, in this classroom toward the end of data collection.

The Second Time Period – Electricity

Table 4.24 Second Time Period Classroom Interaction and Evidence-Based Ideas

Feature	Time Period 1	Time Period 2
Classroom Interaction	1 (1)	1 (1)
Evidence-based Ideas	1 (1)	1 (1)

In the second time period, students state their questions for experimenting (TRN-059-005/014/022/026) and provide guesses to answers as in the first time period (TRN-059-024). Of 22 total student questions in this time period, eleven were determined to be stating experimental questions, four were the result of guessing at an answer, and six were unrelated to the topic at hand. This left one student question: What about just electricity not energy? (TRN-060-193) stated as his group designed their test question and had expressed concern over the difference in terms. This would imply that if students are challenging other students, they are doing so via statements. No examples of students asking other students questions or questions with an explanatory nature are found in the transcripts (TRN-059, TRN-061).

In the second time period, students crafted their own experiments from questions they established as groups. Students reported what they had learned to Edmodo, a forum based website that allows students the opportunity to post replies to student threads. The teacher had the students post "what they had learned" so that they were private between him and the posting student, not available to the whole class (VID-066-2340). This reduces the ability for the class to negotiate claims and evidence in ways that would be consistent with an SWH approach. The terms "claim" or "evidence" do not appear in the transcripts for this time period (Figure 4.20). Dr. Yarker, an author of the analytic framework who scored the transcripts, stated "I could not identify a claim" throughout the discussion (E-mail from Dr. Yarker). Additionally, it is critically important to note the distinction between a presentation of claims and evidence as opposed to posting what had been learned. Two of these submissions are presented below in their entirety. As can be seen in the student reports, there is no supporting evidence offered to support any potential claim they have given.

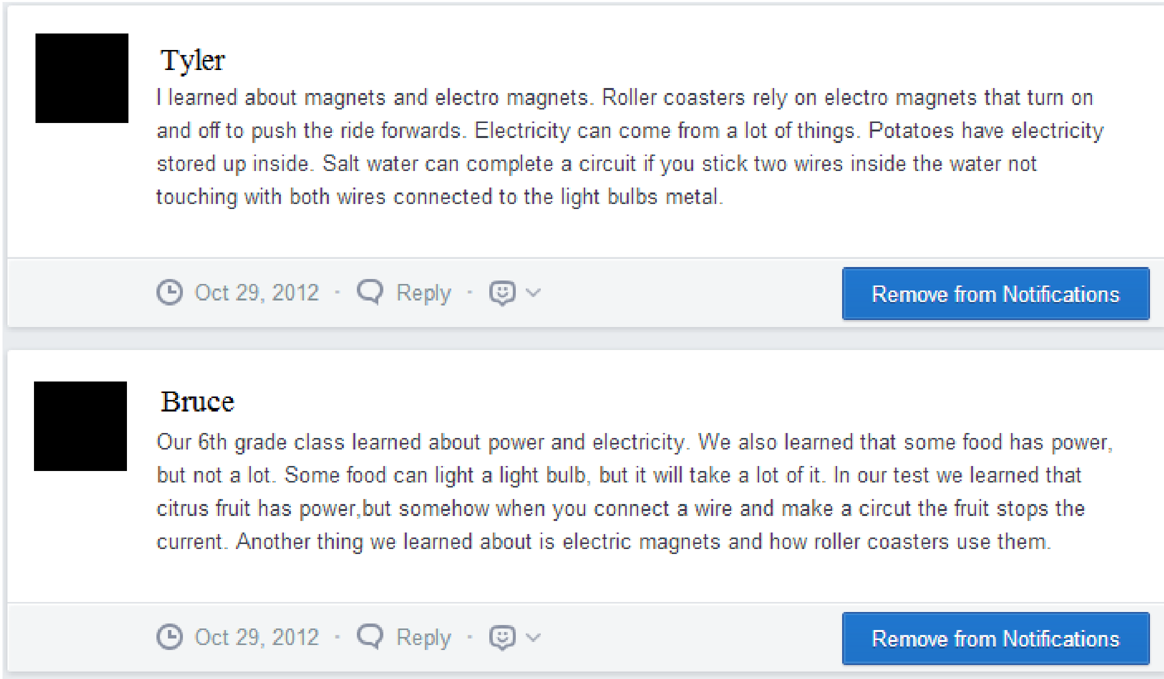


Figure 4.21 Two Edmodo Submissions of What Was Learned

Very few key terms were found during this time period. In none of the available transcripts did the terms claim or evidence appear, though students did experiments in this time period. Students wrote testable and researchable questions at the start of the unit. Some of these students researched about plant energy as they were testing electricity in plants. Below is a copy of a student journal and what she found about energy in plants. Had there been a discussion about these questions, this information could have presented tools to the class to talk about whether or not this energy was electricity. Also on this page was a question about how electricity travels and an answer stating that it needs a circuit (SJ12-166). Neither of these were brought into the class discussion.

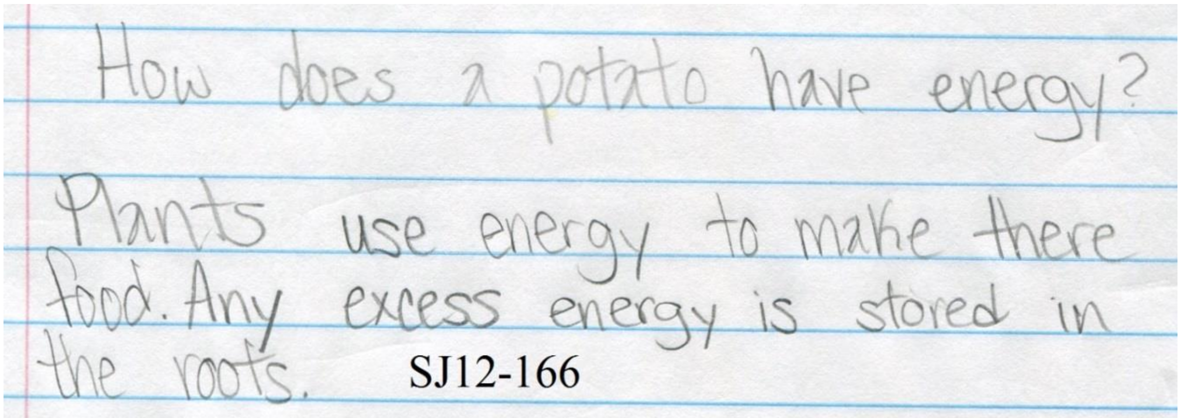


Figure 4.22 SJ12-166 Potato Energy

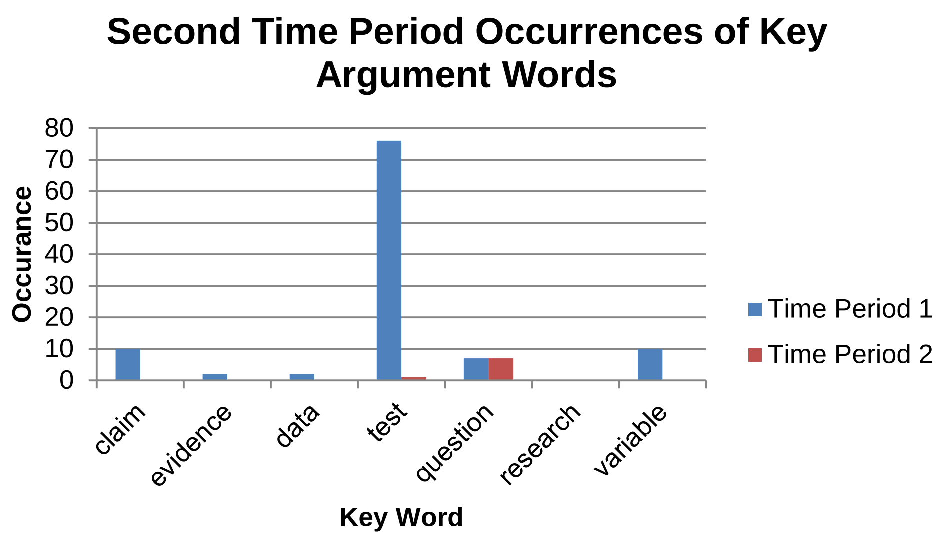


Figure 4.23 Second Time Period Occurrences of Key Argument Words

Summary of Second Time Period Argument

This time period also showed little in the way of claims and evidence, with neither of these terms showing in any of the classroom transcript or student work. Students in this time period did not present claims and evidence, instead submitting what they had learned as a result of experimenting privately to the teacher. None of these submissions contained evidence to support the student claims. Evidence was presented to show that at least one student had researched a question that could have been used to challenge the assertion by students that food contains electricity. This was not done, though many students retained this concept in their Edmodo submissions of what they had learned.

The Third Time Period – Light

Table 4.25 Third Time Period Classroom Interaction and Evidence-Based Ideas

Feature	Time Period 1	Time Period 2	Time Period 3
Classroom Interaction	1 (1)	1 (1)	1 (1)
Evidence-based Ideas	1 (1)	1 (1)	1 (2)

Though students disagreed with one another during the opening discussion of this time period, only two questions were asked by students: one asking for repetition of what had been said and the other asking for clarification of what “sparks” were (TRN-101-008, TRN-101-065). Students in this time period tended to focus their questions to the teacher. Included in a discussion during demonstrations a student asked: “If you know how they work (the answer), why won’t you tell us?” (TRN-107-067). No examples of questions that sought explanatory answers were found in the transcripts (TRN-101, TRN-105, TRN-107, TRN-109).

The students did not perform their own experiments during this time period. The words “claim” and “evidence” also do not appear during any transcripts from this time period (TRN-101, TRN-105, TRN-107, TRN-109). As such, there are no student experiments for which they could report claims or evidence. The students did make “Light Striking Matter” posters which are reported in their student journals, though these were not publically negotiated (RFN-1218-03). As can be seen in Figure 4.24 below, there were no transcripts that contained claims or evidence.

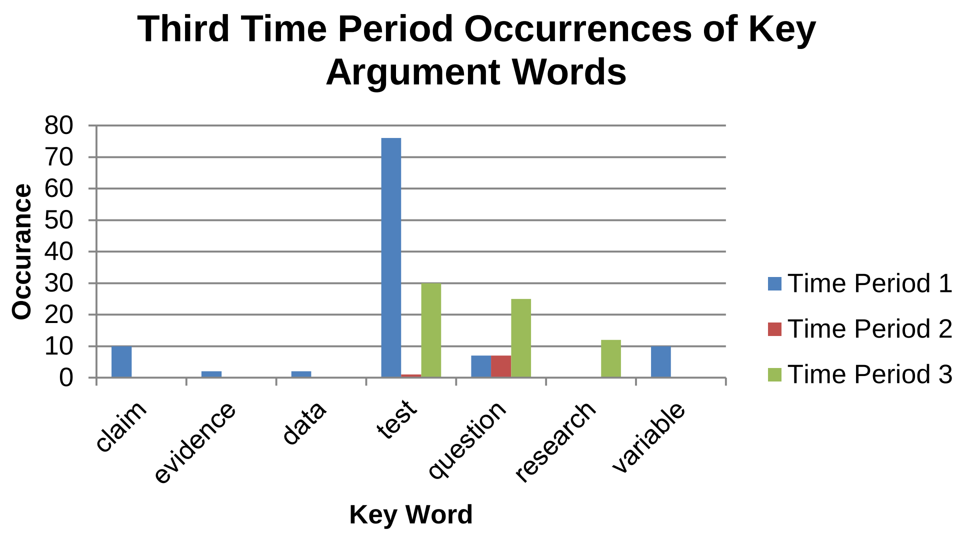


Figure 4.24 Third Time Period Occurrences of Key Argument Words

Summary of Third Time Period Argument

The students in this time period did not perform experiments, nor did they present claims and evidence. The terms claims and evidence did not appear in any transcripts throughout the unit. While the teacher challenged student ideas, from the Dialogue results, he did not ask students to justify their statements. Student ideas that were not in agreement were seen during this time, though there was no mediation by justification or evidence.

<u>Research Question Three Overall Summary of Argument and Finding</u>

This research question had one finding: (5) No significant changes were seen to the use of argument or claims and evidence throughout the study, though the teacher did challenge some student claims in the third time period. The only change noted during the analysis was the onset of the teacher challenging some student statements. Throughout all time periods, the presence of the basic argument and SWH approach terminology including "claims" and "evidence" was scarce, only occurring early in the first time period.

Results Summary

There was only one big idea used throughout the semester, presented in the first time period. Both the second and third time periods contained topics. The start of each unit contained activities designed to elicit the prior knowledge of students which was then followed by a whole-class discussion about those ideas. The discussion varied in terms of how teacher led it was, with the second time period being very teacher led and highly aligned to teacher lesson plans that were written well before SWH implementation. In all of the time periods, the given big idea appeared to be reduced in usage after eliciting prior knowledge and the opening discussion. The student questionnaire indicated nearly half the class identifying the big idea from the first time period, though more students identified the outcome of an experimental test. For the last two time periods, there was more variation in the number of unique replies to this question and many more students leaving the question blank. Taylor expressed uncertainty when asked about what role the big idea should serve in the unit during his interview.

Over the course of the semester, changes were observed in the dialogue analyses. Many of these changes related to changes in teacher questioning seeking more students explaining their comprehension of ideas instead of stating explicit knowledge. This transitioned into Taylor challenging student statements directly by the third time period.

The role of science terminology also appeared to change throughout the semester. Initially, follow up questions about defining science terms or explaining them in students' own words was not seen. By the third time period, explicit activities were assigned by Taylor that had students define science terms and then explain those terms in their own words were given to the students.

Another key change occurred to the general pattern behind idea discussion. Over time, more students were brought in to discuss each idea and ideas tended to be discussed for more turns of talk. The teacher dominated classroom talk in all time periods, having at least twice the number of spoken student words in every time period and five times at the maximum. The teacher also had similar turns of talk to total student turns of talk. This is consistent with the students talking to or through the teacher instead of talking to other students. This would also indicate a teacher that controls the discourse of the classroom by controlling access to who gets to speak.

Argument did not appear to have much development on the frameworks used in this study. Very few key terms that would be expected to be present in a class with an argument-based inquiry approach were present. Students were not afforded the opportunity to publically present their claims or back their claims with evidence. While the teacher challenged student ideas in the third time period, he did not ask students to justify their statements. Student ideas that were not in agreement were seen during this time, though there was no mediation by justification or evidence.

CHAPTER FIVE

DISCUSSION

Introduction

This chapter summarizes the findings of this study in light of current research in science education. First will be a discussion of each research question, starting with how the teacher used big ideas and whether they were consistent with core concepts in the NGSS, changes that were seen in whole-class dialogue, and the lack of changes seen in argument. Implications to teaching, research, and professional development are given. Finally, future research and limitations for this study are also discussed.

Summary of Findings

Five major findings are identified from this study that emerged from three primary questions. The first two findings related to the usage of the big idea throughout the units. Prior to considering how the big ideas were used across each unit it is important to consider the quality of the big ideas given. As mentioned Chapter Two, a big idea has specific requirements in order to qualify as a big idea. Primarily among these the big idea should serve as a tool for investigating more complex ideas and have broad importance across multiple science disciplines or be a key organizing tool for a discipline. In this way, a big idea has a definition that is role-based; it has specific function called for in the NGSS that goes across and beyond the unit (NRC, 2012). The first finding: in this study, only the first time period had a true big idea: force affects motion. The other two units contained topics with no inherent concept: electricity and light.

It is important to note here that the first time period immediately followed the summer professional development workshop, so it is likely that this big idea was negotiated during that professional development. Also, during this study, the researcher did not work with the teacher to develop future lesson plans or big ideas so the second and third units represented ideas developed by the teacher. This would suggest that this teacher struggled to develop big ideas or did not fully understand how big ideas and topics differ. However, this means that big ideas developed across the semester were mostly not consistent with how they are conceptualized within the SWH approach nor were they consistent with NGSS disciplinary core ideas.

The second finding relating to big ideas focused on the use of the big idea across the unit. Each semester contained a similar use for the given big idea; each was used to elicit student prior knowledge in an activity and subsequent discussion. In the first and second time period, this was done through semantic webs while the third time period had a compare and contrast between the current and previous units. Though, after this point there was a large reduction in the use of the given big idea for each unit. Only the first unit contained any mention of a big idea in the transcript data. Additionally, students were mostly able to identify a few core ideas they felt were present in the first time period with much more variability in the last two units. This finding brings to light a lack of use of the terminology associated with the big idea and suggests a lack of understanding for how to utilize the big idea throughout a unit.

The last two research questions focused on the development of dialogue and argument over the course of the semester. The development of dialogue had two major findings. The first was that the types of teacher questions shifted toward students explaining their comprehension of ideas and more students were involved in discussing each idea and for more turns of talk than in earlier time periods. This is an important part of dialogue as idea exchange is predicated on ideas being explicit. Encouraging students to explain their comprehension of ideas makes student ideas more explicit and allows them to be available for exchange with others. More students being involved in discussing each idea over more turns of talk encourages more in depth dialogue as ideas persist longer in the classroom discourse. As mentioned in Chapter Two, IRE type classrooms do not tend to sustain talk around an idea for more than a few turns of talk (Benus et al., 2013). This may indicate this classroom started shifting toward a more dialogue oriented classroom by the end of the semester.

The other finding relates to the role of science terms in this classroom across the semester. It appeared as though understanding science term definitions became more prominent later in the semester, with more stating science terms occurring earlier in the semester. This is consistent with encouraging more student ideas to be expressed in the classroom but also plays an important role in recognizing that students may have a different understanding for science terminology than each other or the accepted science definitions. While some checking for students' knowledge of science terminology did tend to occur in some time periods, the timing of these checks moved earlier and earlier throughout the units even though these science terms were being used by students in all three units during the opening discussion.

The last research question focused on the development of argument. No significant changes were seen to the use of argument or claims and evidence throughout the study, though the teacher did challenge some student claims in the third time period.

Key in this finding was noting a lack of basic terminology that one would expect to find in a classroom using argument-based inquiry. It is also interesting that the basic structure of SWH including questions, claims, and evidence can be found early in the first time period in student notebooks though these were not asked for in the transcript discussions.

Discussion of Findings

Ultimately this study is about the changes that occurred in this classroom on the way towards more proficient implementation of argument-based inquiry. This study focused on three broad areas that help provide a rich description of the classroom discourse. The analysis of the big idea usage provided insight into whether the discourse was oriented around core concepts called for in the Next Generation Science Standards. The dialogue analysis provided insight into the idea exchange present in the classroom. Finally, the argument analysis allowed an understanding into the challenges faced when working to implement an argument approach to inquiry in the classroom.

The Next Generation Science Standards (NGSS) call for inclusion of specific practices into K-12 science classrooms, including argument from evidence (NRC, 2012). As reported in Chapter Two, engaging students in argumentation rarely occurs in science classrooms (Driver, Newton, & Osbourne, 2000; Lemke, 1990) not affiliated with a research program where argumentation in the classroom was a goal (e.g. Clark & Sampson, 2008; Martin & Hand, 2009; McNeill & Krajcik, 2008; Simon, Erduran, & Osborne, 2006; von Aufschnatier, Erduran, Osborne, & Simon, 2008). This study examined changes that occurred during the onset of implementation of an argument-based inquiry approach.

The teacher in this study did not make effective use of core concepts in science throughout the unit. Therefore, this teacher did not utilize disciplinary core ideas as called for in the Next Generation Science Standards. Big ideas, as used in the Science Writing Heuristic approach, also capture core concepts and were similarly not used appropriately throughout this study. When the indicated big idea was used, it frequently was used to elicit student prior knowledge. While this is an important activity, it is not the sole intent of the use of core concepts. Therefore there appears to be a disconnect between the intended use of core concepts both as NGSS and the SWH approach would have them used and the implementation of those core concepts in this classroom. Additional professional development may be necessary for teachers that do not appropriately make use of core concepts.

Big ideas are built around core concepts and set the context behind a unit. They are aligned to learning theory and provide a core idea for students to build upon as they learn and engage in new material. The NGSS states in its limitations that these core ideas for each discipline are the most essential material for students to know that form the foundation for advanced work students may engage with later in their education (NRC, 2012). Throughout this study, there were stumbling blocks associated with the utilization of core concepts as the central focus of the units as called for in the NGSS. In addition to challenges using core concepts, there was also a lack of articulation for how these big ideas should be used and lack of a coherent definition for what big ideas are. The given big ideas present in this study were used almost exclusively for eliciting student prior knowledge instead of being used across a range of activities throughout the unit and demonstrated a lack of fidelity as the unit continued. This raises interesting questions.

Does the lack of a comprehensible articulation of what a big idea is or how it should be used in the unit imply a lack of understanding about big ideas or core concepts? Does this lack of understanding or lack of a clear articulation of an explanation of the big idea imply a lack of ability to make effective use of big ideas throughout the unit and possibly represent existing instruction that is not well aligned to current learning theory?

Differences in implementation between argument and dialogue were also represented in the analysis. Dialogue is oriented around an exchange of ideas and negotiation of those ideas. Dialogue is a generative practice where people can think together about their own ideas in light of others' thinking (Benus, 2011; Schein, 1993). This is somewhat different than scientific argument, which has a specialized structure whereby claims are supported by evidence derived from nature. While argument also necessitates the general dialogic practices of exchanging and negotiating ideas, those ideas are negotiated based on evidence through supporting and refuting claims and evidence.

The discourse observed during this study appeared by all analytic measures to be dominated by teacher talk. This teacher dominated discourse was seen alongside reduced levels of classroom dialogue that increased as more students were brought in to discuss each idea and the discussion length per idea increased. As discussed in Chapter Two, dialogue is seen as a negotiation of ideas between people of ideas that are taken as shared. Might this imply difficulty establishing dialogue in classrooms dominated by teacher talk as seen in this study? If so, might a first step toward establishing dialogue in the classroom be encouraging students to share and discuss their ideas? In this study, a development of dialogue appeared to be mostly occurring with changes in how the teacher questioned students. There are possible implications as to the importance of teacher questions that seek student ideas as a way to improve the development of dialogue, consistent with previous work (Pinney, 2010). Of importance here is the negotiation of ideas in whole-class discussion, which is not possible with few ideas presented into the discussion. As discussed earlier, a classroom engaged in dialogue cannot be a classroom of "passive recipients of knowledge and instruction" (Benus, 2011, p. 21). In dialogue, no one person has ownership; it is a collective experience where people construct understanding after a having a shared experience (Klein, 2006).

In this study, discussions over the semester tended to involve more students and more turns of talk per idea. This makes available more opportunity for additional ideas from students as well as additional time for development of ideas. Throughout this study, the teacher talk tended to dominate the student talk in all time periods and classroom activities. It is uncertain how this may change as he continues with professional development. However, there are indications that his dominant role may be changing toward the end of the study, as he started allowing more students to have turns of talk following other students. Additional data is necessary to understand possible teacher motivations for these changes, if they exist.

Osborne (2005) describes knowledge creation in an argument setting that includes justification of beliefs through reasoning, conjecture, evaluation of evidence, and considering counter arguments that can be considered a social negotiation that leads to deeper and more meaningful knowledge construction (Driver et al., 1994; Driver & Oldham, 1986). The use of argumentation in the classroom incorporates a cyclic reasoning process where students make claims, generate evidence from data that is used to support or refute claims, by critiquing or challenging claims, and evaluate the arguments for or against these claims to determine their validity (Choi et al., 2010; Kelly & Bazerman, 2003; McNeill, 2009; Peker & Wallace, 2009; Berland & Reiser, 2011; Chin & Osborne, 2010). These practices were not seen in the collected data and therefore this classroom does not appear to have developed an ability to engage in argument though practices more consistent with dialogue did appear to change. Toward the end of the study, there were examples of the teacher challenging student ideas, though these challenges did not seek evidence in the manner expected in argument. There was a lack of the use of basic argument terminology, i.e. claims and evidence, present in this classroom across the study, although the SWH approach utilizes a claims and evidence structure.

It appears that the teacher in this study struggled with implementation because he did not have a solid orientation to the utilization of core concepts within the unit or with the structure of argument. He struggled to organize his units around a big idea and to make use of the questions, claims, and evidence structure called for in the SWH approach. However, even while frustrated and struggling with the approach, his modified R-TOP scores which are correlated with implementation of an argument-based inquiry approach, were higher during the first time period than the second time period. Thus, even though the teacher felt as though he was struggling through implementation, the analytic methods applied to his teaching and classroom dynamics indicated an improvement in his implementation over more traditional teaching.

Interesting questions arise both with argument as well as argument related to dialogue. Does a lack of use of basic argument terminology imply a lack of understanding of the importance of basic argument structure? If argument is a dialogic process with specialized structure and dialogue is not present in the classroom, is dialogue development a necessary precursor to argument development or might concurrent development be possible? Research on inclusion of scientific argumentation has shown that shifting teaching practice can take at least 18 months of professional development (Martin & Hand, 2009). Along with the results from this study, the research on development of teaching practice that effectively utilizes scientific argumentation suggests inclusion of argument is a specialized practice that takes significant time and development to advance one's ability to successfully engage in argument.

Two Themes

There are two primary themes from the findings of this study. The first of these themes relates the big idea and argument as seen in this study. Taylor appeared to struggle with the implementation of both of these features throughout the unit. While the big idea was initially present, this was during the first unit which was immediately following his summer professional development where teachers will frequently develop big ideas from their units during the professional development. His use of the big idea became weaker over time both in the sense that as the unit continued it decreased in presence and in that only the first time period contained a big idea. This is consistent with a lack of understanding of how to construct a big idea because the first unit would have been constructed during the professional development. Both the big idea and argument saw a lack of use throughout the semester. The big idea was never used as a reference point outside the opening discussion and prior knowledge activity and the general terminology and structure of argument were also not seen.

Argument also lacked development in many of the analyzed areas. There was some disagreement by the scorers on the dialogue framework as to if there was some inclusion of evidence by students or how heavily this should be weighted on scoring. However, no instances of a request for evidence or justification of claim was observed in the transcripts, noted by the researcher, or seen in the word counts of classroom discourse. Students were not given the opportunity to engage in a presentation of claims and evidence, nor expected to use evidence to support claims. As stated in Chapter Two, science education as argument should include the evaluation and analysis of data in construction of claims that are backed by sound evidence that may be debated by peers (NRC, 2012). These students did not engage in argument to produce the best explanation given current evidence (Bricker & Bell, 2008; Zembal-Saul, 2009). Therefore, these students appear to have been denied an opportunity to develop their derived sense of scientific literacy, which includes developing an understanding of how knowledge claims are made, supported, and refuted in scientific argumentation (Norris & Phillips, 2003).

In addition to the lack of learning about scientific discourse, students also failed to learn about the structure and function of argumentation. In this classroom, the intuitive inferences made by students about the phenomena under study were not distinguished from true argument as explained by Mercier and Sperberg (2011). As a result of this, students were not encouraged to interact with their own ideas and the ideas of their peers using logic, empirical evidence, and counter arguments mediated through argumentative discourse (Benus, 2011; Berland & Reiser, 2011; McNeill, 2009). Ultimately, the findings raise issues as to whether there were barriers to implementation present as a result of a lack of understanding of the big idea and the structure of argument.

The second theme is oriented around argument verse dialogue development in this classroom. Though argument is specialized dialogue, they demonstrated different developmental fates. For this study, a lack of development in argument was seen while dialogue did appear to develop across the semester. Therefore, the lack of development of argument did not appear to be a barrier to the start of dialogue development. Restated another way, it appears that a science classroom can undergo the development of dialogue even while argument does not change. The lack of use of argument terms appeared to prevent the development of argument without preventing the development of dialogue. This may imply that these practices are distinct practices with their own learning curves associated with both. While dialogue was seen to develop first in this study, it is unclear if this is a necessary requirement for the development of argument or if the development of dialogue and argument can occur concurrently. This is an important distinction because the NGSS and science education recommendations urge the use of argumentation in science classrooms, not mere dialogue.

The overlap between argument and dialogue is important as argument is dialogic in nature. Dialogue is a critical component of argument because to engage in argument, one must engage in the exchange and understanding of the ideas of others and self. Even though there was dialogue development, the classroom lacked some activities that are consistent with dialogue-based classrooms including students spending time probing the thinking of their peers as the classroom works to construct a common understanding (Varelas & Pineda, 1999). This classroom appeared to be rather dominated by teacher talk, with much of the discussion being routed through him and therefore lacks this feature of dialogic classrooms as seen by Varelas and Pineda (1999). Also important in this notion is that students are expected to engage in argument with each other, not routed through the teacher. It is unclear if the amount of teacher talk will present as a barrier toward further development of dialogue.

Implications for Professional Development

This study also carries implications for professional development associated around the inclusion of argument in teaching practice. As reported in Chapter Two, the inclusion of argument typically takes at least 18 months for sustained long-term change (Martin & Hand, 2009). While some changes were seen within this study, argument was not a practice that seemed to show significant development across the first semester of implementation. This stresses the importance of long-term sustained professional development when working to include argument. In this study, Taylor appeared to exhibit difficulties implementing argument in his classroom which oriented around his lack of use of the basic terminology of argument. However, argument is more than the use of a few terms that are associated with argument; it is a dialogical process by which knowledge claims and made, advanced, supported, or refuted using evidence-based claims. This highlights the importance of teachers engaging in professional development to help transition from dialogue into argumentative dialogue.

This study also examined units from a middle school classroom to the newly released Next Generation Science Standard core concepts and found a lack of core concepts present and typically only used to elicit student prior knowledge. This is inconsistent with the intent of use of disciplinary core ideas as given by the NGSS (NRC, 2012). Teachers that do not currently utilize core concepts to organize their units are likely to need assistance when building units around core concepts. This was observed in this study with a lack of effective use of the core concepts and a reversion to prior teaching approaches built around topics instead of core concepts. Critically, this was observed even though Taylor gave an indication that big ideas are built out of core concepts. This failure to effectively utilize big ideas or disciplinary core ideas directly from the NGSS highlights the apparent disconnect between the Standards and teacher implementation of those core ideas in the Standards which implies a call for an explicit focus of professional development on how to utilize NGSS core concepts when designing a unit.

It is possible that barriers to effective implementation of disciplinary core ideas exist due to a lack of content understanding. It is noteworthy at this point that the teacher in this study graduated with a Bachelor's of Arts in elementary education though the majority of his teaching is now middle school science. Taylor mentioned during the interview that he was learning content along with the students at several points throughout the units. This would stress content knowledge as an important factor for successful teacher inclusion of core ideas as the core of their units. Ideas expressed throughout the unit should be connected back to these core ideas and a lack of content understanding would likely hinder one's movement between ideas. This possible lack of understanding also may be a barrier to development of argument in this classroom. In one transcript section, Taylor tells his students that they will write down the evidence that they collect. This demonstrates a lack of understanding of the distinction between data and evidence. Being that the SWH approach follows a structure of questions, claims, and evidence; failure to understand the implications of evidence being different to data is likely to create a barrier to effective development of argumentation in the classroom. In this way, students may not support their claims with evidence because an idea of what counts as evidence is not present.

Additionally, teachers are likely to need support when working to utilize disciplinary core ideas as the central concept throughout the unit. This shift helps align teaching practice to learning theory. It is important to restate at this point that the NGSS disciplinary core ideas are written as to not limit teaching approaches but rather to provide teachers with a set of standards for what students should know. These standards provide a core concept that students can build from over years of continued learning on the same core concept. As shown in this study, adapting existing lesson plans to lesson plans oriented around core concepts can present with difficulty.

Implications for Future Research

This study has several interesting implications for future research. As reported earlier, little research has been done on the distinction between dialogue and argument in the science classroom and how they develop. The results from this study would suggest that dialogue can develop independently to argument. What remains unclear is whether a teacher already comfortable with a dialogic practice is necessary prior to the development of argument or if these can occur concurrently. Further work is needed to more clearly demarcate the differences between argument and dialogue and how they impact professional development.

As with any professional development approach, working through teacher frustrations while improving implementation is important. Additional research is necessary to determine how the frustrations and difficulties experienced by this teacher and others undergoing this professional development are resolved as they develop toward better implementation of argument in their classrooms. Through this research, future difficulties can be better addressed prior to the teacher feeling reversion to prior teaching approaches necessary.

Lastly, comparisons of the teaching approaches between novice and experienced argument-based inquiry teachers need to be made. Through these comparisons, differences and similarities to how these teachers resolve situations that prove difficult for new teachers can be determined. These comparisons may shed new light on the processes by which novice teachers move toward more experienced argument-based inquiry teachers. These comparisons may also bring to light how the teacher helps shape classroom discourse toward better inclusion of argument.

Limitations

The researcher has identified four areas of limitations including data, the analytic frame, small sample size and comparability, and generalizability. These will be explained individually. It is expected that other limitations exist.

Data

This study has limitations relating to the data that was collected. First, one student was not present at the start of the school year. As such, contributions from that student may have changed the outcome of the classroom though this effect is expected to be small. Secondly, students also had their own private notebooks in addition to their science notebooks. Though students were instructed to use their science notebooks, it cannot be assured that students did not use their own notebooks. There were certainly times where students were given take home assignments and these would have almost invariably been done in their private notebooks as the science notebooks were to always be left in the classroom.

There is also some challenge in that there are no teacher reflective notes present. He was asked to keep reflective notes as he worked through implementation, but this was not done and so a valuable insight into design decisions, challenges, frustrations, and successes as he saw them at the time are lost if not shared with the researcher. It is also notable that the ability to explicitly state aspects about teaching practice is expected to be difficult. Confronting ones' developing practice can be challenging. Additional teacher interviews, following each unit, would have been preferred.

Analytic Framework

The analytic framework that much of this study is based on primarily looks at the development of dialogue. This study must also take caution when using this framework as it describes general changes across levels of practice seen as relating to argumentation when applying it to the specific case under study. This study did not note argumentation that had developed, possibly as a result of the data collected. Additionally, the facets of development that were seen (orienting around dialogue development) are seen as a necessary skill to holding argumentation in the classroom. However, these changes are not assumed to be the only changes nor as all of the meaningful changes that may have occurred in this teacher's practice during this semester. It is expected that some of these changes may be transient and will continue to change over time as he progresses toward better implementation of argumentation.

Sample Size and Comparability

As with any study, there are additional limitations that relate to comparing different units to each other (some may be more abstract than others). This study mainly focused around whole class discussions that occurred in this classroom. As a result of the ongoing professional development, only the first portions of the units were able to be used due to the influence of the professional development being active as opposed to passive. This limits the data available for review in this study and therefore some changes may not be seen in the available data.

Generalizability

This study is a qualitative study and thus suffers from a lack of generalizability. The changes observed in this study are not necessarily expected to be unique to this teacher but may not necessarily be shared by other teachers. Each teacher brings their own prior experiences and approaches to teaching and as such is expected to undergo unique developmental changes as they work toward better implementation.

APPENDIX A

DATA INDEXING SCHEME

Data Indexing Scheme

Data Source	Type ID	Primary Discriminator	Local Discriminator	Example	Explained
Transcript	TRN	Video Number	Line Number	TRN-009-018	Line 18 of Video 9, in Transcripts
Researcher Field Notes	RFN	Date (mm/dd)	Line Number	RFN-1009-005	Line 5 of Field Notes on 10/09
Teacher Interview	TIN	-	Line Number	TI-047	Line 47 of Teacher Interview
Student Journal (student #)	SJ#	Page Number	Line Number	SJ5-17-22	Line 22 of Page 17 of Student 5's Journal
Teacher Planning Notes (Unit #)	TP#	Slide Number	Line Number	TP1-04-13	Line 13 of Page 4 of Unit 1's Planning Notes
Student Written Question-naire	SWA	Student Number	Line Number	SWA-01-02	Box 2 of Student 1's Written Assay
Teacher E-mail	TEM	Date (mm/dd)	Line Number	TEM-0421-01	Line 1 of e-mail from April 21st.
Video	VID	Video Number	Time Stamp	VID-006-1215	Time Stamp 12:15 of Video 006

APPENDIX B

STUDENT WRITTEN QUESTIONNAIRE

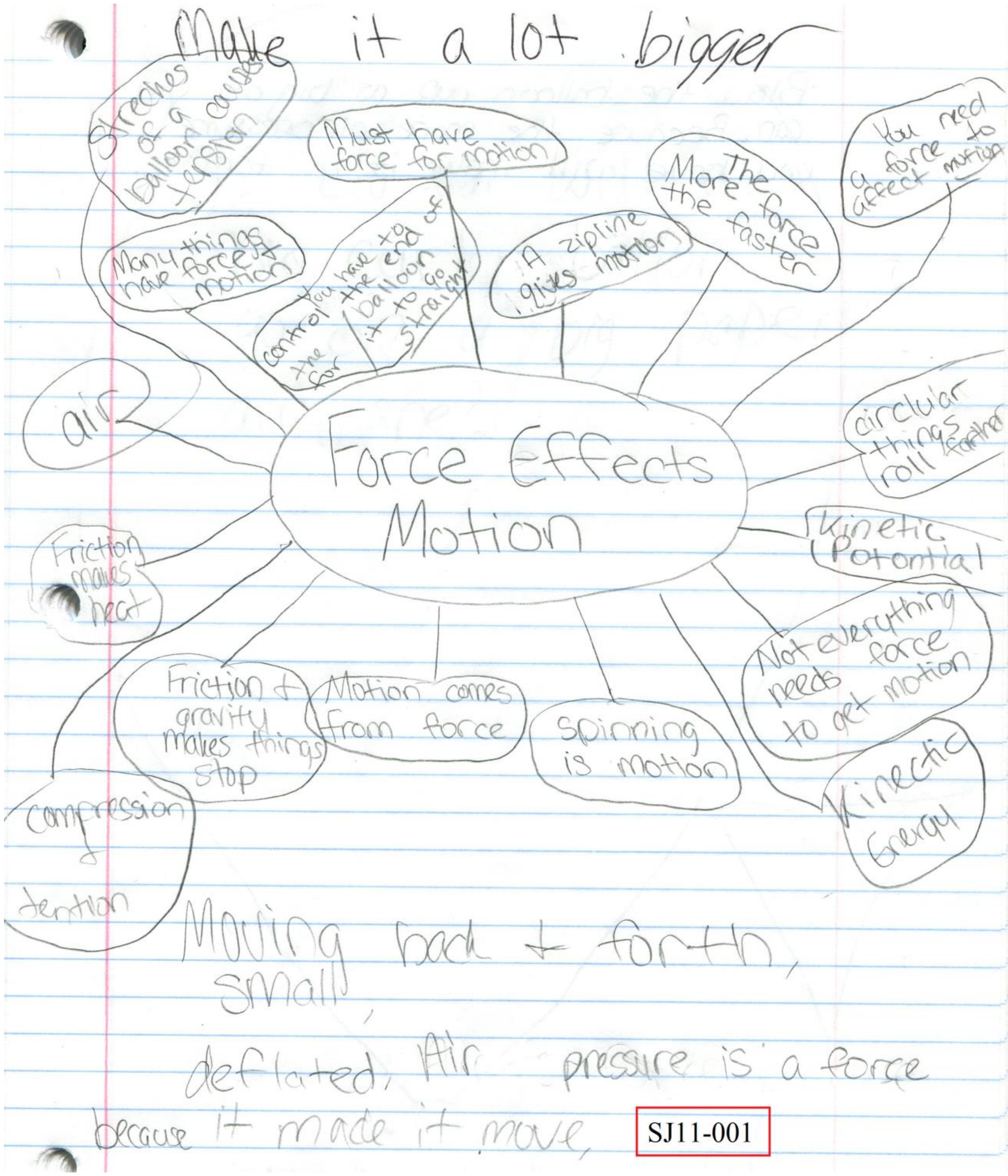
Given: March 7, 2012

In the first semester, you had three "units" you learned about. Please use the table below to help guide your free write.

	Balloons and Rockets	Electricity	Light
What was the Big Idea?			
How did your experiments help you understand the Big Idea?			
What are some key things you learned about the Big Idea in these units?			

APPENDIX C

STUDENT 11 SEMANTIC WEB – FIRST TIME PERIOD



APPENDIX D

DETERMINATION OF TURNS OF TALK AND STUDENTS PER IDEA

Table APP. D. Sample Transcript Analysis for Turns of Talk and Students Per Idea

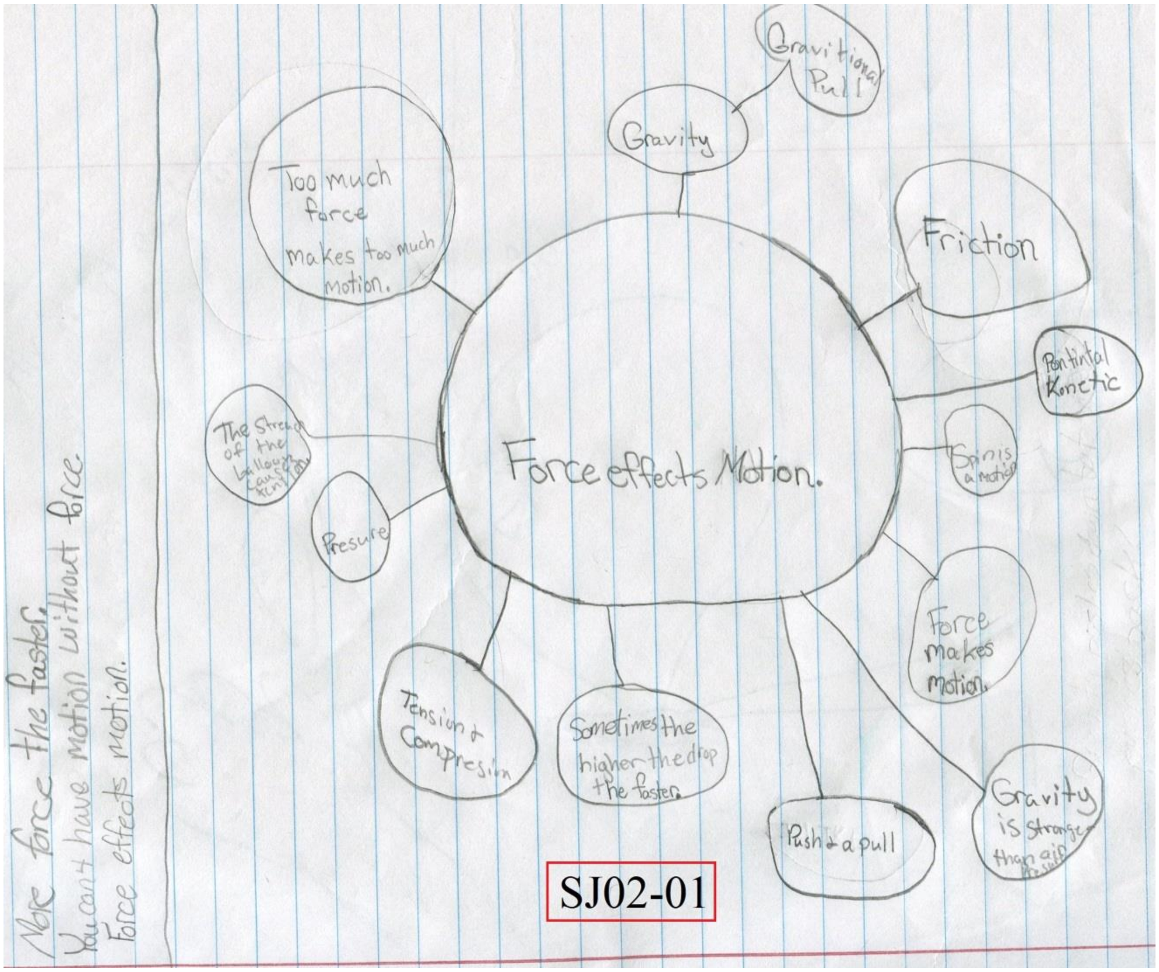
Speaker	Transcript	Turns of Talk Per Idea	Students Per Idea
Teacher	Alright, in years' past… oh, go ahead.		
Ann	It wasn't given enough force to keep going.	1	
Teacher	Ok, how much force would it take to keep going?	2	
Ann	Umm, a lot?	3	
Teacher	A lot?		
Ann	A constant force.	4	
Teacher	A constant force? Why would it have to be constant?	5	
Ann	Because just one push it would go around a few times and stop cause of the weight of the globe itself pulls it back.	6	1
Teacher	Ahh… ok. What was that?		
Stan	*mumbles* gravity	1	1
Teacher	I haven't heard that word yet. Say it outloud.		
Stan	Gravity		

Note: TRN-006-019/030

For this analysis, discrete ideas were identified in the transcripts. A discrete idea is boxed in the transcript selection above. In this section, Ann’s idea constitutes a new start of an idea that ends with the insertion of Stan’s idea because his idea constitutes its own discrete idea that does not build off Ann’s idea. Within each section, turns of talk are counted that move the idea forward. In this example, the teacher asking: “A lot?” is simply repeating what Ann said and thus does not move forward the idea. In this example, there are six turns of talk that move forward the initial idea. After this, the students participating in that box are counted. This example only includes Ann and therefore only one student was included with this idea. These values were tabulated for the entire transcripts of the units.

APPENDIX E

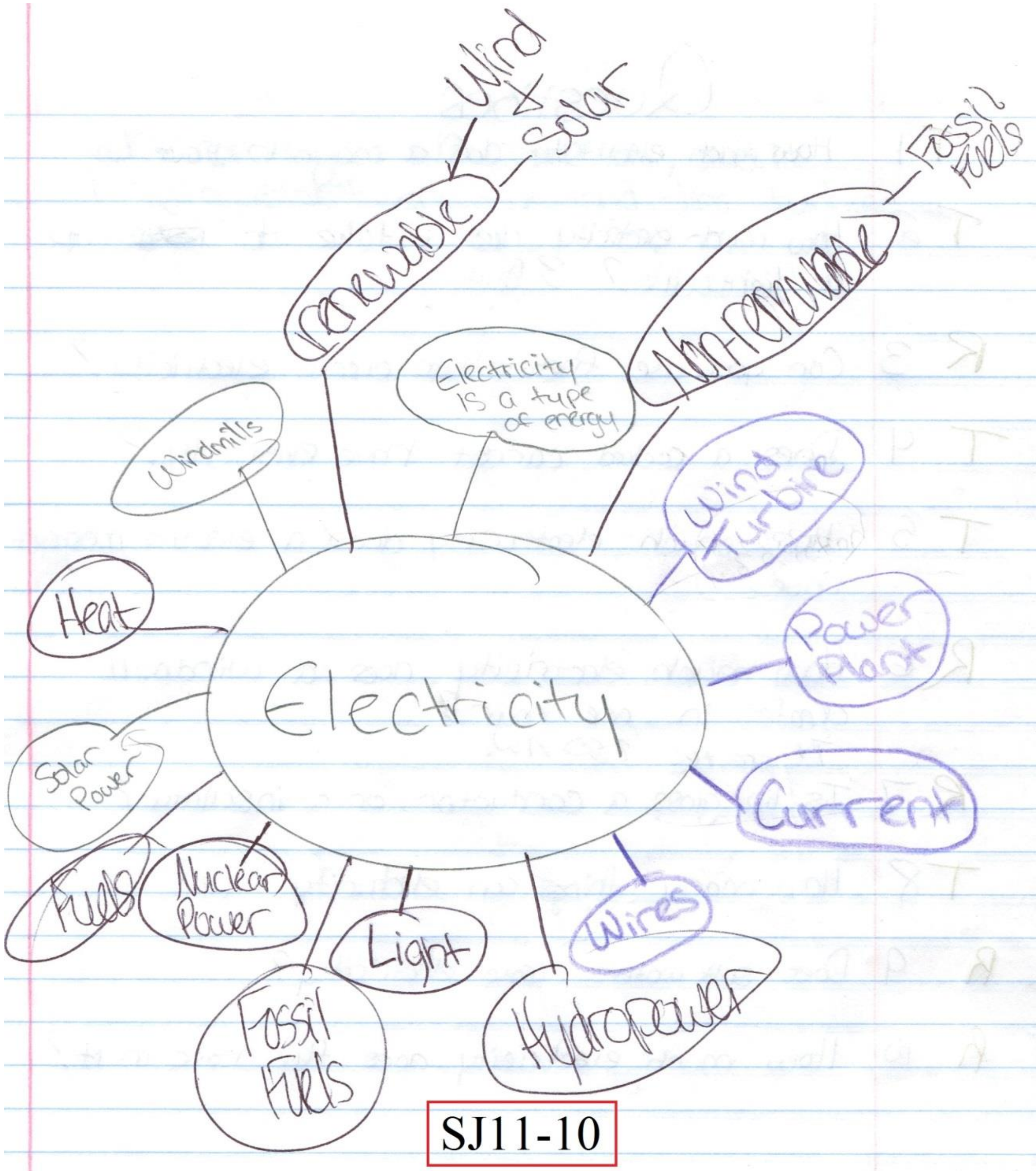
STUDENT 02 SEMANTIC WEB – FIRST TIME PERIOD



SJ02-01

APPENDIX F

STUDENT 11 SEMANTIC WEB – SECOND TIME PERIOD



SJ11-10

APPENDIX G

STUDENT 04 JOURNAL QUESTIONS – SECOND TIME PERIOD

What I know about electricity is that it needs a source, conductor, and a use. The conductor is usally a wire conecting the source to what its being used for. Light can be a source of electricity. Solar panels can be used to turn the sun's light into electricity. It can also go the other way electricity can power lights.

What I would like to know is if a vampire device is a circut. Also I want to know if our battery experament was the same consept as a wind turbine.

SJ04-86

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