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Examining student-generated questions in an elementary science classroom

Juan Francisco Diaz Jr.
University of Iowa

EXAMINING STUDENT-GENERATED QUESTIONS IN AN ELEMENTARY SCIENCE CLASSROOM

by

Juan Francisco Díaz, Jr.

An Abstract

Of a thesis submitted in partial fulfillment
of the requirements for the Doctor of
Philosophy degree in Science Education
in the Graduate College of
The University of Iowa

May 2011

Thesis Supervisor: Professor Brian M. Hand

ABSTRACT

This study was conducted to better understand how teachers use an argument-based inquiry technique known as the Science Writing Heuristic (SWH) approach to address issues on teaching, learning, negotiation, argumentation, and elaboration in an elementary science classroom. Within the SWH framework, this study traced the progress of promoting argumentation and negotiation (which led to student-generated questions) during a discussion in an elementary science classroom. Speech patterns during various classroom scenarios were analyzed to understand how teacher–student interactions influence learning.

This study uses a mixture of qualitative and quantitative methods. The qualitative aspect of the study is an analysis of teacher–student interactions in the classroom using video recordings. The quantitative aspect uses descriptive statistics, tables, and plots to analyze the data. The subjects in this study were fifth grade students and teachers from an elementary school in the Midwest, during the academic years 2007/2008 and 2008/2009. The three teachers selected for this study teach at the same Midwestern elementary school. These teachers were purposely selected because they were using the SWH approach during the two years of the study.

The results of this study suggest that all three teachers moved from using teacher-generated questions to student-generated questions as they became more familiar with the SWH approach. In addition, all three promoted the use of the components of arguments in their dialogs and discussions and encouraged students to elaborate, challenge, and rebut each other's ideas in a non-threatening environment. This research suggests that even young students, when actively participating in class discussions, are capable of connecting their claims and evidence and generating questions of a higher-order cognitive level. These findings demand the implementation of more professional development programs and the improvement in teacher education to help teachers confidently implement argumentative practices and develop pedagogical strategies to help students use them.

Abstract Approved: ______________________________
Thesis Supervisor

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Title and Department

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Date

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The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

PH.D. THESIS

This is to certify that the Ph.D. thesis of

Juan Francisco Díaz, Jr.

has been approved by the Examining Committee
for the thesis requirement for the Doctor of Philosophy
degree in Science Education at the May 2011 graduation.

Thesis Committee: ______________________
Brian M. Hand, Thesis Supervisor

____
Soonhye Park

____
Cornelia Lang

____
Peter Hlebowitsh

____
Cory Forbes

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This study uses a mixture of qualitative and quantitative methods. The qualitative aspect of the study is an analysis of teacher–student interactions in the classroom using video recordings. The quantitative aspect uses descriptive statistics, tables, and plots to analyze the data. The subjects in this study were fifth grade students and teachers from an elementary school in the Midwest, during the academic years 2007/2008 and 2008/2009. The three teachers selected for this study teach at the same Midwestern elementary school. These teachers were purposely selected because they were using the SWH approach during the two years of the study.

The results of this study suggest that all three teachers moved from using teacher-generated questions to student-generated questions as they became more familiar with the SWH approach. In addition, all three promoted the use of the components of arguments in their dialogs and discussions and encouraged students to elaborate, challenge, and rebut each other's ideas in a non-threatening environment. This research suggests that even young students, when actively participating in class discussions, are capable of connecting their claims and evidence and generating questions of a higher-order cognitive level. These findings demand the implementation of more professional development programs and the improvement in teacher education to help teachers

confidently implement argumentative practices and develop pedagogical strategies to help students use them.

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CHAPTER ONE

GENERAL OVERVIEW AND PURPOSE OF THE STUDY

Introduction

Science education depends on knowing how to argue for the truth. Several key studies (Driver, Asoko, Leach, Mortimer, and Scott, 1994) have shown that students need to participate, through talking and writing, in thinking and making sense of the scientific events, experiments and explanations to which they are being introduced. Clearly, class discussions and brainstorming ideas in small groups provide an opportunity for negotiation, argumentation and challenge of ideas while learning science. In such a classroom environment, students will articulate reasons for their claims and justify them with evidence. This pedagogy invites all the students to negotiate, challenge, express doubts and present alternatives, promoting conceptual knowledge that is constructed by the group, in as much as the group interaction enables an understanding whose whole is greater than the sum of the individual contributions. As Newton, Driver and Osborne (1999) pointed out, pedagogies that support arguments are central for an effective education in science. In other words, science is about argumentation and learning is about negotiation.

An effective education in science, however, also requires assimilation of the language of that discipline. Yore, Bisanz and Hand (2003) pointed out that the active use of language is critical to learning. Several studies stress the importance of language in the construction of new understanding of scientific ideas (Lemke, 1990; Norris and Phillips, 2003) leading to the conclusion that skills to use this disciplinary language need to be integrated into classroom discussions. The disciplinary language is essential for negotiating claims of scientific evidence and in presenting the results of investigations, be they in oral or in written forms (Driver, Newton, and Osborne, 2000; Kuhn, 1993).

Traditionally, science teaching has paid limited attention to argumentation; often giving a false impression that science is about memorization or mere recall of facts. Disputes among scientists, whether historical or contemporary, are rendered as puzzling events without context (Geddis 1991; Driver, Leach, Millar, and Scott, 1996). In addition, traditional teaching all too often fails to impart to students the ability to argue scientifically about the kinds of socio-scientific issues that they face in their everyday life (Solomon 1991, Norris and Phillips 1994). Time is a tell-tale factor that underlies the shortcoming of traditional science learning. Teachers are pressed about adequate attention to items in the curriculum. Sometimes administrators impose pressures to perform for nationally standardized tests (Newton, Driver, & Osborne, 1999).

Through argumentative practices, teachers can help the students to understand, or at least to improve their understanding of scientific practice. They will also be invited to develop, or to improve the ability to think scientifically about everyday issues. Researchers have found that argumentative practices in the classroom enable students to be actively involved in scientific investigation (Wallace, Hand, and Prian, 2004). Sadly, such active engagement of students in this kind of pedagogy is rarely observed in today's classroom (Driver, Newton, & Osborne, 2000; Newton, Driver, & Osborne, 1999). Students continue doing verifying/'receipt' type of lab activities in which they follow instructions given by the teacher or the textbook. It seems difficult for teachers to implement an inquiry-based teaching method where argumentative practices are central for students' ability to conduct scientific inquiry and to speak to the reasoning that supports an analysis of their findings.

Argumentation in Science Education

The National Research Council (Duschl, Schweingruber, & Shouse, 2007) in its report *Taking Science to School* provides a new framework for proficiency in elementary science. They base their findings on the view that "science is as both body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge" (p.2). The new emphasis in science education for elementary schools focuses upon skills to interpret scientific explanations of the phenomena, to evaluate and generate scientific explanations, to develop scientific knowledge and finally to participate in scientific practices and discourse. Since science is more than facts and concepts, it must include scientific ways of thinking and reasoning. In order to succeed in science, say the report's authors, the students need to be able to navigate different discourses or ways of knowing, doing, writing, reading and talking. Skills in using one of the four languaging processes and one of the modes for creating a verbal construct is analyzed in the present study (Emig, 1977).

The potential benefits to students thus engaged include learning science concepts, engaging in scientific discourse, altering misconceptions of science, and supporting students' efforts to engage in socio-scientific decision-making (Duschl, et.al., 2007; Driver, Newton, & Osborne, 2000; Varelas, Pappas, Kane & Arsenault, 2008). When young children are provided with appropriate opportunities and support, they are capable of quite sophisticated scientific thinking and reasoning. Student capabilities have been historically underestimated. But in fact they are able to go beyond simple observation and description and enter into negotiations and debate about meanings and explanations.

The present study will be focused on students' pattern of generating questions and the use of argumentative practices as a mode of students doing and learning science in the classroom.

When scientists build explanations, models, theories, and employ claims and provide evidence, argumentation plays a central (Erduran, Simon, and Osborne, 2004; Siegle, 1995). However, scientific argument and the relationship between claims and evidence have been difficult for learners, young and adults alike (Kuhn, 1993). Researchers have found, for instance, that students from junior high and high school do not understand how to establish a logical connection with hypotheses, explanations claims and evidence (Keys, 1999). Although the students gather substantial data in their project/experiments they often fail to make connection on how their evidence is related to their claim (Sandoval and Millwood, 2005).

The research of Toulmin, Rieke and Janik (1984) has assessed students' abilities by applying a pattern to the classroom argumentation. Although Toulmin's pattern of analysis of arguments has its limitations, the general components of argument identified by Toulmin are still used in science education. For instance, Erduran, et. al. (2004) reports some methodological approaches to the analysis of argumentation discourse. In their project titled "Enhancing the Quality of Argument in School Science", the researchers collaborated with middle-school teachers to develop models of instructional activities in an effort to make argumentation a component of instruction. Their study analyzes the dynamics of classroom interaction that initiate and sustain argumentation. They claim that such discourse determines both the effectiveness of instructional interventions in the classroom and also the impact of varying subject-matter contexts on the quality of argumentation.

The primary objective of this study is to focus on the development and use of Toulmin argument pattern (TAP) as a tool for tracing the quantity and quality of argumentation in science discourse. This approach will be employed to explore argumentation in the whole-class discussions among teachers and students, and also in small-group discussions among students, based on the premise that TAP is a reliable indicator of quality and quantity of argumentation in classroom discourse.

Admittedly, use of Toulmin's argument pattern (TAP) to evaluate classroom performances does not always produce an adequate profile for tracing teachers' changing practices and children's enhanced argumentation. Still, this kind of research examines how students manage argument pattern in their discourse, and how they employ claims, evidence or warrants. Thus it helps examine the epistemological premises utilized when producing meaningful claims and evidences based on available data. The advantages gained by using argumentative practices in classroom discourse will be manifest if teacher and students' quality and quantity of argumentation can be traced as improving over time.

Purpose

The type of analysis proposed in this research will help to understand the teachers' practices, providing insights about how the Science Writing Heuristic, SWH, is a professional development program that addresses issues on teaching, learning, negotiation, argumentation, and elaboration in a elementary science classroom. Moreover, using the Science Writing Heuristic (SWH), this study is intended to trace the progress of an elementary science classroom discourse toward promoting argumentation and negotiation in a classroom. The type of classrooms, talk patterns during various classroom scenarios will be analyzed to understand how teacher/student interactions help influence learning. In particular, the study is interested in focusing on students' use of questions and claim-evidence relationship construction across sequences of consecutive lectures, laboratory experiences and/or discussion sessions. This research makes a comparative study of three teachers that have been purposely selected and their science classroom. Comparisons are made across time (2007 – 2009) and across disciplines (topics) for each teacher. This study is built on pilot work previously done with other participant teachers in the SWH approach. In this study, the instruments that are going to be used to follow the progress of teachers in the SWH approach are: Components of Argument (see Chapter Two), the Taxonomy of Educational Objectives (Bloom's Taxonomy), and the Components of Lesson (see Chapter Two) in which the Components of Arguments and Bloom's taxonomy occur in three different stages of analysis (macro, meso and micro).

For clarity's sake, it is important to explain some of the above terms and discuss how they will be used in this study. In an SWH classroom, the environment is a student centered one, where the emphasis is on students constructing their own knowledge. Some teachers need to shift from a teacher centered classroom to a student centered one. It inevitably takes time for some to adapt to the new approach, while the process is easier for others who are already in a student-centered classroom.

First, the research will explore if teachers promote questioning by the students. Questioning, after all, is one of the most frequently used pedagogical methods of teaching, since it is possible to transfer factual knowledge through the process of asking questions. Teachers ask questions for several reasons; for example, to keep students actively involved in lessons, to give students the opportunity to openly express their ideas and thoughts; to enable students to hear different explanations of the material from their peers; and to evaluate student learning and revise lessons as necessary (Brualdi, 1998; Morgan and Saxton, 1991). The present study is more interested in exploring this interaction/dynamic of student generating questions than only their familiarity with scientific ideas. Recent studies on argumentation in seventh graders and higher science classroom show that students are capable to engage in argumentative practices, to elaborate and rebut (Kelly, Druker, and Chen, 1998; Osborne et al., 2004; Zohar & Nemet, 2002). Most of this research in the past has been conducted with junior high and high school students. The present research study contributes to science education in the fact that students in elementary school, when are encouraged to ask questions for inquiry and debates, are also capable to engage in argumentative practices that led to elaborate, rebut and challenge. These fifth graders in the present study are capable to do science as scientists do, which is to make public their findings, be open to debate and discussions.

Second, the research will examine if questions-responses of students are at the same cognitive level as the questions posted or directed by teachers. The Bloom's Taxonomy will be used to see if this relationship between teachers' questions and students' responses match at the same cognitive level. In addition, the researcher wants to see if teachers, across the program, shifted from a lower cognitive level of asking questions (knowledge) to a higher one (analysis-synthesis). The researcher would expect that a teacher that is advanced in the program would ask and engage the students in a higher cognitive level of questions/discussion. Some preliminary data (videos) show that teachers move to a higher level of questioning as they continue participating in the SWH approach. Some of their questions go beyond knowledge (Comprehension, Application, Analysis), since instead of using ‘what’ they use ‘how’. The teachers made the students contrast /compare and relate the learning to an ‘everyday event’. This gives us a possible indication that the teachers are shifting from a lower cognitive level of questioning to a higher one, and all is reflected in their dialog. The researcher would like to see if this occurs in all teachers across sequences in questions-claims-evidences relationships.

Third, this researcher will explore how the argumentation, elaboration, negotiation, challenge of ideas takes place and/or is created in the science classroom. It is anticipated that as teachers feel comfortable with the SWH program, they will employ strategies where the argumentation and negotiation of ideas is conducted in a non-threatening learning environment.

Research Questions

The teachers in this study are from the same school district and have been participating for two years in the SWH program (they all started at the same time). All the data collected (videos and transcripts) from the teachers are from the same subject matter (Physics or Biology) and collected from the years 2007 to 2009. This research is directed by the following research questions:

1. Research Question 1.
    a. At the individual teacher level, is there a shift from teacher generating questions to students’ generation of questions?

b. If there is a change, is this change uniform across time and across subject?

2. Research Question 2.
   a. Do the patterns of teachers' discourse change during a consecutive series of lessons on the same topic, this is, does the teacher promote the use of components of argument in their dialog and discussions:
      i. Across time within one topic?
      ii. Across sequences of lessons?
   b. Are there common characteristics between the three teachers in this study when implementing the SWH approach, across time and across sequences of lessons?

Dissertation Overview

Chapter Two is a review of previous research in this area in order to provide a theoretical framework for this study. This will include literature on argumentative practices in the elementary science classroom. The review also explains the role of language in learning and the SWH.

Chapter Three describes the methods used in this study. It describes the coding system developed to analyze the transcripts and videos. At the end, there will be a discussion of the relationships of the components of arguments, the Bloom's Taxonomy, and the learning phases.

Chapter Four summarizes the findings of this study. The chapter begins with a comparison of all three teachers across time and across subject followed by a description of each individual teacher.

Chapter Five offers possible answer to the research questions, providing an explanation for the results in Chapter Four. Also, the limitations will be described in this chapter along with a summary of the research questions and implications for future works.

CHAPTER TWO

LITERATURE REVIEW

This chapter establishes the theoretical framework for the research questions that are central to this study. In order to do so, the argumentative practices and questions generated in an inquiry-based science classroom using the Science Writing Heuristic (SWH) will be examined. This chapter begins with a discussion of argument and questions in science, followed by a discussion of the components of scientific argument. This review will provide support for the use of the SWH approach, a pedagogical tool used by the teachers in this study.

Science Literacy

The National Science Education Standards defines science literacy as the knowledge and understanding of scientific concepts and processes required for an individual to make informed decisions about scientifically based personal and societal issues (National Research Council, 2000). Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences, as well as describe, explain, and predict natural phenomena (National Resource Council, 1996). The achievement of literacy, however, has not always been associated with an understanding of the nature of science or scientific inquiry. Simon, Erduran, and Osborne (2006) have argued that building understanding of the nature of science and scientific inquiry are important for scientific literacy. In order to build this understanding, students are expected to develop the various skills and abilities that scientists use in pursuit of scientific knowledge, such as observation, inference, data analysis, discussion of results, and presentation of some conclusions. Students are also expected to develop an understanding of the process of scientific inquiry (Simon et al., 2006).

Scientific literacy also implies a capacity to pose and evaluate arguments based on evidence and to apply appropriately conclusions from such arguments. Students are expected to understand the characteristics of scientific knowledge that are directly derived from how that knowledge is developed. For example, scientific knowledge is always subject to change, it involves some degree of subjectivity and creativity, and it is empirically based. These expectations imply that to be scientifically literate, students must know how scientific knowledge is developed and understand its limitations. This will enable students, as part of our citizenry, to make informed decisions about scientifically based issues in society (Lederman, 2011).

In its 2007 report, *Taking Science to School*, the National Research Council (Duschl, Schweingruber, & Shouse, 2007) provided a new framework for what it means to be proficient in elementary science, based on the view that "science is both body of knowledge and an evidence-based, model-building enterprise that continually extends, refines, and revises knowledge" (p. 2). The new trends in science education for elementary schools are to look for proficiency in interpreting scientific explanations of phenomena, evaluating and generating scientific explanations, developing scientific knowledge, and participating in scientific practices and discourse. In other words, science is more than facts and concepts; it also includes scientific ways of thinking and reasoning. In order to succeed in science, Duschl et al. (2007) argue that students need to be able to navigate different discourses, or ways of knowing, doing, writing, reading, and talking. Talking, one of the four language processes, is one of the modes that is analyzed in the present study. Talking means creating and originating a verbal construct that is not graphically recorded, with the exception of a transcribed tape (Emig, 1977). Researchers argue that engaging in scientific argumentation has many potential benefits for students, who may learn scientific concepts, engage in scientific discourse, have their views of science altered, and improve their socio-scientific decision making (Duschl, et al., 2007; Driver, Newton, & Osborne, 2000; Varelas, Pappas, Kane, & Arsenault, 2008). Driver et al. (2000) and Varelas et al. (2008) found that young children, when provided with appropriate opportunities and support, are capable of quite sophisticated scientific thinking and reasoning. Children's abilities, which have been historically underestimated, go beyond simply observing and describing to negotiating and debating meanings and explanations. The present study focuses on students' pattern of generating questions and on the use of argumentative practices as a mode of students doing and learning science in the classroom.

Argumentation in Science Classrooms

Recently, an increasing number of researchers have focused on promoting argumentation in school science teaching (von Aufschnaiter, Erduran, Osborne, & Simon, 2009; Erduran, Simon, & Osborne, 2004). These research studies have centered on the proposition that scientists engage in argumentative practices to develop and improve scientific knowledge (Lawson, 2003) and that the public has to use argumentation to engage in scientific debates (Simon, Erduran, & Osborne, 2003). Another proposition is that students' learning of science requires argumentation (Osborne, Erduran, & Simon, 2004). These three propositions emphasize that coordination between argumentation and scientific knowledge is important for students to learn how to do science. Furthermore, the third proposition stresses that argumentation can also serve as a heuristic for developing an understanding of scientific concepts, asserting that as students learn how to present arguments, they will also learn science (von Ausfchnaiter et al., 2009). Researchers (von Ausfchnaiter et al., 2009; Zohar & Nemet, 2002) argue that students engaged in activities based on argumentation are able to consolidate and elaborate on their existing knowledge. Through their engagement, students are able to develop high-level argument.

In addition, these studies, focused on students' understanding, indicate that teaching argument can increase the quality of students' arguments and the frequency with which students use arguments, as well as improve students' conceptual understanding (von Ausfchnaiter et al., 2009; Osborne et al., 2004; Zohar & Nemet, 2002; Kelly, Druker, & Chen, 1998). These studies also found that a lack of content knowledge may result in poor argumentative performance. In the study of von Ausfchnaiter et al. (2009), the teachers (12 at the beginning of the study) incorporated into their eighth-grade (age 12–13) classrooms a series of nine argument-based lessons. Six of the teachers in the study who showed progress in promoting argumentative practices were chosen for the following academic year. In their analysis of the data (videos and transcripts), the researchers measured the quality of a student's argumentation by determining whether his or her argument contained any reasons or warrants substantiating the claim (i.e., not just opinions). Students' ideas became more elaborate as they were encouraged to construct arguments, but higher areas of abstraction were rarely reached because, within a single lesson, their understanding rarely exceeded their initial understanding. In conclusion, the researchers suggest that argumentation is essential to support students in developing stable understanding, because it provides the opportunity for students to use similar ideas in differing circumstances. Such a process leads to consolidation; ideas that are initially understood tentatively are confirmed and elaborated upon. Researchers agree that argumentation appears to have an important function in improving students' thinking, as students' discourse helps them to develop specific ideas more quickly and to make connections across (familiar) contexts.

Learning to Teach Argument

The importance of developing scientific literacy has been highlighted in recent debates within science education (Millar & Osborne, 1998; Norris & Phillips, 2003). The publication of the American Association for the Advancement of Science (AAAS)-edited volume on inquiry (Minstrell & Van Zee, 2000), the release of *Inquiry and the National Science Education Standards* (National Research Council, 2000), and the inclusion of scientific inquiry as a separate strand in the UK Science National Curriculum all point to an institutional commitment that science education should be concerned with more than knowledge of scientific facts. Instead, it should place value and emphasis on the processes of critical reasoning and argument that enable students to understand science as a way of knowing (Driver, Leach, Millar, & Scott, 1996; Driver et al., 2000; Millar & Osborne, 1998). Science education requires a focus on how evidence is used to construct explanations. That is, students should be asked to examine the data and arguments that form the substantive basis for acceptance of scientific ideas and theories, and they should understand the criteria used in science to evaluate evidence (Osborne et al., 2004).

The competence to comprehend and follow arguments of a scientific nature is a crucial aspect of scientific literacy in its fundamental sense. Inferring meaning from scientific texts requires the ability to recognize the standard genres of science, their appropriate use, and, in the case of disagreement, to evaluate the claims and evidence advanced. If, as Norris and Phillips (2003) argue, scientific literacy in its fundamental sense means comprehending, interpreting, analyzing, and critiquing texts, then the study of argument and its construction, the evaluation of data and reasoning, and the consideration of opposing hypotheses must become a core pedagogic practice within science education.

The adoption of any new approach promoting the use of argument would require a shift in the nature of science education. Studies focusing on the language of the science classroom (Lemke, 1990; Mortimer & Scott, 2003; Sutton, 1992) have increased our awareness of how teachers' "use of language influences the pedagogy of science" (Simon et al., 2006, p. 236). The analyses of Lemke (1990) and others show how the use of language reflects teachers' implicit beliefs about teaching and learning science. In particular, the discourse of the classroom frequently articulates a view of science as a body of essentially unequivocal and uncontested knowledge. To transform that model, Mortimer and Scott (2003), along with others, argue that the discourse of the science classroom needs to be more deliberative and dialogic (Mortimer & Scott, 2003; Scott, 1998). To shape a new world, teachers need to adopt a new mode of discourse. This shift is not simply a case of teachers changing their vocabulary. More fundamentally, they must assimilate new goals that will foreground and support teaching argumentation.

Previous research on argument includes a range of different perspectives on the role of argumentative discourse in science education (Osborne et al., 2004; Erduran et al., 2004). One significant contribution to the original thinking behind the research reported here is the work of Kuhn (1991). Her research highlights the fact that, for the overwhelming majority of students, the use of valid argument does not come naturally, but is acquired only through practice. The educational implication is that argument is a form of discourse that needs to be explicitly taught by providing suitable activity, support, and modeling. Other researchers have reached similar conclusions more recently (Hogan & Maglienti, 2001; Zohar & Nemet, 2002).

Components of Argument

Promoting debate in the classroom

Recently, researchers have been promoting the debate of socio-scientific issues in the classroom as an effort to democratize science in society (Albe, 2009). Some authors have suggested training citizens in how to think critically about science for the purposes of social reconstruction and political action (Pedretti & Hodson, 1995; Roth & Désautels, 2002). As Albe (2009) emphasizes, the objective is to give young citizens the means to be able to participate in discussion of socio-scientific issues and to negotiate with authorities and/or specialists. According to Driver et al. (2000), "… in our democratic society it is critical that young people receive an education that helps them to both construct and analyze arguments relating to the social applications and implications of science" (p. 297). Other authors emphasize instruction in the nature of science itself. According to Oulton, Dillon and Grace (2004), "society would benefit if science education encouraged pupils, who are both today's and tomorrow's citizens, to adopt a more positive and realistic view of science and its potential for resolving conflicts, to recognize the tentative nature of scientific knowledge" (p. 419).

I will argue that immersing students in scientific debates and argumentation helps them to familiarize themselves with the interpretation and evaluation of scientific issues, helping to minimize confusion about scientific concepts, which could lead to misconceptions. Debating might help students to reinforce their understanding of scientific concepts.

Recent review tends to confirm this point. For example, Cavagnetto (2010) explores the efficacy of teaching K-12 students to conduct scientific arguments. He says that the way scientists argue is different from lawyers' arguments, which tend to be win-lose. Scientists argue to vet ideas as they work toward a common goal of advancing scientific knowledge. As he writes, "collaboration through critique is a process of negotiating meaning" (p. 339). In theory, scientific argumentation in classrooms should develop cognitive and metacognitive processes, develop communication skills, develop critical reasoning skills, support students' understandings of scientific culture and practice, and foster scientific literacy. However, argumentation is used in very few science classrooms, says Cavagnetto:

> Historically in school science, the facts or the right answers have been emphasized often to the exclusion of scientific practices and thinking. As such, students often work independently or in pairs with little opportunity to share findings, interpretations, or ideas with peers … Science instruction attempts to replicate the science process using cookbook-style labs that serve as verification of ideas rather than construction and critique of ideas. Such activities focus on surface structures of science – hypotheses, methods, results, and conclusions – rather than the discourse at the heart of these processes. The lack of argument has led to a conception of science as a collection of static facts about nature and a

perception of science as a secular religion. (p. 340)

Cavagnetto (2010) reviewed 54 studies and found three approaches to teaching scientific argumentation. The first approach involves arguments at the intersection of science and society (e.g., moral, ethical, and political issues). In the second approach, students are immersed in scientific argument. For example, students might be asked to generate questions, design experiments, interpret data, and construct and defend evidence-based knowledge claims. The third approach involves teaching the structure of scientific argument. For example, students might be asked to evaluate the quality and significance of evidence and defend a particular theory.

Cavagnetto (2010) discusses patterns underlying these three orientations towards argument. A number of the interventions found in the literature appear to be guided by the second, immersive approach, keying in particular on the notion that students learn scientific argument when they use it in investigative contexts. Interventions in this mold facilitate argument through scaffolds such as prompts, strategic selection for group collaboration, and use of student misconceptions. Scaffolds may be used to inform both argument construction and student investigative decisions. For example, the Science Writing Heuristic approach (Keys, Hand, Prain, & Collins, 1999; Martin & Hand, 2009) utilizes questions to provide a scaffold for students' construction of arguments. Students are prompted with questions such as the following: "What is my question?", "How can I answer my question?", "What is my claim?", "What is my evidence?", and "How does my claim compare with those of others?" These questions helped students in these studies to construct explanations of phenomena and required them to make decisions about how to approach the investigation.

Cavagnetto concludes that the immersive approach does the best job of teaching cognitive skills and scientific literacy. The goal, he says, is not to learn how to argue, but rather to understand scientific practice.

According to Sadler (2004), “the most fruitful interventions would be those which encourage personal connections between students and the issues discussed, explicitly address the value of justifying claims and expose the importance of attending to contradictory opinions” (p. 523). This intervention often implies debates or group discussions. Some authors warn, however, that the social demands of group discussions might be too great. Dawes (2004) emphasizes that “group talk can help learners to exchange ideas, to have access to different perspectives and to make meaning together. However, this may not happen if groups of children remain unaware of talk as a tool for thinking together” (p. 678). Differences between discussion groups can also lead to questions about the equity of learning through this type of activity (Kelly, Crawford, & Green, 2001).

One of the goals of the present research is to develop a framework that analyzes students’ argumentative practices. To this end, the criteria and findings of previous studies in argumentative practices are reviewed. The components of argument used in this research study, namely Elaboration, Rebuttal, and Challenge, were first described in the pilot study (Benus, Diaz, Hand, & Norton-Meier, 2009).

Elaboration

In the classroom setting, elaboration is defined as the ability of a student to talk more in depth or expand on what is given in response to a question or challenge from the teacher or classmates (e.g., 'why did you choose that type of fin for your rocket?').

Elaboration can take the form of adding details to the information already provided, clarifying an idea, explaining the relationship between two or more new concepts, making inferences, visualizing an image of some aspect of the material, applying an analogy relating the new ideas to familiar things, or in some other way associating the new material with known information or past experiences. Such elaborative activity aims to make the new material more meaningful to the learner and, therefore, easier to understand and remember. However, learners rarely engage in elaboration, particularly with expository material, unless they are prompted to do so (Britton, Van Dusen, Glynn, & Hemphill, 1990; Pressley, Wood, & Woloshyn, 1990; Spires, Donley, & Penrose, 1990), and do not spontaneously activate and use their relevant prior knowledge without such prompting (Pickert & Anderson, 1977; Pressley, McDaniel, Turnure, Wood, & Ahmad, 1987; Pressley, Woloshyn, King, Wood, Martin, & Menke, 1992).

Classroom discussions are of vital importance for learning, and they continue to be the main alternative to lecturing (Philipsen, 1995). Previous research indicates that discussion can prompt reasoning in students when guided by teachers or trained peers (Barnes & Todd, 1977; Inagaki, 1981; Minstrell & Stimpson, 1995; Roschelle, 1992; Resnick. Salmon, Zeitz, Wathen, & Holowchak, 1993; diSessa & Minstrell, 1994). Discussions can help students expand their repertoires of ideas, consider the views of others, and motivate the revisions of discussed concepts (Brown & Palinscar, 1989; Linn et al., 1994; Strike & Posner, 1985, 1992). Peers within a discussion can also play an important role in contributing to a group's expertise by distributing responsibility for learning and remembering new ideas (Brown et al., 1993, 1994; Newman et al., 1989; Pontecorvo, 1993). Comprehension among peers often improves because other peers place ideas in familiar student-like terms (Songer, 1993).

However, classroom discussions have drawbacks. Rather than considering the views of others, students can often misconstrue evidence, misinterpret ideas, and accept authoritative views without personal reflection during discussions (Pea & Gomez, 1992). Without the time to subsequently reflect on the ideas presented in a discussion, students cannot change their ideas or revise their knowledge. Ideally, students should relate the scientific concepts under debate to personal problems or scenarios instead of blindly adopting the view of an authority figure (Linn & Songer, 1993; Schank & Cleary, 1995).

Self-generated elaborations have been found to be more conducive to learning than elaborations provided by a teacher, textbook, or other external source (e.g., Pressley et al., 1987; Wittrock, 1990; Wood, Pressley, & Winne, 1990). Such personalized elaborations are likely to be more memorable to the learner because they are more consistent with his or her own experiences and knowledge base. Schema theory suggests that because personal knowledge is already schematized, when new information is related to it, it is easier to process and recall (King, 1992). Self-generated elaborations have the potential to create more links to what is already known and, therefore, they can provide more and stronger cues for recall. In addition, learners may simply find the activity of engaging in personal elaboration more motivating than the memorization of others' ready-made elaborations, and such motivation may play a role in enhancing recall.

King (1992) presents a procedure for prompting self-generated verbal elaboration. This procedure is a guided student-generated questioning strategy that can aid the understanding of regular course material presented in a typical classroom setting and comprises two components: rebuttals and challenges.

Rebuttals

Rebuttals are introduced as a form of evidence that is presented to contradict or nullify the evidence presented by an adverse party. Kuhn (1991) argues that rebuttals are an essential element of better quality arguments and demonstrate a higher-level skill in argumentation. Rebuttals are more difficult than is elaboration because they require proponents to integrate original and alternative theories by arguing that the original theory is more accepted or more correct while the alternative has flaws. Osborne, Erduran & Simon (2007) finds that most rebuttals are one of three types: a weak rebuttal with a counterargument that is not self-evident, an argument with a clear rebuttal, or an argument with multiple rebuttals.

There are two basic approaches to rebutting an argument: you can refute the argument or you can counter-argue (Faigley & Selzer, 2011). In the first case, you demonstrate the shortcomings of the argument you wish to discredit and may offer a positive claim of your own. In the second case, you focus on the strengths of the positions you support and spend less time on the specifics of the arguments you are countering. There can be substantial overlap between these two tactics, and good rebuttals often employ both refutation and counter-argument.

This definition of these rebuttal tactics demonstrates the epistemological differences in the argumentation contexts being studied. By contrast, Erduran et al. (2004) state that only arguments that rebut the grounds of another person's argument can undermine the beliefs of that individual. In other words, oppositional episodes that do not rebut the grounds have no potential to change the thinking of the participants because the basis of each participant's beliefs rests on the grounds used as justification. When the purpose of engaging in argumentation is to reach consensus about a socio-scientific issue (e.g., whether zoos are 'good' or 'bad'), attacking a grounded claim (e.g., 'zoos are good because people can see the animals and want to protect them') with a grounded reply (e.g., 'zoos are bad because the animals are unhappy') is considered a counterclaim rather than a rebuttal. The attack presents another perspective but does not disqualify the initial claim and, therefore, fits with the Erduran et al. (2004) coding definition that only comments that attack grounds can be coded as rebuttals (Clark & Sampson, 2008).

Most of the rebuttals found in this present study were brought by the student as a natural response to an elaboration. Most of the students' rebuttals are about an idea (concept) and methodology (design of an experiment), and in this research study seemed to be discipline-related.

Challenges

Challenges and negotiations are part of our daily lives, whether it is internally with a colleague or externally with a business partner, classmate, colleague, or spouse. A challenge, as defined in the present study, is a process of negotiation by consensus within a class where students make sense of the theories 'negotiated' in learning communities. By engaging in such processes, students can realize that a 'viable' theory depends on what is known at the time and the context in which the theory is to be applied. The ability to prepare thoroughly for this process is crucial to success in debates and discussions. Through interaction and negotiation with their teacher and peers in activities that focus on the construction, evaluation, and refinement of representations, students develop a richer sense of what makes a good scientific representation within their classroom community.

At school, learning is mediated by the social interactions among members of a learning community (Rogoff, 1990) as they engage in a learning activity. Learning at school is thus influenced by the social activities within the classroom, where student's actions and understanding are grounded in the context of the actions and understanding of other participants in the activity (Rogoff, 1990). Moreover, a student's capacity to learn is influenced by the nature and goals of the activity, the norms and practices of the community (Rogoff, 1990), and the expected and accepted rules and roles of participation (Berger & Luckmann, 1966).

Studies by Danish and Enyedy (2006), Shepardson (1996), and Brown and Palincsar (1989) indicate that social interactions mediate children’s learning. Shepardson (1996), in her study of fourth graders working in small groups, showed that social interactions failed to negotiate a shared meaning of the concept under study (they were studying the butterfly and beetle life cycles). Although their social interactions did improve their science learning, they rather reflected the scientific tendency of describing or naming phenomena in contrast to understanding them. The teacher mediated this learning activity through discourse that (i) negotiated each child’s status, actions, and meaning and (ii) established the normative structure of the small group. Thus, the socially expected and accepted ways for the children to interact within the small group was established by the teacher. With this direct intervention, the process of individual learning shifted toward the teacher’s guidance. This activity might have been more productive if the students had discussed meanings and ideas without the teacher’s intervention (Danish, 2004). The teacher’s discourse enculturated the children into the taken-for-granted way of seeing, knowing, and talking about scientific phenomena (as indicated by Driver, Asoko, Leach, Mortimer, & Scott, 1994).

Coding the Components of an Argument

Recent studies have focused on analyzing students' dialogues as part of the argumentation process. Specifically, these studies focus on the relationships between levels of opposition within a discourse, on the one hand, and the types of comments students make, the quality included in those comments, and the conceptual quality of their ideas, on the other (Clark & Sampson, 2008; Erduran, Simon, & Osborne, 2004; Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Kuhn, 1993; Siegel, 1989). By focusing on the relationships between these aspects of argumentation, this framework offers researchers a specific analytic tool to examine possible connections between argumentation and subject matter learning. For instance, Clark and Sampson’s (2008) framework outlines the theoretical perspectives on dialogic argumentation, then focuses on the coding of individual comments, then discusses the parsing and coding of larger discourse episodes, and finally outlines the analytic approach used to investigate the relationships between discourse episodes and constituent comments.

The framework used in some of the abovementioned studies assigns a code to each comment based on the comment’s role in the discussion. The framework codes each comment in relation to the parent comment to which it responds. These codes take into account comments that are typically examined as part of a structural analysis (e.g., claims, counterclaims, rebuttals), meta-organizational comments that help organize the interaction (which are typically overlooked in a structural analysis), and the occasional off-task interaction. In Clark and Sampson's (2008) study, the coding system for argumentation discourse is an extension of other code systems used in previous studies (Osborne, Simon, & Erduran, 2002; Simon, Erduran, & Osborne, 2002, 2006).

The coding system of argumentation discourse used in the present study follows the works and coding system of Erduran, Simon, and Osborne (2007). The present study focuses on the ways students engage in argumentation when the object of the discussion involves a more 'scientific issue'. A set of the components of an argument that was built and tested in pilot studies is used as a coding system for analyzing students' uses of arguments (Benus, Diaz, Hand, & Norton, 2009).

Generating Questions in a Science Classroom through Inquiry

Recent studies emphasize learning science through inquiry (Lustick, 2010; Keys, 1998; Rosenhire, Meister, & Chapman, 1996; King, 1992; Palincsar & Brown, 1984). The *National Science Education Standards* assert that the main strategy for teaching science is to get students involved in inquiry (e.g., asking questions)(National Research Council, NRC). For school years five to eight, the standards expect students to be able to (i) identify questions that can be answered through scientific investigations and (ii) design and conduct a scientific investigation by developing descriptions, explanations, predictions, and models using evidence. These standards reflect the views of science educators, who believe that students should build on their own knowledge, explore questions that are of interest to them, and learn to use inquiry strategies to build conceptual understandings. However, there is little research on how young students respond when they are asked to pose their own questions and design investigations to answer those questions. For instance, Keys (1998) examines the reasoning strategies of sixth grade students who had the freedom to generate their own investigations in an everyday classroom setting. The reason in selecting sixth graders was because this represents a transitional age between the more concrete thinking of the elementary child and the more abstract thinking of the secondary child. Her study indicates that students could generate science questions and investigations within the context of generative and exploratory science instruction. Furthermore, students were interested in both experimental investigations, where variables were manipulated in order to change the outcome, and descriptive investigations, where natural phenomena were observed and compared. Unlike younger children (third and fourth grades) in earlier studies of children's question and investigation generation (Biddulph, Symington, & Osborne, 1986), students were able to conceive of hands-on activities that would answer their questions, although their investigations were sometimes flawed or incomplete.

Several studies have indicated that children do not think like scientists when confronted with experimental tasks. Clinical research on the development of scientific reasoning in pre- and early adolescents (Carey & Smith, 1993; Kuhn, 1993; Kuhn, Amsel, & O'Loughlin, 1988; Kuhn, Schauble, & Garcia-Mila, 1992; Schauble, Klopfer, & Raghavan, 1991) has indicated that elementary children tend to remain attached to their personal theories. Consequently, they have difficulty deducing the possible consequences of their causal hypotheses and effectively evaluating the meaning of experimental data. Kuhn, Schauble, and Garcia-Mila (1992) conclude that both primitive and sophisticated strategies for making inferences from data are simultaneously present in a child’s repertoire and compete with one another.

Some classroom studies of experimental design in children aged 11–13 (Duggan, Johnson, & Gott, 1996; Germann, Aram, & Burke, 1996) have indicated that most 11-year-olds can design clear experiments when given only one independent and one dependent variable. However, most have difficulty with cognitive tasks such as manipulating two independent variables, conceptualizing data as continuous, quantifying data, graphing, and evaluating the validity of data. Although the students were proficient at observing, describing, and measuring, their processes of hypothesizing, concluding, and explaining were generally weak.

However, recent evidence has indicated that students can attain a deeper understanding of science content and processes when they engage in inquiry (Lustick, 2010; Brown & Campione, 1994; Metz, 1995). Teaching in these recommended ways, however, will require most teachers to develop new knowledge and skills in teaching methods (Borko & Putnam, 1996). Environments that cultivate questioning support student thinking in different ways to traditional science classrooms. Student inquiry is characterized by opportunities to find solutions to real problems by asking and refining questions, designing and conducting investigations, gathering and analyzing information and data, making interpretations, drawing conclusions, and reporting findings (Lunetta, 1998; Minstrell & Van Zee, 2000; Roth, 1995). To guide students in their inquiry efforts teachers need to press students to explain, justify, critique, and revise their ideas as they examine their experiences with phenomena.

Keys (1998) finds that allowing children to pose their own questions has a profound impact on the direction of classroom instruction. She argues that children’s questions help them understand the concepts, processes, and cognitive difficulty of the investigation tasks. The advantages of this approach include stimulating excitement and curiosity, exploring new concepts, and encouraging profound thinking about relationships among questions, tests, evidence, and conclusions. In her study, children were able to change their naive science ideas into more accurate conceptual understandings. For example, learners understood the concept that sound energy can travel for great distances or that fog results when warm moisture meets cold air. Furthermore, students practiced recognizable science process skills such as defining variables operationally, measuring, predicting, inferring, observing, and controlling variables in the context of investigations that were meaningful to them.

However, Keys (1998) acknowledges some disadvantages in such an open-ended instructional approach. Having several groups of students all working on different investigation topics requires teachers be able to quickly evaluate and mediate their questions and plans. Teachers need to determine what needs to be modified, how to probe students so that they can assess their own plans, and make decisions about what changes to suggest. Second, allowing students to generate their own questions compelled teachers to leave scientific concept development open-ended.

The findings of these studies indicate that students can benefit from opportunities to generate their own questions and investigation designs, although the teacher must modify his or her expectations of learning outcomes to reflect that not all students may learn the same concepts. These studies suggest that children should be given the opportunity to raise questions of interest to them in order to validate their science ideas. Firsthand opportunities to transform abstract ideas into actual physical investigations promote a deep level of thinking. However, few textbooks or other curriculum materials are currently available to help teachers facilitate open-ended investigation in primary schools. For example, the distinction between descriptive and experimental types of investigations should be emphasized, so that teachers and students recognize that different types of investigations are appropriate to answer different types of questions. In those studies, students who designed descriptive investigations were able to avoid the difficulties of confounding the variables, suggesting that this may be a good starting place for young children to develop their skills in question generation and corresponding data collection and analysis. Still, to support the statements made in current science education reform documents more classroom research is needed, for instance the development and evaluation of instructional modes that focus on the use of descriptive investigations with young children. Investigations into how teachers and students generate, evaluate, and select questions for descriptive studies are needed, while research must also determine the potential learning outcomes of this form of instruction. Students might also be allowed to design their own experiment variables to test their ideas and curiosity.

Student-generated Questions

Question generation is an important cognitive strategy for fostering comprehension (Palincsar & Brown, 1984) and promoting self-regulation. The act of composing questions focuses the student's attention on content, because the act requires students to concentrate on main ideas while checking to see if content is understood (Palincsar & Brown, 1984). Scardamalia and Bereiter (1985) and Garcia and Pearson (1990) suggest that question generation is one component of teaching students to carry out higher-level cognitive functions for themselves. For example, generating questions about material that has been read is an example of a cognitive strategy. However, this does not lead directly to comprehension. Rather, in the process of generating questions, students need to search the text and combine information, and it is these processes that then help students comprehend the information. Teaching students to ask and generate questions is important because it helps them become sensitive to important points in the text (Wong, 1985). In generating and answering their own questions concerning the key points of a selection, students may find that the problems of inadequate or incomplete comprehension are identified and resolved (Palincsar & Brown, 1984). Student questioning may also aid in clarifying and setting dimensions for the hypotheses being formulated and assist in the control of premature and faulty conclusions.

A number of researchers have examined the benefits on students' comprehension of teachers' uses of higher-order questioning during instructions. However, few have examined the utility of student-generated questions and higher-order questioning on learning. Higher-order questions, based on Bloom's taxonomy, require that students have an increased level of cognitive understanding to answer a question (Bloom, 1956). A question that requires a student to think more elaborately is considered higher than a question in which a student simply relies on factual knowledge. Research studies have found that when the responsibility is placed on students to ask questions, more questions are created and students answer their own higher-order questions (Blais, 1988; Brook, 1990; Wheatley, 1991; Foote, 1998). This approach, which requires students to create questions that elaborate on lecture materials by using generic stems that are based on the higher levels of Bloom's taxonomy, may be of greater benefit to student learning (King, 1989, 1990, 1991).

Furthermore, King (1992) suggests that this procedure is compatible with the schema theory and that new information obtained from lectures is easier to process and recall because it is consistent with the learner's knowledge base. Thus, questions generated by the student allow for an elaboration of the course information in a manner that will build upon existing schemes, which is essentially the constructivist position. By contrast, teacher-initiated questions are based on the assumption that students hold common conceptualizations about a lecture topic. King claims that students using guided questioning that make use of higher-order questions outperform students using the other forms of study; generally, the data suggest that such questioning is superior. She also suggests that students who work in groups perform better than do students studying individually. This claim is based on the assumption that the process of explaining something to someone else promotes learning (Pressley, Woloshyn, King, Martin, & Menke, 1992). In King's research study, usually two sections are randomly assigned to one of the two treatments: guided questioning or review. Within each of the sections, students were randomly assigned to either a cooperative or an individualist learning context. The cooperative contexts were made up of students randomly assigned to triads. A pretest and a posttest were administered to measure comprehension of lecture materials. The test, containing multiple choice and open-ended questions, was designed to measure higher level of thinking. King's results also imply that groups that use question generation techniques improve over time, whereas review groups do not.

Foote (1998), in a study on college students, finds that there is no significant differences between studying in peer groups and self-study groups, and no significant differences between guided or student-generated questioning and unguided questioning. Coupled with some of King's (1991) findings, she suggests that honors students, upper level undergraduates, and graduates are more adept at individualizing study; thus, the effort necessary to learn new cooperative strategies interferes with their typical patterns of learning.

Components of Lessons

The components of arguments (elaboration, rebuttal, and challenge) are the learning scenarios that occur in an elementary science classroom when a Science Writing Heuristic (SWH) approach is employed. These components of this approach are *teacher lecturing*, *hands-on activities*, and *students' presentations* (Benus, Diaz, Hand, & Norton-Meier, 2009). The importance of studying these three different components is to see how the different interactions, dialogs, and argumentations take place. For instance, in teacher lecturing, the relation is usually one-to-one between teacher and student; the teacher asks questions and students respond. Here, the teacher usually stays in front of the classroom, asks questions about a topic, and writes ideas and concepts on the blackboard. The teacher tries to engage all students in discussions. In hands on activity, students work in groups where they brainstorm and negotiate ideas by reaching a consensus and present their findings to their classmates. In this component, students are usually the main actors. Students pose ideas, ask questions, make claims, describe evidence, solve problems, reflect on one another's concepts, and try to gain agreement. In the students' presentations component, students present their findings to their classmates and then run a question and answer session afterwards. Classmates ask the presenters about their ideas, questions, claims, evidence, and reflections on the topic.

For these three learning scenarios to be effective the teacher, more than a facilitator, should act as an 'active listener', where he or she pays close attention to the students' ideas, dialogs, and discourse and helps them address the best approach to solve a particular problem or situation. 'Active listener' is the label this research has utilized to analyze the skill of listening to the conversation for words that can interact with the environment.

Bloom's Taxonomy

Bloom's taxonomy was first published in 1956 by psychologist Benjamin Bloom and several colleagues. Originally developed as a method of classifying educational goals for evaluating student performances, Bloom's taxonomy has been revised over the years and is still utilized in education today. Its original aim was to focus on three major domains of learning: cognitive, affective, and psychomotor.

Bloom's taxonomy originally contained six developmental categories in a cumulative hierarchical framework; the achievement of the next more complex skill or ability required the achievement of the prior one. The categories were knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom, 1956). The first step in the taxonomy focused on knowledge acquisition and at this level students recall, memorize, list, and repeat information. In the second tier, students classify, describe, discuss, identify, and explain information. Next, students demonstrate, interpret, and write about what they have learned and solve problems. In the subsequent step, students compare, contrast, distinguish, and examine what they have learned with other information, and they have the opportunity to question and test this knowledge. Then, students argue, defend, support, and evaluate their opinions on this information and finally create a new project, product, or point of view.

The application of Bloom's taxonomy spans content areas and can be used with any age student. It is versatile and has been widely accepted as a way to promote higher-order thinking. For example, using Bloom's taxonomy as a scaffold, teachers can assess reading comprehension by facilitating conversation and the exchange of ideas (Forehand, 2005; Granello, 2000). As teachers use this scaffold, they can identify the level of reading comprehension while sharpening and clarifying the ways students think critically. They can then challenge students using an oral inquiry scaffold of higher-level questioning based on Bloom's taxonomy.

In this study, Bloom's taxonomy is used to codify the questions generated by teachers and students through oral inquiry. Such oral inquiry, conversations, and debates promote students toward higher-level cognitive thinking as they gain experience and become comfortable debaters.

The SWH approach

The SWH approach is a writing-to-learn model for learning from laboratory activities and can be used by teachers as a framework to design classroom activities. It was developed by Hand and Keys (1999) as a pedagogical tool for embedding language into science instruction. The SWH consists of two heuristic templates. One template, designed to facilitate students in constructing explanations for their observations, guides students in their science activity. This template encourages learners to generate questions, claims, evidence, and arguments based on good reasoning. The second template designed for use by teachers outlines a series of activities that encourage students to think about laboratory concepts and provides teachers with strategies to enhance learning. This template emphasizes the use of social and individual negotiation and provides a format for teachers to structure their curricula around key concepts. The generation of questions by students is negotiated with the teacher and their peers, which allows them to take the lead role in their own learning while satisfying curricular goals.

In order for students to engage in science argumentation, an environment must be fostered by the teacher that allows students to talk in a real science context (Lemke, 1990). This environment must be non-threatening, in which students feel free and safe to ask, argue, rebut, and challenge within the limits imposed by the teacher. The SWH approach provides multiple opportunities for students to develop a conceptual understanding by integrating practical work with peer group discussion, writing, and reading.

Research on the SWH approach has demonstrated its positive impact on students' conceptual understanding at a secondary and college level (Hand & Keys, 1999; Keys, Hand, Prain, & Collins, 1999; Wallace, Yang, Hand, & Hohenshell, 2001; Hohenshell & Hand, 2006; Rudd, Greenebowe, Hand, & Legg, 2001). Hand, Wallace, and Yang (2004) report that seventh graders tutored under the SWH approach performed in their study significantly better than control students did. In another study, ninth and tenth graders using the SWH approach performed significantly better on conceptual questions than did a control group after writing activities (Hohenshell & Hand, 2006). According to Hohenshell and Hand, the SWH template thus provides opportunities for students to think critically and to reason about the meaning of their data while promoting the development of scientific concepts.

There are limitations to the SWH approach, too. Its effectiveness depends on the teacher, while Burke, Greenebowe, and Hand (2006) suggest that effective instructor strategies are necessary for implementing it successfully. They argue that instructors should assist students in negotiating meanings from experimental data and observations. Cavagnetto, Norton-Meier, and Hand (2006) find that students perform better when the level of implementation increases. Teachers that implement the approach more fully can internalize pedagogical skills when students are in control of their own learning.

In summary, the SWH is a framework for instruction based on providing multiple opportunities for students to develop a conceptual understanding. This researcher was interested in using the SWH approach because of its emphasis on argumentation and student-generated questioning.

Summary

This chapter established the theoretical framework on which the present study is based. Drawing from the studies summarized in the literature review, a framework was devised to assess students' uses of argumentative practices and a method for interpreting the findings. This review provided a theoretical basis for the analytical framework that examines the components of an argument (elaboration, rebuttal, and challenge) and how well students are engaged in questioning.

CHAPTER THREE

DESIGN AND METHODS

This chapter will describe the methods used to analyze usage of argumentative practices in three different science classrooms employing the SWH approach. In the first part of the chapter, these methods will be described against the background of the Bloom's Taxonomy found in these classrooms. Rationale will be explored in the chapter's second part before exploring the research context by reviewing videos and transcripts made of the science classes. The chapter will close with a discussion of the relevant instruments, data collection and analytical procedures.

Research Methods

This study uses a mixture of qualitative and quantitative methods. The qualitative aspect of the study analyzes teacher and student interactions in the classroom using video recordings of science class periods. The content of these videos has been transcribed for reference purposes. Each video was examined for incidences of argumentation, identifying the teacher, the subject matter and the specific phases of the learning environment when the argumentation occurred, such as whether during lecturing, small group interactions or hands-on activities. A coding system for classifying and ordering the components of arguments and Bloom's Taxonomy observed was developed and used for classifying/ordering the data.

The quantitative aspect of the study uses descriptive statistics, tables and plots to analyze the data. Graphical data plots and tables are utilized to aid in the analysis by providing visual tools to evaluate trends and patterns across years and across subject. Since the major criticism against such visual analysis by graphs, plots and tables has been centered on the low-inter-rater reliability shown in such empirical studies, the suggested alternative has been to use inferential statistics. This statistical method, however, requires an intensive study of the individual (teacher) rather than of groups. To overcome this problem, the researcher used qualitative method to perform a deep and intensive study of each subject by using three levels of analysis (Gall, Gall, and Borg, 2003) each of which is discussed below.

Recognizing that while it has its drawbacks, a graphical or tabular approach is considered to better fit the purposes of this study rather than inferential statistics. For this reason, the researcher will display the information in graphical or tabular form (descriptive statistics). A contingency table has been used to compare the distribution (occurrence) of questions generated by either students or teacher administered in year 2007 to the distribution in year 2008, and from 2008 to 2009. This technique enables the researcher to make assertions about the questions for each or any particular of the three teachers, rather than of the whole population of teachers participating in the SWH approach study. The claims about each of the individual teachers in this study are grounded in this technique, avoiding generalizations about teachers that have participated in the SWH approach.

The use of multiple instruments also helps with consistency for the findings. Triangulation increases opportunities to control, or assess some of the threats that can influence the results. Through intensive study of these three teachers, the researcher will be able to provide the reader with a picture of how the teachers interact with the Science Writing Heuristic approach through the use of argumentative practices and the components of the Bloom taxonomy.

Admittedly, this study suffers from the lack of video recordings of teachers in early stages of using the SWH approach. If there had been such early recordings it would have been possible to track the usages of the argumentative practices in the classroom from the beginning and include an early stage in comparative analysis with a present stage. It must also be noted that the sequences of lessons and subjects are not exactly the same for all teachers. For instance, videotapes of two of the teachers are from the first semester of the 2008-2009 academic year, but the videotapes of the third teacher are from the previous year – 2007.

In summary, a mixed method approach was used to increase the quality of the final results and to provide a comprehensive understanding of the analysis performed. The use of overlapping data sources assists with the total validity of the outcomes. No generalizations will be made beyond cases similar to the study, and the cases selected will be based on dimensions of a theory (pattern matching). The findings of this study will not be generalized to other populations and the cases selected for analysis were chosen on the basis of mixed method approach and population purposely selected.

Context

The three fifth grader teachers involved in this study were currently enrolled in a professional development project (2007-2009) focusing on the Science Writing Heuristic (SWH) approach, developed by Hand and Wallace (1999). The project aims to help teachers transition from traditional teacher centered forms of instruction to a student centered approaches.

This study evaluates the use of argumentative practices in the form of elaborations, rebuttals and negotiations and of higher order questions by both teachers and students in each teacher's fifth grade science classroom. Information about the case and analysis of the content are organized by patterns and trends across time and between teachers.

Table 1

Participant Teachers, Unit Address, and Length of Videos

Teacher	Semester/year (in the project)	Units address	Topics	No. Video and length (approx.)
John	2nd 2008	Physics	Rockets	4 (60 min.)
	3rd 2008	Biology	Plants, Respiratory System	4 (60 min.)
	4th 2009	Physics	Rockets	4 (60 min.)
Jane	2nd 2008	Physics	Rockets	4 (60 min.)
	3rd 2008	Biology	Plants, Respiratory System	4 (60 min.)
	4th 2009	Physics	Rockets	4 (60 min.)
Karen	1st 2007	Biology	Plants, Respiratory System	4 (60 min.)
	3rd 2008	Biology	Plants, Respiratory System	4 (60 min.)
	4th 2009	Physics	Rockets	4 (60 min.)

The data was collected from videotapes and transcripts of science classes, twelve classes per teacher with each class lasting approximately 60 minutes. The data was organized chronologically and by subject and subtopics (Physics – Rockets, Biology – Plants and Living Things, Respiratory System). The data collected from each of the participating teachers are drawn from two consecutive years of instruction. The students from the academic year 1 (2007-08 fall-spring semesters) of the study are the same in both semesters. The students from the academic year 2007 – 2008 (fall – spring, 1st year) are the same in both semester; they are from the same cohort. The students from the academic year 2008 – 2009 (fall – spring, 2nd year) are the same but from a different cohort of the academic year 2007 – 2008.

The researcher selected videos that best represents a science classroom in a SWH approach that uses argumentative practices, this is all videos must show the components of lesson in action. The videos used for analysis are not all of the same length of time (class period). For example, one video recorded more than 100 minutes for a single lesson, but not all the video was appropriate for analysis since in some of them the students were conducting experiments out of the classroom, where no interaction of the argumentative practices or questioning were observed.

The researcher 'normalized' the length of time by having approximately 240 minutes per teacher per subject in four videos with a sequence of 60-minute lessons per teacher per semester. The videos were selected for analysis based on the following criteria: the video was representative of a SHW approach; all teachers used the same subject and topic; the videos were sequences of the same lesson; the learning phases (teacher lecturing, hands on activities, students presentation) were observable in the videos; and the argumentative practices were discernable.

The data gathered in developing this study for all three teachers highlight the teacher and students' usages of argumentative practices (elaborations, rebuttals and challenges) along with the cognitive level of questioning included videos (for each teacher 12, each of approximately 60 minutes science period) and transcripts of all the videos. The data is organized in a chronological order (semester 1, semester 2, etc.) and by subject and subtopics (Physics – Rockets, Biology – Plants and Living Things and Respiratory System).

A narrative that integrates and summarizes information around the focus of the study is included. This narrative describes the interaction between the teacher and the student in the different phases in which the SWH classroom is divided by three phases of different teacher actions, there being, teacher lecturing (TL), hands on activities (HoA), and students presentations (SP). The next section describes the teachers.

Sample

Students and School

The subjects in this study were fifth grade students and teachers from an elementary school in the Midwest, during the academic years 2007 – 2008, and 2008 – 2009. The students from the first semester were enrolled in Physics (studying rockets), and the class sessions were on the topics of rockets. In the second semester of academic year 2007 – 2008, the students took the biological topic Plants and Living Things. The students in academic year 2008 – 2009 were analyzed completing the same lessons in both semesters.

Teachers

All teachers in this study taught at the same Midwestern elementary school. These teachers were purposely selected because they were using the SWH approach and participants in a SWH professional development program during the two years of the study. They were all experienced teachers with more than six years teaching science. Class sizes were usually less than 25 students, as the student-teacher ratio in the district was less than 20:1. All the classes were in the sciences, with topics ranging from biology

(Plants and Living Things and Respiratory System) to physical science (Rockets). Table 2 shows the participant teachers including their teaching experience (in years), time in the SWH approach, school system and the grades that they teach.

Table 2

Participants Teacher, Years of Experience and Unit Address

Teacher	Experience (years)	Years in SWH	Grades	Units address	Semester/year (in the project)
John	9	3rd	5	Physics Biology Physics	2nd 2008 3rd 2008 4th 2009
Jane	6	3rd	5	Physics Biology Physics	2nd 2008 3rd 2008 4th 2009
Karen	19	3rd	5	Biology Biology Physics	1st 2007 3rd 2008 4th 2009

John

John is an experienced teacher who has taught at the elementary level for 9 years, but in two different schools district within the same state. He teaches fifth grade science which includes Earth Science, Life Science and Physical Science. In addition, John has taught fourth and fifth grade special education, mathematics, and vocabulary and spelling. John holds a Bachelor of Arts in Elementary Education, with emphasis in Special Education and Multi-categorical K-6. John is currently in his third year using the SWH approach. John has indicated the he feels confident with his science knowledge, but stated that he feels more comfortable teaching Physics than Biology. He mention that he has struggled implementing the SHW approach, but as time goes on he feels more confident using this approach in his classroom.

Karen

Karen is an experienced teacher who has spent 19 years at elementary schools in the same Midwestern state. She teaches general fifth grade Science, Mathematics, History and Languages Arts. In addition, Karen has a K-12 Reading Endorsement. Karen holds a Bachelor of Arts in Elementary Education. She completed a Master of Science in Educational Administration from a large Midwestern university. Karen has indicated that she feels confident with her science knowledge; however, she has indicated that she feels more comfortable teaching Biology than Physics. Schoolteachers recruited her into the SWH approach. Karen has been in the SWH approach for the last three years, and she has been using the approach in her classes for the last two years. She has indicated that she struggles implementing the SHW approach at the beginning, but now feels more confident using it in her classes.

Jane

Jane is also an elementary school teacher with more than six years of teaching experience at two elementary schools in the same district in the Midwest. For three of these years the school was a k-5 building and for the other three years the school was a 4-6 (grade) building. She teaches fifth grade science which includes Physics, Biology, Chemistry, and Earth Science. In addition, she teaches elementary Mathematics, and Languages Arts. Jane has a reading endorsement and a minor in Spanish. Jane holds a Bachelor of Arts in Elementary Education from a college in the Midwest. Like John and

Karen, Jane is in her third year of the SWH approach. Jane states that she has been using the SWH in her classroom since 2007. Jane has mentioned that she is "semi-confident" with her science knowledge. She says, "I don't feel like I know it all, but I do know how to find the answer". Karen recruited Jane to the SWH approach. Jane was looking for a way to improve her students writing skills, but notes that she struggled a lot at the beginning implementing the SWH approach. She says that part of her struggle was 'how to spark conversation' with her students. Even though Jane feels that she has not yet fully mastered the SWH approach, she now feels more confident implementing it and that she is getting better in 'sparking' conversation in the classroom.

John, Jane and Karen help each other with science concepts and ways to implement the SWH approach. For instance, Jane says that when she has a science question, she asks John, since he "knows a lot of science." Karen has a lot of books on curriculum topic studies and they talk about the common misconceptions fifth graders often have about science. Jane says that with the SWH approach she doesn't always need to know everything about what she teaches, because she can learn along with the students. "The students need to see me as a learner in the classroom, not the giver of information. This lends itself to me not having to know right away". She says that can learn with the students during class and then go do research after she finds out where they are leaning or heading with their discussions and what they think they know.

All three teachers have expressed satisfaction with the usefulness of the SWH approach in their classes. It has helped them to interact with the students by making questions, starting debates and using arguments to defend their claims.

Data Analysis

This study was conducted to determine three aspects of implementation to the SWH approach: if the teachers are promoting the use of argumentative practices and higher cognitive levels of questioning; if this is observed across time and/or across sequences of lessons; and if the teachers implement the SWH in similar ways. The study examines the relationship between what teachers say and the level of argumentation in the class using the SWH approach. In particular, the study focuses on how students use questions and construct claim-evidence relationships in different components of a lesson – lectures, laboratory experiences and discussion sessions or presentation – in their classroom.

A three level analytical approach was adopted in order to provide an in depth analysis. Table 3 illustrates levels of analysis. The first level of analysis (macro) consisted in observing the video and reading the transcript. The compatibility of the transcript with what was said in the video was checked, and then the transcript was divided into sections, corresponding to three different activities or components of a lesson in the classroom, that is, hand on activities, students' presentation, or teacher lecturing. The macro analysis also identifies when the different activities (components of a lesson) occurred. A science class period could start with a lecture from the teacher, and move to students working on an activity or making presentations. On occasion all three phases occur in a single class period.

The second level of analysis (meso) is a more in depth analysis. At this level the dialogue that occurs during the class is coded for occurrences of Bloom's taxonomy and several components of arguments, including the use of challenges, rebuttals and requests for elaboration by teachers and students in response to questions and claim-evidence relationship constructions during the class. The meso analysis also identifies questions that lead to the construction of an argument.

The micro level of analysis is the deepest of all the analysis. Once the video was watched/observed and coded properly, the researcher looked for patterns in the teacher and students' discourse (see sample in Appendix A); "dialogue patterns" that prompted students to make arguments and elaborate on their thinking, or helped the teacher to stimulate challenges, elaborations, rebuttals, and talk from the students. At the meso level of analysis, individual questions and claims were identified. At the micro level, the questions were analyzed to identify those that led to a spoken inquiry or request for information. Claims were analyzed to identify those that were believable and convincing; that is, based on facts or good reasoning. Three criteria were used to code dialogue / discourse in the classroom as argumentation. These were *elaboration, rebuttal* and *challenge.*

Table 3

Three Level of Analysis of the Science Class Period

Macro level of analysis: Identification of the teacher action; type of teaching. It consists in watching/observing the video and reading the transcript. Identification of the three components of lesson in a classroom.	**Meso level of analysis**: It consists in watching the video and reading the transcript, and coding it using Bloom Taxonomy, the discourse analysis coding and the argumentation criteria (challenges, rebuttals, elaboration on students' questions, claims and evidence relationships) in the different components of lesson.	**Micro level of analysis**: This level of analysis looks for patterns in the teacher and students' discourse. If the questions trigger students to argue and elaborate in their thinking, is the teacher using higher cognitive level of questioning, if the teacher promotes negotiation, rebuttals, and talk

As described in Chapter Two, teacher interaction with students has been linked to one of the three phases or components of lesson, namely: teacher lecturing, hands-on activities and student presentations. These phases are import for evaluating how the different interactions, dialogs, and argumentations take place. In addition, attention was paid to the role of the teacher as an active listener, where she/he pays close attention to the students' ideas, dialog, and discourse so as to help them address the best approach for solving a particular problem and how the argumentative practice process is promoted in such a situation. "Active listener" is the label this research has utilized to analyze the skill of listening to the conversation for words that can interact with the environment. It has three possible categories, each of which presents particular advantages and disadvantages.

The first category for active listener skills is a monologue. Either a one-to-one or a one-to-none communication, the monologue occurs when the teacher asks questions to one student and waits for that particular student to respond. The teacher gives instruction/direction/guidance and is in charge of the classroom environment. The teacher's voice is present and strong, while the student's voice is almost silent or non-existent. The teacher never receives feedback from students nor encourages dialog and discussion. The teacher selects who will answer and respond. The monologue mode purposely inhibits all dialogs, discussions and conversation.

The second category is Dialogue: one-to-multiple students. In this category the student is encouraged to be an active participant. All students have the same opportunity and amount of time to participate in discussions. In this mode the goal is not to interrupt students' argumentation, and the student's voice is respected.

The last category is Advanced Dialogical Interaction. In this mode, the teacher knows *when* and *what* to ask in the proper space and time. The relationship/dynamic between teacher and student allows for variation. The primary mode is the teacher to student interaction, where the teacher asks questions, and the student response invites elaboration. The teacher lets the students do the talking and does not allow evaluation to impede the students' responses. The other mode for Dialogical Interaction is student-to-student. The student interacts with his/her peer by asking questions, making elaborations, and challenging or rebutting ideas. In all of these interactions between teacher and students, the students' voice is respected and each student is encouraged to be active participant.

Dialogue / discourse was coded as *elaboration* if the student expanded on or elaborated what was given in response to a question or challenge from the teacher or classmates, like "what do you mean" or "could you elaborate."

Dialogue was considered rebuttal if a student presented a form of evidence that contradict or nullify other evidence that was presented by an adverse party (student or group of students). Rebuttals usually took the form of phrases or words like "your data says something different from what we found;" "they can't be tiny (minerals); or "they can't be tiny because they are kind of big (uses her hands to show how big it is)".

A challenge is defined as a process of negotiation by consensus within a class where the students make sense of the theories 'negotiated' in learning communities. By engaging in such processes, students can realize that what is regarded as a viable theory depends on what is known at the time and the context in which the theory is to be applied.

The components of argument are listed in Appendix A, Table A2. Examples of these different coding categories are shown in Appendix A, Table A3, used. On Appendix A, Table A the researcher gave an interpretation and a brief analysis of the situation, and mention in which learning scenario occurs. These examples are drawn from examples of the lessons that have been analyzed.

Instruments, Data Collection, and Analysis

Transcripts and Videos

Videos of a complete sequence of a science lessons in a particular subject were collected and analyzed for all three teachers. In the second semester of year 2008 the teachers recorded at least five videos in Physics on the topic of Rockets (unit of study). In the first semester of year 2009 the teachers recorded at least five videos per unit of study with the subject matter Biology and the topic Living Things and Plants. The data was analyzed as described above. For the distribution of questions, three categories of the Bloom Taxonomy were used: Knowledge (recall information), Comprehension (understanding information), and Analysis (seeing patterns). The reason for only three categories is that these are the categories that have been consistently observed in all the analysis done. The components of argument three categories were used, *elaboration*, *rebuttal* and *challenge*. The distributions of categories were code by identifying the occurrences of discourses fitting the components of argument across the different semesters.

As well as identifying the components of arguments (*elaboration, rebuttals and challenges*) in the discourse, the researcher also examined the overall quality of student arguments. Examining students' argument statements can assess the quality of the students' argument. Statements that make up an argument are divided into one or more premises, but have only one conclusion (Hurley, 1985). The premises and conclusions together are argument statements: premises are set for evidence, with the conclusion following from the evidence. In this study, the researcher analyzed students' arguments for logic in the structure of their conclusion and whether it followed the evidence. This was measured by looking for premise indicators (typically, words such as 'since', 'because', 'for', 'as', etc.) and for conclusion indicators (such as 'therefore', 'hence', 'as a result', etc.). This method was used to identify statements where a conclusion was properly linked to evidence.

The researcher counted the occurrences (per unit of study in a video session) of components of argument (*elaboration, rebuttals or challenge*) and the argument statement (where a conclusion follows a premise). These were matched to components of the lessons where these occurred. The researcher intends to measure any increase from semester to semester in the components of argument and the quality of argument statements. Certainly, not all arguments are sound or good and cases where a conclusion does not follow the premises (statements) or the argument is considered weak are not counted in the distribution (frequency) table. Only where conclusions are followed from premises is the discourse considered an argument statement and counted as such in this study. Conclusions need not achieve a hundred percent accuracy for such purposes. The norm adopted is that the students, after they have done their presentations and discussions, look to an authority or expert (teacher, researcher, books, internet, etc) to learn more about the topic. This makes the process of argumentation valid in the study.

Validity or Inter-rater Reliability

To insure the research is reliable, two doctoral students and the researcher met in five occasions to discuss the methods used for coding the components of argument and the Bloom's Taxonomy. The two scholars are doctoral students from the College of Education at the University of Iowa. They have been working doing research on teachers' perceptions of science classrooms and teachers' discourse analysis, among other topics related to teachers, education and science education. One of the doctoral student's areas of research expertise is Discourse in Systematic Functional Linguistic Perspective and Multimodal representation at Teaching and Learning. The doctoral student has three years of teaching experience in private schools with a teacher certificate, and has been involved in educational research for four years, two with the SWH approach. The other doctoral student has more than five years of teaching experience, several publications including book reviews and has been an instructor at a university in the Midwest. His research interests include how students learn and argumentative practices in a science classroom.

The meetings held for discussing the argumentative practices and developing the coding system were divided into three sets of sessions. The first session of meetings was to delineate the procedure by which the discourse would be coded. Other meetings clarified what would be classified as "Knowledge", "Comprehension", "Application" and "Analysis" questions. This process resulted in definitions for components of arguments to be used in the coding system. It was agreed that the argument statements were going to be coded holistically instead by line or utterance. During these meeting it was also established that when a question is formulated or an argument is stated in the videotape, this would be noted, categorized according to whether it is considered an example of Bloom's Taxonomy, or an argument component or an argument statement. A second set of meetings was held for training, in which we took the same transcripts of different teacher and applied the coding scheme. The transcripts were of different classes and topics (Physics, Biology and Earth Science), but from the same teacher. After this training, a last meeting was scheduled for coding a set of transcripts of one of the teachers of this study.

The researcher and other two scholars (fellow researchers) conducted inter-rater reliability of scoring the Components of Arguments and the Bloom taxonomy over 25 minutes of videos per lesson per teacher for four lessons. A Pearson's correlation coefficient was generated to determine inter-rater reliability for the components of argument and Bloom Taxonomy score and yielded a correlation coefficient of 0.83 across 4 trials of 25 minutes each of a video class period.

Summary

This study utilized a mixed methods design to explorer how the teachers in a SWH approach (or setting) promotes the use of argumentative practices. The observation of the three teachers participants in the study were made to construct a contextualized picture of what occurred in the classroom in the components of lesson (teacher lecturing, hands on activities and students presentations). Frequency tables were made and quantified by the number of time a component of arguments or Bloom Taxonomy was reported.

CHAPTER FOUR

RESULTS

Overview

Before presenting the qualitative data for each participant teacher, it should be noted that the mixed method approach described in Chapter Three was shaped to count and label each teacher's use of argumentative practices. Attention was paid to noting differing phases and establishing criteria to grade the necessary and sufficient conditions for argumentative practices to occur. This chapter will begin by presenting the characteristics of the phases or components of lessons in the study. Descriptive statistics formed the basis for comparing the distributions of questions administered in semesters 1–4 between 2007 and 2009. This technique provided the researcher with data to substantiate assertions about the questions for each of the three teachers and to assess their combined performances.

As described in Chapters Two and Three, teacher–student interactions are linked to one of the three lesson components, namely teacher lecturing, hands-on activities, and students' presentations. These phases are important for evaluating how different interactions, dialogs, and argumentations take place.

The researcher selected videos that best represent a science classroom that operates under a SWH approach. The videos used for analysis were different lengths, for example one video recorded more than 100 minutes for a single lesson, but not all the video was appropriate for analysis because for a proportion of the time no argumentative practices or questioning were observed.

The researcher 'normalized' the length of time by having approximately 240 minutes per teacher per subject (i.e., four 60-minute lessons per semester). The videos were selected for analysis based on the following criteria: the videos were representative of an SWH approach; all teachers used the same subjects and topics; the videos were sequences of the same lesson; the learning phases (teacher lecturing, hands-on activities, and students' presentations) were observable in the videos; and the argumentative practices were discernable.

Comparison across Teachers

A comparison across time and subject for all teachers was used to evaluate argumentative practices in a fifth grade science classroom. Information about the case and the analysis of the content were organized according to the patterns found in the data, and a cross comparison (by time and by teacher) was employed for the analysis.

The data gathered highlighted the teachers and students' usages of argumentative practices (elaborations, rebuttals, and challenges) along with the cognitive level of questioning, as ascertained from the videos and transcripts. The data were organized in chronological order (semester 1, semester 2, etc.) and by subject and subtopics (Physics – Rockets, Biology – Plants and Living Things and Respiratory System).

A narrative that integrated and summarized information around the focus of the study was included. This narrative described the teacher–student interactions in the different learning phases (teacher lecturing (TL), hands-on activities (HoA), and students' presentations (SP)).

The videos analyzed were all sequences of the same lesson (from different, but consecutive, days). The subjects were physics (the topic was rockets) and biology. The sequence started with a lesson (teacher lecturing), then the students worked in small groups (hands-on activities) before presenting their findings to the class (students' presentations). Brief descriptions of the analysis for all teachers are given below.

We used Bloom's taxonomy in the analysis for two reasons: (i) to assess if there was a relationship between a teacher’s questions and students’ responses (in terms of being matched at the same cognitive level) and (ii) to investigate if students were engaged at a higher cognitive level of questioning.

The researcher expected that a teacher who is advanced in the program would engage students at a higher cognitive level of questions and discussions. These teachers have been using the SWH approach for more than three years, and they have been ranked by a group of independent researchers as ‘medium-high' and 'high' using the Reformed Teaching Observation Protocol (Piburn & Sawada, 1999).

Table 4

Participant Teachers, Subject Matter, and Time-line

Semesters, Year	John	Jane	Karen
Semester 1, 2007	No data	No data	Biology
Semester 2, 2008	Physics	Physics	No data
Semester 3, 2008	Biology	Biology	Biology
Semester 4, 2009	Physics	Physics	Physics

The following sections analyze the videos selected according to the study’s criteria. A description of the components of the argumentative practices is provided for all teacher–student interactions. This description includes the teacher, the class subject, and the semester. These categories were assembled into four tables: one describes the distribution of Bloom's taxonomy versus the components of an argument, while the other describes the components of an argument versus the learning phases. The third set of tables profiles the questions generated by the teachers or students using the terms in Bloom's taxonomy (analysis, comprehension, and knowledge). The final table lists the components of an argument that were generated by the teachers or students.

Generating Questions

The *National Science Education Standards* assert that the main strategy for teaching science is to get students involved in inquiry (e.g., asking questions). For school years five to eight, the standards expect students to be able to (i) identify questions that can be answered through scientific investigations and (ii) design and conduct a scientific investigation by developing descriptions, explanations, predictions, and models using evidence.

Introducing students to generating questions is viewed as crucial for the process of active learning. Asking questions helps the learner develop and nurture a sense of curiosity, inquiry, and motivation to gain knowledge. It can also encourage learners to link ideas, pose claims, and defend positions with evidence. Without questions, there is no spark of learning. Questions are generally used to determine the facts of a case, request information, or clarify previous claims.

Bloom's Taxonomy lists six cognitive levels in the following hierarchical order: Knowledge, Application, Comprehension, Analysis, Synthesis, and Evaluation. Of these six levels, only three (Knowledge, Comprehension, and Analysis) are pertinent to this study since they always occur in dialogical teacher–student and student–student interactions. Although Table 5 shows the Application level of Bloom's Taxonomy, this level was not considered for analysis since it represents less than 3% of all scores. The distribution of the components of arguments across semesters is shown in Table 6.

Table 5

Components of an Argument and Bloom's Taxonomy for All Interactions

	Knowledge	Comprehension	Application	Analysis	Totals
Elaborations	40	91	12	186	329
Rebuttals	3	41	0	35	79
Challenges	0	17	1	32	50
Totals	43	149	13	253	458

Table 6

Components of Arguments by Year

Semesters	Elaborations		Rebuttals		Challenges		Totals	
	T	S	T	S	T	S	T_{total}	S_{total}
Sem 1, 2007	34	5	0	6	6	1	40	12
Sem 2, 2008	34	25	7	13	7	9	48	47
Sem 3, 2008	71	49	0	14	0	0	71	63
Sem 4, 2009	60	39	19	20	10	16	89	75
Totals	199	118	26	53	23	26	248	197

Note: T stands for teacher and S for student

Altogether, 458 scores were counted (including the Application Level). However, as mentioned above, the analysis was completed with 445 scores because the Application scores were eliminated. Over half (56%; 248/445) of the components of arguments were generated by teachers. Elaboration was the component that had the highest score.

To determine whether the questions generated belonged to any of the three levels observed, the researcher looked at the dialogical interaction (or conversation) as a whole. A dialogical interaction describes how a question was coded according to whether it had a response at the same cognitive level as it was asked at. This interaction could take up to 20 ‘talking turns’, as the teacher on some occasions continued to talk. However, the process was counted as one question/one answer when the question was finally properly answered by the student.

Generating Questions: Analysis,
Comprehension, and Knowledge

The Analysis level, as described by Bloom (1954), examines if students divide information into parts by identifying motives and finding evidence to support generalizations. The Comprehension level addresses whether students demonstrate an understanding of the facts and ideas by comparing and stating the main ideas. The Knowledge level examines whether students remember previously learned materials.

A total of 253 Analysis questions were studied, which represents 57% of all questions coded (n=445), while Comprehension questions numbered 149 (33%) and Knowledge questions 43 (10%). The following table codes the Analysis questions by semester and year, by subject and by teacher.

Tables 7 and 8 show that of the 253 Analysis scores, questions that led to an argument generated by teachers totaled 148 (58%) and those that led to an argument by a student 105 (42%). In general, students generating questions in class increased over time. This applied to all three teachers. By teacher, John remained the highest, while Jane increased by 15% from semester 2 to semester 3 and Karen increased from 5% in semester 1 to 34% at the last semester. Comparing all three teachers, John had the highest percentage of students generating Analysis questions with 75%, followed by Jane (33%) and Karen (18%). In John's classes, the questions in both subjects seemed to be generated mostly by students, with more being generated in Physics than in Biology. In Jane and Karen's cases, the teachers generated most questions.

Table 7

Semesters	Knowledge		Comprehension		Analysis		Totals	
	T	S	T	S	T	S	T_{total}	S_{total}
Sem 1, 2007	8	0	16	11	18	1	42	12
Sem 2, 2008	1	1	17	13	34	26	52	40
Sem 3, 2008	19	9	24	18	46	22	89	49
Sem 4, 2009	5	0	33	17	50	56	88	73
Totals	33	10	90	59	148	105	271	174

Distribution of Questions per Semester per Subject

Comprehension questions, as seen in Table 8, represented 33% of all questions properly coded (149/445). The students generated 59 (40%) of the Comprehension questions, while the teachers generated 90 (60%). John, as before, was the highest ranked teacher. Jane increased by 28% from semester 2 to semester 3 but dropped in the last semester. Karen decreased from 41% in semester 1 to less than 10% at the final two semesters.

Table 8

Generating Analysis Questions for All Three Teachers

Semester – Subject	John		Jane		Karen	
	Teacher	Student	Teacher	Student	Teacher	Student
Sem. 1 2007 Biology	N/D	N/D	N/D	N/D	18/19	1/19
Sem. 2 2008 Physics	6/23	17/23	28/37	9/37	N/D	N/D
Sem. 3 2008 Biology	7/17	10/17	14/23	9/23	25/28	3/28
Sem. 4 2009 Physics	7/39	32/39	24/38	14/38	19/29	10/29
Totals	20/79	59/79	66/98	32/98	62/76	14/76

Knowledge questions represented 10% of all questions generated (43/445). Student participation in generating knowledge questions was only about 23% (10/43). Knowledge questions are used to start a conversation/discussion. Thus, over three-quarters (77%) were started by teachers (especially John and Karen). In the case of Jane, this came after an Elaboration during the students' presentations phase. Karen always generated the questions in her classroom, whereas Jane’s students generated most of the knowledge questions.

Table 9

Generating Comprehension Questions for All Three Teachers

Semester – Subject	John		Jane		Karen	
	Teacher	Student	Teacher	Student	Teacher	Student
Sem. 1 2007 Biology	N/D	N/D	N/D	N/D	16/27	11/27
Sem. 2 2008 Physics	0/9	9/9	17/21	4/21	N/D	N/D
Sem. 3 2008 Biology	4/13	9/13	6/14	8/14	14/15	1/15
Sem. 4 2009 Physics	0/9	9/9	13/19	6/19	20/22	2/22
Totals	4/31	27/31	36/54	18/54	50/64	14/64

Note: N/D stands for no data available.

Table 10

Generating Knowledge Questions for All Three Teachers

Semester – Subject	John		Jane		Karen	
	Teacher	Student	Teacher	Student	Teacher	Student
Sem. 1 2007 Biology	N/D	N/D	N/D	N/D	8/8	0
Sem. 2 2008 Physics	0/1	1/1	1/1	0/1	N/D	N/D
Sem. 3 2008 Biology	8/9	1/9	2/10	8/10	9/9	0
Sem. 4 2009 Physics	3/3	0/3	0	0	2/2	0
Totals	11/13	2/13	3/11	8/11	19/19	0/19

Generating Components of Arguments

The search for patterns in discussions is of great importance because it offers a better picture of how students are progressing in science. Three criteria were used in the micro-level analysis for coding argumentation in the three learning phases: *students' elaborations, students' rebuttals, and students' challenges*.

Generating Components of Arguments:

Elaboration, Rebuttals, and Challenges

The researcher defined the components of arguments in Chapter Three. Briefly, *student's elaborations* are defined as when the student was capable of expanding or elaborating upon what was given and how the teacher addressed the students and helped them elaborate. *Students' rebuttals* are defined as a form of evidence that is presented to contradict or nullify evidence presented by an adverse party. *Students' challenges* are defined as a process of negotiation by consensus within a class where students make sense of the theories 'negotiated' in students' learning communities.

The component Elaboration represented 71% (317/445) of all components. Students generated only 38% (121/317) of the elaborations, but tended to become more involved or elaborated more in class discussions over time. John was again the highest ranked teacher (Table 9). The subject matter plays a role here.

The component Challenge represented 11% (50/445) of all components. Students generated 27 of the 50 (54%) Rebuttals. In John's classes, 90% of the challenges were led by students, while in Jane and Karen's sessions the challenges were predominately led by the teacher, with scores of 60% or above.

Table 11

Generating Components of Arguments: Elaboration

Semester – Subject	John		Jane		Karen	
	Teacher	Student	Teacher	Student	Teacher	Student
Sem. 1 2007 Biology	N/D	N/D	N/D	N/D	34/39 (87%)	5/39 (13%)
Sem. 2 2008 Physics	7/23 (30%)	16/23 (70%)	27/36 (76%)	9/36 (24%)	N/D	N/D
Sem. 3 2008 Biology	12/34 (35%)	22/34 (65%)	9/33 (27%)	24/33 (73%)	50/53 (94%)	3/53 (6%)
Sem. 4 2009 Physics	9/31 (29%)	22/31 (71%)	26/35 (74%)	9/35 (26%)	25/33 (76%)	8/33 (24%)
Totals	28/88 (32%)	60/88 (68%)	62/104 (60%)	42/104 (40%)	109/125 (87%)	16/125 (13%)

Interestingly, Table 12 shows that in semester 3 neither John nor Karen scored any challenges in Biology and that Jane's only score was led by a student. Physics is a very strong area for John with more than 87% of all challenges generated by students (compared with Jane 25% and Karen 40% in one semester). In total, John had 90% of challenges being generated by students (Jane 33%; Karen 25%). This raises the issue of whether the type of activity influences how students argue.

Table 12

Generating Components of Arguments: Challenges

Semester – Subject	John		Jane		Karen	
	Teacher	Student	Teacher	Student	Teacher	Student
Sem. 1 2007 Biology	N/D	N/D	N/D	N/D	6/7 (86%)	1/7 (14%)
Sem. 2 2008 Physics	1/8 (13%)	7/8 (87%)	6/8 (75%)	2/8 (25%)	N/D	N/D
Sem. 3 2008 Biology	0	0	0/1 (0%)	1/1 (100%)	0	0
Sem. 4 2009 Physics	1/12 (8%)	11/12 (92%)	6/9 (67%)	3/9 (33%)	3/5 (60%)	2/5 (40%)
Totals	2/20 (10%)	18/20 (90%)	12/18 (67%)	6/18 (33%)	9/12 (75%)	3/12 (25%)

The component Rebuttals represented only 18% (79/445) of all components. Rebuttals were mostly generated by students (67%; 53/79).. In John's classes, rebuttals were led by students solely. In Jane's Biology semester 3, all rebuttals were driven by students, while in semester 4 Physics this changed to 50%. Karen and her students also shared an equal percentage. However, in her semester 4 Physics class, 75% of the rebuttals were generated by the teacher. Table 13 suggests that students gradually found their voices over time in this area. In total, all John and Karen's rebuttals were generated by students, whereas only two-thirds were for Jane.

Table 13

Generating Components of Arguments: Rebuttals

Semester – Subject	John		Jane		Karen	
	Teacher	Student	Teacher	Student	Teacher	Student
Sem. 1 2007 Biology	N/D	N/D	N/D	N/D	0/6 (0%)	6/6 (100%)
Sem. 2 2008 Physics	0/5 (0%)	5/5 (100%)	7/15 (47%)	8/15 (53%)	N/D	N/D
Sem. 3 2008 Biology	0	0	0/13 (0%)	13/13 (100%)	0/1 (0%)	1/1 (100%)
Sem. 4 2009 Physics	0/10 (0%)	10/10 (100%)	7/13 (54%)	6/13 (46%)	12/16 (75%)	4/16 (25%)
Totals	0/15 (0%)	15/15 (100%)	14/41 (34%)	27/41 (66%)	12/23 (52%)	11/23 (48%)

Results for each Individual Teacher

John

John is the most passive of all three teachers; although his voice is present, he tends to let the students do most of the talking. Typically, he does not overwhelm the students by asking too many questions. Most videos show John walking around the classroom, asking a few questions, and letting the students ask questions, debate, and elaborate. John paid attention to students while they presented their data, letting them elaborate and defend their positions. Table 14 shows that of the 445 components of arguments scored for all three teachers (generated by either the teacher or student), John has 123 (28%), 76% (93/123) of which were Elaborations, with the teacher generating 35 (38%) of these and the students generating 58 (62%). Table 15 shows the distribution of the Elaborations, Rebuttals, and Challenges across the three levels of Bloom's taxonomy.

The Analysis level in Bloom's taxonomy has 55/123 (63%) of all questions generated on Elaboration. Of those 55 questions 18/123 (15%) were generated by the teacher and 37/123 (30%) by the students. Comprehension has a score of 31/123 (25%) with the students generating 27/123 (22%) across all components. Most questions on Comprehension are associated with Elaborations and they were mostly generated by students. Finally, Knowledge (11% of all questions coded) was mostly generated by the teacher. Notice that higher -order cognitive questions (Comprehension and Analysis) were generated by students, whereas lower-order cognitive questions were generated by the teacher. If the Elaborations in the Knowledge level occur in the phase Teacher Lecturing, it could be asserted that this is because the teacher leads the conversation and students respond.

The distribution of Bloom's taxonomy questions within Rebuttals and Challenges represents 28% of all components. It occurred in only two of the levels: Comprehension, where all 11 questions were student-generated, and Analysis, of which 22 of the 24 questions were generated by students. In the Students' Presentations phase, it is likely that students generate most questions (presentations are followed by a question and answer session led by the class).

As Table 15 shows, most Elaborations are related to the highest cognitive questions (Analysis level). For all three subjects, Analysis scored 63% (55/88), although the percentages in both Physics semesters were higher than those in the Biology semester. In Biology, only 44% (17/39) of Elaborations were associated with Analysis questions. No Rebuttals or Challenges were reported in Biology.

Table 14

John's Bloom's Taxonomy Distribution versus the Components of Arguments - All Semesters

CoA	Knowledge		Comprehension		Analysis		Total in Phases
	Teacher	Students	Teacher	Students	Teacher	Student	
Elaborations	11	2	4	16	18	37	88 (T=33, S=55)
Rebuttals	0	0	0	5	2	8	15 (T=2, S=13)
Challenges	0	0	0	6	0	14	20 (T=0, S=20)
Totals	11/13	2/13	4/31	27/31	20/79	59/79	123

Note: CoA stands for Components of Arguments.

Table 15

John's Bloom's Taxonomy Distribution versus Components of Arguments per Semester

CoA	Semester	Knowledge		Comprehension		Analysis	
		Teacher	Students	Teacher	Students	Teacher	Student
Elaborations	Phys. 2nd	0	1	0	4	5	10
	Biol. 3rd	8	1	4	9	7	10
	Phys. 4th	3	0	0	3	6	17
Rebuttals	Phys. 2nd	0	0	0	2	1	2
	Biol. 3rd	0	0	0	0	0	0
	Phys. 4th	0	0	0	3	1	6
Challenges	Phys. 2nd	0	0	0	3	0	5
	Biol. 3rd	0	0	0	0	0	0
	Phys. 4th	0	0	0	3	0	9

The distribution in Table 16 shows in which the components of lessons the components of argument occurs. Teacher Lecturing registered 18/123 (14%) of all scores recorded, Hands-on Activities represented 71 (58%) and Students' Presentations 34 (28%). The phase Hands-on Activities, a component led mostly by student–student interactions, scored 51/88 (58%) of the Elaborations reported. Students' Presentations had 19/88 (22%) while Teacher Lecturing had 18/88 (20%). Only in Biology semester 3 was an Elaboration observed during Teaching Lecturing.

Table 16

John's Components of Arguments Distribution versus Components of Lessons

CoL	Elaboration		Rebuttals		Challenges		Totals
	Teacher	Students	Teacher	Students	Teacher	Students	
Phys. 2nd TL	0	0	0	0	0	0	0/33
Phys. 2nd HoA	4	9	0	0	1	7	21/33
Phys. 2nd SP	1	6	0	5	0	0	12/33
Biol. 3rd TL	10	8	0	0	0	0	18/39
Biol. 3rd HoA	4	17	0	0	0	0	21/39
Biol. 3rd SP	0	0	0	0	0	0	0/39
Phys. 4th TL	0	0	0	0	0	0	0/51
Phys. 4th HoA	7	10	0	2	1	9	29/51
Phys. 4th SP	2	10	0	8	0	2	22/51

Note: Phys. stands for Physics second and fourth semester, and Biol. stands for Biology. CoL is for component of lessons.

Jane

Jane is in her third year of the SWH approach. She states that she has been using the SWH in her classroom since 2007 and is 'semi-confident' about her science knowledge. Jane is a more active teacher than is John in terms of commanding actions in the classroom. She has a tendency of asking most of the questions, although in the late semester she began to let the students' voices be heard.

Table 17 shows that of the 445 scores for all three teachers (generated by either the teacher or students), Jane's classes generated 38% (163/445). Of those, 105 (64%) were generated by Jane and 58 (36%) were generated by students. Altogether, 104 (64%) scores were on Elaborations where 69 (42%) were generated by the teacher and 35 (21%) generated by the students. Of the 41 Rebuttals, 23 were generated by the teacher and 18 by the students. Of the 18 Challenges, 13 were generated by the teacher and only five by the students. In terms of Bloom's taxonomy scores, 98 (60% of all Jane's scores) were in the Analysis component (with 66 generated by the teacher), 54 scores for Comprehension (36), and 11 scores for Knowledge (three).

Jane distribution of Bloom's taxonomy levels looks different to that of John. She generates most of the questions in Comprehension and Analysis. Furthermore, looking at the components of arguments, Jane achieved 64% (69/104) of the Elaborations and generated 61% (36/59) of the Rebuttals and Challenges.

Table 17

Jane's Bloom's Taxonomy Distribution versus the Components of Arguments - All Semesters

CoA	Knowledge		Comprehension		Analysis		Total
	Teacher	Students	Teacher	Students	Teacher	Student	
Elaboration	2	7	19	8	48	20	104(T=69,S=35)
Rebuttals	1	1	13	9	9	8	41(T=23, S=18)
Challenges	0	0	4	1	9	4	18(T=13, S=5)
Totals	11/163		54/163		98/163		163

As shown in Table 18, most Elaborations in all three semesters are related to the higher-order cognitive questions (Analysis and Comprehension levels) and most are generated by the teacher. For instance, in the Analysis level, 71% of Elaborations were generated by the teacher. In Biology, the students' percentage of generating questions (39%) is higher than that in Physics (26%). No Challenges were reported for the Knowledge level.

Table 19 shows that Students' Presentations scored 74% (120/163), with 64 questions generated by the teacher and 56 questions generated by the students. Hands-on Activities scored 22% (36), with the teacher generating 21 and the students 15, while Teacher Lecturing had 4.3% (7). Elaboration was most involved in all three components (64%; 104/163), with 62 generated by the teacher and 42 by the students. Notice that the teacher generating most questions in Physics but the opposite is true in Biology.

Rebuttals are more student-driven, scoring almost twice as many as did the teacher, and most occur in Students' Presentations. Challenges are mostly teacher-driven.

Table 18

Jane's Bloom's Taxonomy Distribution versus Components of Arguments per Semester

CoA	Semester	Knowledge		Comprehension		Analysis	
		Teacher	Students	Teacher	Students	Teacher	Student
Elaboration	Phys. 2nd	0	0	7	3	20	6
	Biol. 3rd	2	7	4	2	11	7
	Phys. 4th	0	0	8	3	17	7
Rebuttals	Phys. 2nd	1	0	8	1	3	2
	Biol. 3rd	0	1	2	6	2	2
	Phys. 4th	0	0	3	2	4	4
Challenge	Phys. 2nd	0	0	2	0	5	1
	Biol. 3rd	0	0	0	0	1	0
	Phys. 4th	0	0	2	1	3	3

Table 19

Jane's Components of Arguments Distribution versus Components of Lessons

CoL	Elaboration		Rebuttals		Challenges		Totals
	Teacher	Students	Teacher	Students	Teacher	Students	
Phys. 2nd TL	0	0	0	0	0	0	0/57
Phys. 2nd HoA	5	0	1	0	0	0	6/57
Phys. 2nd SP	20	9	6	8	6	2	51/57
Biol. 3rd TL	3	2	0	2	0	0	7/47
Biol. 3rd HoA	4	10	0	1	0	1	16/47
Biol. 3rd SP	2	12	0	10	0	0	24/47
Phys. 4th TL	0	0	0	0	0	0	0/59
Phys. 4th HoA	8	2	2	0	1	1	14/59
Phys. 4th SP	20	7	5	6	5	2	45/59

Note: Phys. stands for Physics second and fourth semester, and Biol. stands for Biology. CoL is for components of lessons.

Karen

Karen is the most experienced teacher of the three (19 years as an elementary school teacher in the Midwest). She has indicated that she feels confident with her science knowledge. She struggled to implement the SWH approach at the beginning, but now feels more confident using it in her classes. Karen is the most active of the three teachers. Her voice is strongly present, and in her earlier videos she asked virtually all the questions. Over time, Karen has shown a willingness to let the students talk in small discussion groups. In her later videos, she said 'talk to your neighbor' when a topic for discussion came out of an inquiry. Table 20 proves that she generates most questions (131/159; 82%). As with the other teachers, Analysis generates most questions, and Elaborations are most used (79%).

Table 20

Karen's Bloom's Taxonomy Distribution versus the Components of Arguments - All Semesters

CoA	Knowledge		Comprehension		Analysis		Total
	Teacher	Students	Teacher	Students	Teacher	Student	
Elaboration	18	0	39	5	52	11	125(T=109,S=16)
Rebuttals	1	0	6	8	5	3	23(T=12,S=11)
Challenges	0	0	5	1	5	0	11(T=10,S=1)
Totals	19/159		64/159		76/159		159

As shown in Table 21, most Elaborations are related to higher-order cognitive questions: Analysis (63; 52 by teacher) and Comprehension (44; 39 by teacher). Almost one-third of all Elaborations occurred in the Biology 3rd semester with 51 out of 125 Elaborations scored across all disciplines. The students' percentage of generating questions across disciplines is less than 18%. However, in the final semester (Physics 4th) there is an increase in students generating questions in the Analysis level.

Table 22 shows that Elaboration is more evenly distributed in Karen's data than in those of John or Jane. Hands-on Activities scores 42 on Elaboration generated by the teacher, while Students' Presentations and Teacher Lecturing score 36 and 32, respectively. Most Elaborations across semesters and disciplines are generated by the teacher. The total score by Karen is 159, making Elaborations generated by the teacher 69% of her total. Note that only in the phase Students' Presentations in both Physics semesters does the percentage of students generating questions increase. Biology seems to be more teacher-driven in this respect.

Table 21

Karen's Bloom's Taxonomy Distribution versus Components of Arguments per Semester

CoA	Semester	Knowledge		Comprehension		Analysis	
		Teacher	Students	Teacher	Students	Teacher	Student
Elaboration	Biol. 1st	8	0	13	4	15	1
	Biol. 3rd	9	0	14	1	25	2
	Physics 4th	1	0	12	0	12	8
Rebuttals	Biol. 1st	0	0	0	6	0	0
	Biol. 3rd	0	0	0	0	0	1
	Physics 4th	1	0	6	2	5	2
Challenge	Biol. 1st	0	0	3	1	3	0
	Biol. 3rd	0	0	0	0	0	0
	Physics 4th	0	0	2	0	2	0

Table 22

Karen's Components of Arguments Distribution versus Components of Lessons

CoL	Elaboration		Rebuttals		Challenges		Totals
	Teacher	Students	Teacher	Students	Teacher	Students	
Biol. 1st TL	6	0	0	0	0	0	6/51
Biol. 1st HoA	14	1	0	0	5	0	20/51
Biol. 1st SP	14	4	0	6	0	1	25/51
Biol. 3rd TL	15	0	0	0	0	0	15/54
Biol. 3rd HoA	18	3	0	0	0	0	21/54
Biol. 3rd SP	17	0	0	1	0	0	18/54
Phys. 4th TL	10	1	0	0	0	0	11/54
Phys. 4th HoA	10	2	10	2	3	2	29/54
Phys. 4th SP	5	5	2	2	0	0	14/54

Summary of Results

The findings presented here suggest that all teachers are becoming more student-centric by using the argumentative approach. In John's classes, Elaborations are mostly generated by students. In addition, John has the highest percentage of students generating Elaborations. Jane shows an increase in students generating Elaborations in an academic year (same students but different subject). However, this drops back in the last semester (Physics 4). Jane acknowledges that she has some difficulties with Physics and her scores

(Elaboration-driven) seem thereby to be subject related. Karen also shows an increase, but she still generated most of the questions in her classes. The same tendency was observed with Rebuttals and Challenges but to a lesser degree (those two components are less than 30% of all reported). Looking across semesters John is the highest ranked teacher in terms of students generating Elaborations.

Another finding is that students consistently engage with the critical components of arguments. Evidence of this can be seen in the phases Hands-on Activities and Students' Presentations, where most Elaborations were observed. In these phases, students comment, judge, and discuss whether a claim is convincing or based on facts. Students show a depth and quality in their discussions while elaborating; they also analyze whether statements have the necessary and sufficient conditions for a claim to be a sound one.

CHAPTER FIVE

DISCUSSIONS OF THE RESULTS

This concluding chapter will interpret the implications of the findings reported in Chapter Four. After a brief review of the original the research questions, the chapter will explore the overall findings and elaborate how this research may be applied to the usage of argumentative practices in the classroom science education.

Answer to Research Questions

Research Questions # 1

At the individual teacher level, is there a shift from teacher-generated questions to student-generated questions? If there is a change (shift), is this change uniform across time and for all subjects?

The results of this study suggest that as they became more familiar with the SWH approach, all three teachers moved from using teacher-generated questions to student generated questions. Looking at individual results, the data shows that one teacher consistently promoted student generated questions. Although the other two teachers still generated most of the questions, they also exhibited a greater tendency to use more student generated questions. The increase of student generated questions is reflected for all across time, from semester two to semester four. The changes, however, are not uniform. As stated above, one teacher was observed at the beginning of the research to have already adopted a classroom practice of promoting student questions. The others were observed initially to have generated most of the questions themselves. During the observation, however, their growing familiarity with the SWH approach over the course of two semesters induced them to gradually shift to an approach that more frequently encouraged students to ask the questions. The data show that the shift appears to be related to the subject-matter for the particular teachers. In subjects in which an individual teacher has a higher expertise there is a higher increase in student generated questions.

Research Question # 2.

Do the patterns of teachers' discourse change during a consecutive series of lessons on the same topic. In other words, does the teacher promote the use of the components of argument in their dialog and discussions: across time within one topic? Across a sequence of lessons? Are there common characteristics between the three teachers in this study when implementing the SWH approach, across time and across sequences of lessons?

The results suggest that all three teachers promoted the use of the components of arguments in their dialog and discussions, and encouraged students to elaborate, challenge and rebut each other's ideas in a non-threatening environment.

Although the three teachers had different personalities – for example, one was very quiet and another was very talkative – all three implemented the SWH in similar ways. All students, regardless of which teacher they had, learned to build a series of plausible and convincing statements using solid facts and offering reasons or evidence to support their conclusions.

Explanation of Research Findings

This section discusses how the findings of this research study might contribute to our understanding of how teachers can promote the use of argumentative practices and how students learn to develop an argument. The findings of this study suggest that (a) teachers can successfully encouraged students to generate questions as a way to improve their comprehension of scientific concepts (b) that teachers effectively promoted the use of argumentative practices that (c) led to higher order cognitive thinking and (d) engaged students in the process of "doing science".

Promoting the use of Argumentative Practices
in a Fifth Grade Science Classroom

Argumentative practices are of vital importance in science education. As Newton, Driver and Osborne (1999) pointed out, pedagogies that support arguments are central for an effective education in science. The classroom use of argumentative practices gives the student the opportunity to inspect, and engage with, arguments that lead to the construction of scientific explanations (Osborne, Erduran, & Simon, 2007). Osborne, et al., (2004) argue that learning science requires argumentation; additionally, argumentation can serve as a heuristic to develop an understanding of scientific concepts. Students not only have to learn how to develop valid arguments but in the process also learn scientific concepts / scientific methods. In recent studies researchers have focused on argumentation in scientific communities, either in classrooms or among scientists themselves. In this research study, videos and transcripts of student-teacher interactions were analyzed to investigate how teachers in three SWH classrooms used the components of argument as measured against Bloom's Taxonomy in teaching their students in argumentative practices. The research on teachers' and students' arguments was conducted to evaluate both their quality and quantity, and, as in the case for evaluating teacher generated questions, the student generated questions were analyzed using the components of argument and Bloom Taxonomy.

The results suggest that the process of generating questions in an inquiry based approach increases the quality of students' arguments and the frequency with which students use arguments. This apparent increase means that students use claims and evidence effectively to support their understanding of scientific concepts. Furthermore, as the students generate evidence, they support their claims in accord with the professional scientific method, that is, by making claims publicly and debating them with their peers.

The findings of this study are consistent with recent studies on argumentation in seventh grade and higher science classroom which shows that the students are capable of engaging in argumentative practices, to elaborate and rebut (Kelly, Druker, and Chen, 1998; Osborne et al., 2004; Zohar & Nemet, 2002). It must be noticed, however, that this particular study was focused on students in elementary school and shows that these students appear to be capable of engaging in argumentative practice as well as been able to elaborate, rebut and challenge.

Promoting Students Questions in a Science Classroom

Factual knowledge can be transmitted in the classroom through the process of asking questions, making such questioning one of the most frequently used pedagogical methods of teaching. Teachers ask questions for several reasons: to keep students actively involved in lessons; to give students the opportunity to openly express their ideas and thoughts; to enable students to hear different explanations of the material from their peers; and to evaluate student learning and revise lessons as necessary (Brualdi, 1998; Morgan and Saxton, 1991). These reasons also outline the type of questions that facilitate the learning process. Although many studies have been conducted investigating how questions facilitate the process of learning, most focus on the teacher as the one who generates the questions and not on the student's role in generating questions.

There are some studies in which students were taught to generate questions as a means of improving their comprehension. These showed gains in comprehension, as measured by tests given by the researchers in those studies (Rosenshine & Meister, 1994; Rosenshine, Meister and Chapman,1996; McKeown, 1993). Whatever approach is used to teach questioning skills, researchers have shown that it is important for teachers to provide students with procedural prompts in the form of signal words or generic question stems. Likewise, scaffolding that includes modeling and thinking aloud with a gradual increase in difficulty and independence produces similar results (Rosenshine et al, 1996). For younger children, who are often intimidated by textbooks, researchers have recommended that teachers encourage students to engage in a direct questioning of the author. By seeking out the ideas behind the author's words, engagement and motivation are increased, and by thinking more carefully and deeply about the text, comprehension increases (McKeown et al, 1993). Writing questions during note taking or reviewing can improve students' retention and performance on assessments (King, 1992; Laidlaw, 1993). This has implications for both aural and oral learning, such as through lectures, as well as reading comprehension (King, 1992). However, in these studies, traditional skill-based instructional approaches and reciprocal teaching approaches (students generating the questions) yielded similar results. In addition, the students were taught to ask questions about the content of texts after reading or listening to passages from them. Note that these text-based questions were for clarity, and not for the purpose of debate or argument. Furthermore, these studies were not conducted in a student centered classroom environment, an environment which facilitates student questions.

A student centered classroom is focused on the learner rather than the teacher. The role of the teacher in student-centered learning is to provide a framework (i.e. activities for students to complete) that facilitates their learning. For example, the teacher posts activities or questions that students complete. Projects can include writing papers, essays, and reports, publishing web pages, conducting research, answering open-ended questions, creating artwork, and organizing events. Constructivists believe that for higher levels of cognition, students must build their knowledge through activities that engage them in active learning. Effective learning happens when students take stock of what they already know and then move beyond it.

If the student is the one in charge of his/her own learning, then the learner should be the one in charge of generating the questions that lead to debates and arguments. Theoretically, this will facilitate learning as the learner will need to have a deeper comprehension of the subject matter and alternative ideas in order to debate, elaborate and to rebut an argument. As a teacher feels more comfortable with the SWH approach, the teacher should start shifting from a teacher centered approach to a student centered approach and encourage students to generate more questions in the process of teaching argumentation. This study suggests that the teachers did move toward a more student focused environment, while they (the students) improve their comprehension and debating skills.

The data were analyzed to find out who generated the questions that promoted discussions and negotiations and helped the students to develop a deeper understanding of scientific ideas and the scientific process. In a student centered classroom, where the student is in charge of his own learning, the researcher would expect students to generate most of the questions. The results show that there is a pattern; as teachers felt more comfortable with the SWH, students' voices were heard more and students generated more of the questions that led to debate and arguments. This was most obvious when students asked questions for clarification. By the end of semester 4, although two of the teachers were still generating most of the questions, the number of students generating questions in these two classes had increased compared to previous semesters (see Table 7, Table 8, and Table 9).

It is noticeable (Table 7, Table 8 and Table 9) that the number of questions generated was also discipline related. For instance, John, who stated that he felt more comfortable teaching physics than biology and had the highest number of student generated questions, had a higher number of student questions in the two semesters that he taught physics than in the semester that he taught biology. Meanwhile, Karen and Jane had more students generating questions in Biology. Nevertheless, in all teachers and in both disciples the students have been generating questions at a higher cognitive level as presented in Bloom's Taxonomy. Table 6 shows that more than 60% of the questions generated by the students are in the level Analysis. This might indicate that the students while are conducting an investigation, participating in debates and discussion, or brainstorming ideas, are capable of produce information that supports claims or views. By asking higher order questions the students become actively participants in the community of learning, developed learning attitudes that encouraged inquiry, and made connection with previously learned materials strengthening ideas and concepts. It has been observed in the students' discourse that when students engage in a generated-questioning strategy where the teacher allows students to generate their questions and prompt them to elaborate they are led to a better understanding of the topic in study.

An example on how the discourse patterns change across time can be seen in Table 22 and Table 23. Table 22 shows a sample on when the teacher is the one who is generating the questions and how the interaction between teacher and students take place, at early state. Table 22 and 23 shows how the components were coded. The component of lessons observed on the sample of the transcript is Hand on Activities. Table 23 shows a sample of students' interaction, with occasional teacher intervention, this example is from later in the study.

Table 23

Sample of Teacher-Generated Questions at an Early Stage and Coding

Person	Dialog	CoA	BT
Teacher	Why are we going with the same design?		A
Girl B	Because otherwise that would be too many variables. Cause we're changing how much we touch the tape, and if you change to many, if you do more than one variable in an experiment, you can't tell which one changed it. Um	E	
Teacher	So we're testing to see if they blew up because of our construction?		
Girl B	Yup.		
Teacher	What do you think's gonna happen tomorrow when we launch?		C
Boy A	Well if we didn't viscerate it as much it should go somewhere…	E	
Teacher	Something should happen? Okay.		

Note: CoA stands for components of argument, A is for analysis, C is for Comprehension, E is for Elaboration, and BT is for Bloom's Taxonomy

Table 24

Sample of Students-Generated Questions

Person	Dialog	CoA	BT
Student UNK	But how could they have no cells and dead cells at the same time	R	A
Student UNK	No, cause…		
Student UNK	Like a rock has no cells		
Teacher	So Carter, I here you saying non living things have no cells or dead cells		
Carter	Yeah, just dead cells		
Teacher	And you said living things have cells and dead cells		
Carter	Yes		
Student UNK	The living one does, but how could you have dead cells on both of them		A
Student UNK	Because if they just had dead cells	E	
Student UNK	Non living was never alive so it didn't have cells	R	
Class	Chatter		

Note: R stands for rebuttals, A is for analysis, E for elaboration, CoA is for Component of Argument, and BT is for Bloom's Taxonomy

In summary, the results suggest that as teachers learn / become more familiar with the SWH approach, they move toward more student generated questions, and that this shift is discipline related, in that teachers do better when teaching subjects with which they are more comfortable.

Components of Argument

This study suggest that the students use different components of argument to expand their knowledge of a concept they are studying. Three particular argument components were examined in this study, elaboration, rebuttals and challenges. Students elaborate more when they are asked for clarification, while rebuttals, are used to nullify ideas or concepts. Challenges appear in acts of negotiation and discussions between students about ideas and concepts.

Elaborations, Challenges, and Rebuttals

The component of Elaboration refers to the process of explaining something more in detail, talking about it more in depth or questions that result in an improvement of what has been stated. When a student is asked to elaborate in a discussion, additional information needs to be given for clarification. In this study, Elaborations were the component of argument most observed during student presentations and hands on activities. This may have been because students have more opportunities to negotiate their ideas during these activities.   Students used Elaborations as a response to rebuttals. When students were confronted with rebuttals, they responded with an elaboration. This is what the researcher would expect at this level (fifth graders), given that recent studies indicate that junior high and high school students have difficulties responding to a rebuttal and that they use an elaboration most of the time as a way to answer a rebuttal (Osborne et al., 2007). Kuhn (1991) argues rebuttals are an essential element of better quality arguments and demonstrate a higher-level skill in argumentation. Rebuttals are more difficult than elaboration because they require integrating an original and alternative theory, arguing that the original theory is more accepted or more correct while the alternative has flaws. Osborne, et al., (2007) found that most rebuttals are one of three types: a weak rebuttal with a counterargument that is not self-evident, an argument with a clear rebuttal or an argument with multiple rebuttals. Most of the rebuttals found in this present study were weak, and the use of elaboration appears to be a natural response.

Most of the students' rebuttals are about an idea (concept) and method (design of an experiment), and in this research study seemed to be discipline related. For instance, in Physics while the students were working on Rockets, they suggested that the design of the rocket was a reason why it didn't fly high. Meanwhile in Biology, when the students were working on the Respiratory system, they discussed the design (anatomy) of the respiratory system, but most of the questions were related to concepts, for example, how the respiratory system actually works. Research in argumentation has found similar patterns in which high grade students (middle and high school) tend to answer a rebuttal with an explanation or elaboration.

Outcome of This Study

Are the students doing science? Do they achieve the goals of argument based inquiry? Do they engage high order thinking ideas/questions? Do teachers facilitate this process? In what way?

To understand if these three teachers and their students were engaging in the argumentative process of science in the classroom it is important to understand what scientists do and how scientific knowledge is constructed. Construction of scientific knowledge is first of all public, a collaborative effort among a community of peers working in a particular area. When a scientist presents arguments for a new knowledge claim, the scientific peers examine the inferential chain that forms the "explicit connection" to the explanation. The architecture of that claim is also explored. Under peer scrutiny is how the framing of the phenomenon aligns with the new knowledge claim. Does the reasoning contain errors? Does it ignore confounding factors? Is the identified pattern underlying the research caused by the posited factor? Have the measurements been made accurately? Are the data offered misleading?

Peers are particularly effective at identifying such scientific errors for at least two reasons. First, they have an individual interest in errors because they are typically in competition with the scientist who put forward the claim. Second, peers often have worked for some time in the same conceptual and material space. They have faced some of the same problems and have weighed options, and therefore are intimately familiar with the tedious details involved in the presented knowledge claim and its chain of evidence. It is hard to imagine anyone better suited to identify errors in a scientific argument than a scientist’s peers.

The data suggests that what these teachers were doing in the classroom with their students appears very similar to what happens in the community of scientists in term of the argumentation process. They help the students to make their ideas public, open them to discussion and debate, and guide and help their students to construct elaborations, rebuttals or challenges. They also help their student to seek clarification when a concept or idea is not clear, or, in some cases, to ask for expert which could be the teacher, a book or a website. All three teachers in this study approached this inquiry process slightly differently, however all three teachers successfully led their students to the point at which they were engaging with arguments and constructing knowledge claims in a similar process to professional scientists arrived at the point of which the scientific practices were implemented as practicing argumentation as done by scientist.

In summary, what the results of this research has shown is that students appear to be able to engage in argumentative practices of science, which is to make their ideas public and open to debate. By engaging in implementing argumentative practices the students were able to generate questions, argue and elaborate in ways that increased their comprehension of the subject under study.

Implications

Implication for Teaching and Learning

The findings of the present study have some implications for professional development and for the use of argumentation and generating questions as a practice that can enhance science learning. Prevalent practices in science teaching offer young audience (young children from elementary school) few opportunities to engage in argumentative practices since they assume that are too young to be able to do this. Most of the recent studies in argumentation have been done with middle and high school students. The results in this research suggest that even young students, when they are actively participating in class discussion, are capable of making the connection between their claims and evidence, and to elaborate upon ideas, and to generate questions of higher order cognitive level. Still, the students need to practice organizing and clarifying scientific ideas to be able to communicate with the world in a more effective way (and the use of big words), but not let's forget that these are elementary students that are showing that they can do science as scientists do by the use of argumentative practices.

In addition, the results of this study suggest that by allowing the students to be more in charge of his/her own learning teachers are inclined to move from teacher-generated questions to a more student-generated class. The results also suggest that teachers allow students to generate questions in areas in which the teacher feels more comfortable or dominated (his/her are of expertise). For instance, John indicates that he feels more comfortable teaching Physics, with the results indicate this when more student-generated questions were observed, while Jane and Karen expressed their favorite subject was Biology and the same results were obtained. In short, it appears teachers need to be comfortable in their area (discipline, Biology, Physics, etc) of expertise as well as in areas that they will teach.

These results suggest the need for more professional development programs and teacher education, which will help the teacher to be more confidence in implementing argumentative practices in the science classroom and simultaneously develop pedagogical strategies to help the students in the use of argumentative practices.

Implications for Future Research

This study points to some future investigations. A longitudinal study that tracks the progress of the students in the use of argumentative practices in their sixth, seventh and/or eighth grades would help clarify the findings reported here. Since these students will be in advances grades, the same analytical framework could be used for assessing the quality of the argument. Other useful direction for future research would track the teachers' progress in the implementation of argumentative practices in the science classroom as well as in other disciplines. Establishing a control group (teacher and students not participating in the SWH approach) to compare performances would provide evidence that practicing argumentation is the factor than induces students to do science, as it implied by the researcher that science is about argumentation. More refinement of the components of argument, and of rebuttals in particular would help illustrate the soundness of these approaches. As some researches have argued, rebuttal is a most difficult skill since it entails understanding not only of one's own review but of others as well in the development of a strong argument.

In addition, there needs to be further research on how the teachers develop the use of argumentative practices in other areas than science, for example History and Social Sciences. It would be interesting to see that teachers, who have been participants in the SWH and practice argumentation in their classroom can do the same in other classes/disciplines.

Limitations of the study

The researcher recognizes the limitations of the present study. The sample size of this study; the number of teachers involved is small (only three teachers). Furthermore, these teachers were purposely selected, since all of them are involved in the SWH approach. This violated the assumptions of randomly sampling.

The researcher had to review data collected from videos made by others. Most of these videos were recorded by the teacher, and in a few occasions were edited. When the teachers were filming students working on small groups (hand on activity components of lesson), not all the students could be filmed at the same time (this is virtually impossible); the camera could focus only on certain students, even if most of the time the teacher was walking around the class observing them.

Another limitation is that the topics did not line up exactly for every teacher. As Table 3 illustrate, one teacher has a set of videos starting in 2007 while the other two has videos starting from 2008-09. This might create a problem of continuity of a sequence of lessons and parity (in terms of the same lessons observed) with the other two teachers.

APPENDIX A

GENERAL DESCRIPTION OF THE COMPONENTS OF ARGUMENT

Definitions and examples of the different coding categories are shown in Appendix A, tables A1, A2 and A3.

Table A1. Components of Argument

Components of Argument	Definition
Students' Elaboration	For student's elaboration, I want to examine if the student, in any learning scenario, is capable of expanding or elaborating upon what is given, and how the teacher addresses the students and helps them to elaborate. The teacher and classmates could ask for clarification by using phrases or words like "what do you mean", "could you elaborate". The teacher should act as an active listener paying attention to the conversation for words that can interact with the environment. The criteria students' elaboration can be found in any learning environment, but occurs mostly in SP and in TSI when students (classmates) ask for clarification about certain concept that has been presented in the classroom.
Students' Rebuttal	In students' rebuttals I will be looking at forms of evidence that is presented to contradict or nullify other evidence that has been presented by an adverse party (student or group of students). This criterion appears in all learning environment, but mostly in SP.
Students' Negotiation	As for students' negotiation, this is a process of negotiation by consensus within a class where the students make sense of the theories 'negotiated' in students' learning communities. By engaging in such processes, students can realize that what is regarded as a viable theory depends on what is known at the time and the context in which the theory is to be applied. Like the others criteria, it appears in all learning environments, but mostly in HoA.

Table A2. Level Analysis: Criteria Coding Argumentation.

Criteria	Example	Interpretation/Analysis
Student's elaboration	Teacher: Let's have the middle group show theirs. You didn't come up with a claim? Kevin's group, did you come up with a claim? A statement? Okay. Read what you have, Steve. Chleo, pay attention so you can ask a question maybe. Steve: The sun reflects off the moon and gives us light… Teacher: The sun reflects off the moon and gives us light. Show me what you think is happening with the sun and the moon. Steve: We thought the sun…it shines like this…we thought it would bounce off of this…and like, the Earth…	The students are in the learning scenario "SP" and they are showing their findings and their collaborative claims that they have reached in agreement. The student is asked for clarification, to elaborate on his posted claim. The teacher asks the student "show me what you think is happening". The student is trying to defend his claim explaining how the light is reflected by using his words and the black board. Most of the *students' elaboration* criterion occurs on SP.
Student's rebuttals	Teacher: Okay, so you think the Sun gives the Earth light, and the moon has light that bounces off……..the Earth. William doesn't get it. William: I don't get how the Earth can bounce- not the Earth- the moon can bounce off of those two. Teacher: Okay, so you're saying the moon has light... like the Sun and it shines it down? Steve: We know the sun just goes off that…so we're thinking it goes these two ways and bounces off that a little bit and...(not sure what he's explaining)	The evidence that is presented by Steve seems to contradict other evidence that has been presented by William. In previous presentation William posted his questions relate to the moon phases and his ideas about the reflections are in the sense that the moon has its own light.

Table A2.   Continue

Student's Challenge	Teacher: Who's "they" Red: The people in the… Pink: Like in China. Red: Say it's… this is us, then China gets a new moon, and we get a full. We get a full and they get a new… Teacher: Oh. Black: So the stuff are turned around. So one's a crescent, and one's crescent, but it's on the other side. Teacher: So it is your thinking, because of night and day, you're thinking… okay. Write that down.	The students are trying to make sense of the theories 'negotiated' in students' learning communities.

The segment transcribed in Table A3 is part of a video made by one of the teachers (John, video ID 001-02-02-04-2008). The topic studied is Physics, Rockets. The component of lesson observed in the segment is hand on activities (HoA) and student presentation (SP). The video starts with the students working on the design of their rocket. The students are discussing the construction and design of their rockets and making the necessary improvement. The teacher walks around the room and asks the students why they think went wrong with the launch of the rocket and what they need to do to improve it. This table is a brief sample on how the codes were identified. Not all the components of argument (CoA or CA) or all the Bloom's Taxonomy (BT) are presents in this sample. The components of arguments have been labeled as En, elaborations with n from 1 to N (natural number), Rn, rebuttals with n from 1 to N, and Cn, challenges. The Bloom's Taxonomy elements have been labeled in a similar form (A for analysis, C for comprehension and K for knowledge).

Table A3. Sample Transcribed for Analysis

Person	Dialog	CoA	BT
Teacher	Why are we going with the same design?		A
Girl B	Because otherwise that would be too many variables. Cause we're changing how much we touch the tape, and if you change to many, if you do more than one variable in an experiment, you can't tell which one changed it. Um	E	
Teacher	So we're testing to see if they blew up because of our construction?		
Girl B	Yup.		
Teacher	What do you think's gonna happen tomorrow when we launch?		C
Boy A	Well if we didn't viscerate it as much it should go somewhere…	E	
Teacher	Something should happen? Okay.		
******	Another Group ******		
Emily	Hello		
Teacher	Hi. What ya making Emily?		
Emily	Um, the fins.		
Girl C	Hey, can you please go get some tape. Masking, please.		
Teacher	Did you change anything?		
Girl C	Ah we changed the (inaudible) …		
Teacher	The nose cone?		
Girl C	Yup. I've been attempting to put it on but it doesn't go		
Teacher	It doesn't want to stay on?		
Girl C	Yep.		
Teacher	What do you think is gonna happen with this launch?		C
Girl C	I think it's gonna be better than the other one.		
Teacher	Why?		A
Girl C	Because the nose cone wasn't really good, as a nose cone	E	
Teacher	Why wasn't it good?		A
Girl C	Because we did it a weird way and it was all morphed and everything. And all we need to do for this one is cover the hole. So yeah	E	
Teacher	Do you know why you have a nose cone?		A
Girl C	So the air doesn't just go through.		
Teacher	What do you mean just go through?		A
Girl C	Like if you had it like this, and you didn't have a nose cone it'd just go straight through. It wouldn't launch up.	E	
Teacher	Okay. Good, back with the group, good job. How's it going		

Note: A stands for Analysis, E is for Elaboration, C is for Challenge, CoA is for Components of Argument, and BT is for Bloom's Taxonomy

APPENDIX B

BLOOM'S TAXONOMY

Level 1-Knowledge: Students exhibit memory of previous learned materials, terms, basic concepts and answers. Examples of questions at the knowledge level include:

- What is?
- Can you recall?
- Which one?
- Can you list the three…?

Level II-Comprehension. Students demonstrate understanding of facts and ideas of organizing, translating, interpreting, giving descriptions and stating main ideas. Examples of Questions at the Comprehension level include:

- How would you compare........ ?
- Contrast?
- What facts or ideas show?
- What statements support?

Level Ill-Application: Students solve problems to new situations by applying acquired knowledge, facts, techniques, and rules in a different way. Examples of questions at the application level include:

- What examples can you find to...?
- What other way would you plan to...?
- How would you apply what you learned to develop…?

Level IV-Analysis: Students examine and break information into parts by identifying motives or causes and finding evidence to support generalizations. Sample questions at this level:

- How is… related to…?
- Why do you think…?
- What conclusions can you draw?

Level V-Synthesis: Synthesis involves compiling information together in a different way by combining elements in a new pattern or proposing alternative solutions.

- How would you test…?
- Can you predict the outcome if...?
- What would happen if…?

Level VI-Evaluation: Evaluation involves presenting and defending opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria.

- How would you prove…? Disprove?
- What data was used to make the conclusion?
- How would you determine?

REFERENCE

Albe, V. (2009). Students; argumentation in group discussions on a socio-scientific issue. In R. Pintó and D. Couse (Eds.), *Contributions from science education research* (pp. 389–402). Dordrecht, The Netherlands: Springer.

Aufschnaiter, C., Erduran, S., Osborne, J. & Simon, S. (2009). Argumentation and the learning of science. In R. Pintó and D. Couse (Eds.), *Contributions from science education research* (pp. 377–388). Dordrecht, The Netherlands: Springer.

Barnes, D., & Todd, F. (1977). *Communication and learning in small groups.* Routledge and Kegan Paul: Boston.

Benus, M.J., Diaz, J.F., Hand, B., Norton-Meier, L. (2009, January). *Talk Pattern in Upper Elementary Science Classroom*. Paper presented at the National Science Teacher Association (NSTA) Hartford, CT.

Berger, P.L., & Luckmann, T. (1966). *The social construction of reality.* New York: Doubleday.

Biddulph, F., Symington, D., & Osborne, R. (1986). The place of children's questions in primary science education. *Research in Science & Technological Education, 4*(1), 77-88.

Blais, D. M., (1988). Constructivism: A theoretical revolution in teaching. *Journal of Developmental Education, 11*(3), 2–7.

Bloom, B. S. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook 1: cognitive domain*. New York: David McKay Co. Inc.

Borko, H. & Putnam, R.T. (1996). Learning to teach. In R.C. Calfee & D.C. Berliner (Eds.), Handbook of educational psychology. New York: Macmillan.

Britton, B. K., Van Dusen, L., Glynn, S. M., & Hemphill, D. (1990). The impact of inferences on instructional text. In A. C. Graesser & G. H. Bower (Eds.), *Inferences and text comprehension* (pp. 53–87). San Diego: Academic.

Brooks, J. G., (1990). Teachers and students: Constructivists forging new connections. *Educational Leadership, 47*(5), 68–71.

Brown, A. L., and Palinscar, A. S. (1989). Guided, cooperative learning and individual knowledge acquisition. In L. B. Resnick (Ed.), *Knowing, learning, and instruction,* (pp. 393–451) Hillsdale, N.J.: Lawrence Erlbaum Associates.

Brown, A.L. & Campione, J.C. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), Classroom lessons: Integrating cognitive theory and classroom practice (pp. 229–270). Cambridge, MA: MIT Press/Bradford Books.

Brualdi, Amy C. (1998). Classroom questions. *Practical assessment, research & evaluation*, *6*(6). Retrieved December 14, 2010 from http://PAREonline.net/getvn.asp?v=6&n=6

Burke, K. A., Greenbowe, T. J., Hand, B. M. (2006). Implementing the science writing heuristic in the chemistry laboratory. *Journal of Chemical education*, *83*(7), 1032–1038.

Carey, S., & Smith, C. (1993). On understanding the nature of scientific knowledge. *Educational Psychologist, 28*(3), 235-251.

Choi, A., Notebeart, A., Diaz, J. & Hand, B. (2010). Examining arguments generated by year 5, 7 and 10 students in science classroom. *Research in Science Education*, *40*(2), 149–169.

Clark, D. B. & Sampson, V. (2008). Assessing dialogic argumentation in online environments to relate structure, grounds, and conceptual quality. *Journal of Research in Science Teaching*, *45*(3), 293–321.

Danish, J. A. & Enyedy, E., (2006). Negotiated representational mediators: How young children decide what to include in their science representations. *Science Education*, *91*(1), 1–35.

Dawes, L. (2004). Talk and learning in classroom science. *International Journal of Science Education*, *26*(6), 677–695.

diSessa, A. A. (1988). Knowledge in Pieces. In G. Forman and P. Pufall (Eds.), *Constructivism in the computer age* (pp. 49–70). Hillsdale, NJ: Lawrence Erlbaum Associates.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, *23*(7), 5–12.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Buckingham, UK: Open University Press.

Driver, R., Newton, P., H., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, *84*(3), 287–312.

Duggan, S., Johnson, P., & Gott, R. (1996). A critical point in investigative work: Defining variables. *Journal of Research in Science Teaching, 33*(5), 461–474.

Duschl, R., Schweingruber, H., & Shouse, A. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academies Press.

Elaboration. (n.d.). Dictionary.com Unabridged. Retrieved March 18, 2010, from Dictionary.com website: http://dictionary.reference.com/browse/elaboration

Emig, J. (1977). Writing as a mode of learning. *College Composition and Communication*, *28*(2), 122–128.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's argument pattern for studying science discourse. *Science Education*, *88*(6), 915-933.

Faigley, L. & Selzer, J. (2011). *Good reasons: Researching and writing effective arguments* (5th Ed.). Glenview, IL: Longman

Foote, C. (1998). Student generated higher order questioning as a study strategy. *Journal of Educational Research, 92*(2), 107–116.

Forehand, M. (2005). Bloom's taxonomy: Original and revised. In M. Orey (Ed.), *Emerging perspectives on learning, teaching, and technology*. Retrieved: February 10, 2011, from http://projects.coe.uga.edu/epltt/

Gall, M. D., Gall, J. P. & Borg, W. R. (2006). *Educational research: An introduction* (8th Ed.). Boston, MA: Perason/Ally & Bacon.

Garcia, G. E., & Pearson, P. D. (1990). *Modifying reading instruction to maximize its effectiveness for all students* (Tech. Rep. No. 489). Champaign, IL: University of Illinois, Center for the Study of Reading.

Geddis, A. (1991). Improving the quality of classroom discourse on controversial issues. *Science Education*, *75*(2), 169–183

Germann, P, J., Aram, R., & Burke, G. (1996). Identifying patterns and relationships among the responses of seventh-grade students to the science process skill of designing experiments. *Journal of Research in Science Teaching*, *33*(1), 79–99.

Granello, D. (2000). Encouraging the cognitive development of supervises: Using Bloom's taxonomy in supervision. *Counselor Education & Supervision*, *40*(1), 31–47.

Hand, B. & Keys, C. W. (1999). Inquiry investigation. *The Science Teacher*, *4*, 27–29.

Hand, B., Wallace, C. W. & Yang, E. (2004). Using science writing heuristic to enhance learning outcomes from laboratory activities in seventh-grade science: Quantitative and qualitative aspects, research report. *International Journal of Science Education*, *26*(2), 131–149.

Hogan, K. & Maglienti, M. (2001). Comparing the epistemological underpinnings of students' and scientists' reasoning about conclusions. *Journal of Research in Science Teaching*, *38*(6), 663–687.

Hohenshell, L. M., Hand, B. (2006). Writing-to-learn strategies in secondary school cell biology: A mixed methods study. *International Journal of Science Education*, *28*(2-3), 261 – 289.

Hsi, S. & Hoadley, M. (1997). Productive discussion in science: Gender equity through electronic discourse. *Journal of Science Education and Technology*, *6*(1), 23–37.

Hurley, P. J. (1985). *A Concise Introduction to Logic*, (2nd Ed). Beverly, MA: Wadsworth Publishing Company.

Inagaki, K. (1981). Facilitation of knowledge integration through classroom discussion. *The Quarterly Newsletter of the Laboratory of Comparative Human Cognition*, *3*(2), 22–28.

Jimenez-Aleixandre, M., Rodriguez, M., & Duschl, R. A. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education*, *84*(6), 757–792.

Kelly, G. J., Druker, S., & Chen, C. (1998). Students' reasoning about electricity: Combining performance assessments with argumentation analysis. *International Journal of Science Education*, *20*(7), 849–871.

Kelly, G., Crawford, T. & Green, J. (2001). Common task and uncommon knowledge: Dissenting voices in the discursive construction of physics across small laboratory groups. *Linguistics and Education*, *12*(2), 135–174.

Keys, C. W. (1998). A study of grade six students generating questions and plans for open-ended science investigations. *Research in Science Education*, *28*(3), 301–316.

Keys, C. W., Hand, B., Prain, V. & Collins, S. (1999). Using the science writing heuristics as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching*, *36*(10), 1065–1084.

King, A. (1989). Effects of self-questioning training on college students' comprehension of lectures. *Contemporary Educational Psychology*, *14*(4), 366–381.

King, A. (1990). Enhancing peer interaction and learning in the classroom through reciprocal questioning. *American Educational Research Journal, 27*(4), 664–687.

King, A. (1991). Improving lecture comprehension: Effects of a metacognitive strategy. *Applied Cognitive Psychology*, *5*(4), 331–346.

King, A. (1992). Facilitating elaborative learning through guided student-generated questioning. *Educational Psychologist*, *27*(1), 111–126.

Kuhn, D. (1991). *The skills of argument.* Cambridge: Cambridge University Press.

Kuhn, D. (1993). Science argument: Implications for teaching and learning scientific thinking. *Science Education*, *77*(3), 319–337.

Kuhn, D., Schauble, L., & Garcia-Mila, M. (1992). Cross-domain development of scientific reasoning. *Cognition and Instruction*, *9*(4), 285–327.

Lawson, A. E. (2003). The nature and development of hypothetico-predictive argumentation with implications for science teaching. *International Journal of Science Education*, *25*(11), 1387–1408.

Lerdeman, N. (2011, February). *The nature of science and inquiry: Their importance in developing scientific literacy*. Paper presented at the 2011 American Association for the Advancement of Science (AAAS). Washington, DC.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.

Linn, M. C., & Songer, N. B. (1993). How do students make sense of science? *Merrill-Palmer Quarterly, 39*(1), 47–73.

Lunetta, V.N. (1998). The school science laboratory: Historical perspectives and contexts for contemporary teaching. In B.J. Fraser & K.G. Tobin (Eds.), International handbook of science education (vol. 1, pp. 249–264). Dordrecht, The Netherlands: Kluwer Academic Publisher

Lustick, D., (2010). The priority of the question: Focus questions for sustained. reasoning in science. *Journal of Science Teacher Education*, *21*(5), 495–511.

Metz, K. E. (1995). Reassessment of developmental constraints on children's science instruction. *Review of Educational Research, 65*(2), 93–127.

Millar, R. & Osborne, J.F. (Eds.) (1998). Beyond 2000: *Science education for the future*. London: King's College London.

Minstrell, J. M., & Stimpson, V (1995). A classroom environment for learning: Guiding students' reconstruction of understanding and reasoning. In R. Glaser and L. Schauble (Eds.), *The contributions of instructional innovation to understanding learning.* Mahwah, New Jersey: Lawrence Erlbaum Associates.

Minstrell, J., & Van Zee, E. (Eds.). (2000). *Teaching in the inquiry-based science classroom*. Washington, DC: American Association for the Advancement of Science.

Morgan, N., and Saxton, J. (1991). *Teaching, questioning, and learning*. New York: Routledge.

Mortimer, E., & Scott, P. (2003). *Meaning making in secondary science classrooms*. Maidenhead, UK: Open University Press.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards*. Washington, DC: National Academy Press

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academies Press.

Newton, P., Driver, R., & Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education*, *21*(5), 553–576.

Norris, S. P., & Phillips, L. M. (1994). Interpreting pragmatic meaning when reading popular reports of science. *Journal of Research in Science Teaching*, *31*(9), 947–967.

Norris, S. P., Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education*, *87*(2), 224–240.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, *41*(10), 994–1020.

Osborne, J., Erduran, S., & Simon, S. (2007). *Talking to learn and learning to talk*. Association for Science Education.

Oulton, C., Dillon, J. & Grace, M. (2004). Reconceptualizing the teaching of controversial issues. *International Journal of Science Education*, *26*(4), 411–424.

Palincsar, A., & Brown, A. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction*, *7*(2), 117–175.

Pea, R., & Gomez, L. (1992). Distributed multimedia learning environments: Why and how? *Interactive Learning Environments, 2*(2), 73–109.

Pedretti, E. & Hodson, D. (1995). From rhetoric to action: Implementing STS education through action research. *Journal of Research in Science Teaching*, *32*(5), 463–485.

Philipsen, G. (1995). The invention of discussion. In Jaakko Lehtonen (Ed.), *Critical perspectives on communication research and pedagogy* (95–105). Germany: Rohrig Universitatsverlag, 95-105.

Piburn, M. & Sawada, D. (1999). *Reformed teaching observation protocol (RTOP)* (Tech. Rep. IN00-1). Tempe, AZ: Arizona State University, Arizona Collaborative for Excellence in the Preparation of Teachers.

Pichert, J. W., &Anderson, R. C. (1977). Taking different perspectives on a story. *Journal of Educational Psychology*, *69*(4), 309-315.

Pressley, M., McDaniel, M. A., Turnure, J. E., Wood, E., & Ahmad, M. (1987). Generation and precision of elaboration: Effects on intentional and incidental learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*(2), 291-300.

Pressley, M., Wood, E., & Woloshyn, V. (1990). Elaborative interrogation and facilitation of fact learning: Why having a knowledge base is one thing and using it quite another. In W. Schneider & F. E. Weinert (Eds.), *Interactions among aptitudes, strategies, and knowledge in cognitive performance***.** New York: Springer-Verlag

Pressley, M., Woloshyn, V. E., King, A., Wood, E., Martin, V., & Menke, D. (1992). Encouraging mindful use of prior knowledge: Attempting to construct explanatory answers facilitates learning. *Educational Psychologist*, *27*(1), 91–109.

Pontecorvo, C. (1993). Social interaction in the acquisition of knowledge. *Educational Psychology Review, 5*(3), 293–331.

Resnick, L. B., Salmon, M., Zeitz, C. M., Wathen, S. H., & Holowchak, M. (1993). Reasoning in conversation. *Cognition and Instruction, 11*(3-4), 347–364.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context.* Oxford, England: Oxford University Press.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Sciences, 2*(3), 235–276.

Rosenshine, B., Meister, C., & Chapman, C., (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research, 66*(2) 181–221.

Roth, W.M. (1995). Authentic school science. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Roth, W. M. & Désautels, J. (Eds.) (2002). *Science education as/for social action.* New York: Peter Lang.

Rudd, J. A., Greenbowe, T. J., Hand, B., & Legg, M. J. (2001). Using the science writing heuristic to move toward an inquiry-based laboratory curriculum: An example from physical equilibrium. *Journal of Chemical Education*, *78*(12), 1680–1686.

Sadler, T.D. (2004). Informal reasoning regarding socio-scientific issues: A critical review of research. *Journal of Research in Science Teaching*, *41*(5), 513–536.

Sadler, T.D., Chambers, F.W. & Zeidler, D.L. (2004). Student conceptualisations of the nature of science in response to a socioscientific issue. *International Journal of Science Education*, *26*(4), 387–410.

Sadker, M., & Sadker, D. M. (1994). *Failing at Fairness: How America's schools cheat girls.* New York: Scribner & Sons.

Sampson, V., & Clark, D. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. *Science Education, 92*(3), 447–472.

Sandoval, W. A., & Millwood, K. A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction*, *23*(1), 23-55

Scardamalia, M., & Bereiter, C. (1985). Fostering the development of self-regulation in children's knowledge processing. In S. F. Chipman, J. W. Segal, & R. Glaser (Eds.), *Thinking and learning skills: Vol. 2. Research and open questions* (pp. 563-577). Hillsdale, NJ: Erlbaum.

Schank, R. C., & Cleary, C. (1995). *Engines for education.* Hillsdale, NJ: Erlbaum.

Schauble, L., Klopfer, L., & Raghavan, K. (1991). Students' transition from an engineering model to a science model of experimentation. *Journal of Research in Science Teaching, 28*(9), 859-882.

Scott, P. (1998). Teacher talk and meaning making in science classrooms: A Vygotskian analysis and review. *Studies in Science Education, 32,* 45-80.

Shepardson, D. P. (1996). Social interactions and the mediation of science learning in two small groups of first-graders. *Journal of Research in Science Teaching, 33*(2), 159 – 178.

Siegel, H. (1995). Why should educators care about argumentation. *Informal Logic*, *17*(2), 159–176.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28* (2-3). pp. 235–260.

Solomon, J. (1991). Group discussions in the classroom. *School Science Review*, *72*(261), 29–34.

Songer, N. B. (1993). Learning science with a child-focused resource: A case study of kids as global scientists. In *Proceedings of the fifteenth annual meeting of the cognitive science society*. Hillsdale, NJ: Erlbaum.

Spires, H. A., Donley, J., & Penrose, A. M. (1990, April). *Prior knowledge activation: Inducing text engagement in reading to learn.* Paper presented at the annual meeting of the American Educational Research Association, Boston.

Sutton, C. (1992). *Words, science and learning.* Buckingham, UK: Open University Press.

Toulmin, S., Rieke, R., and Janik, A. (1984). *An introduction to reasoning* (2nd ed.). New York : Macmillan.

Wallace, C. S., Hand, B., Prain, V. (2004). *Writing and learning in the science classroom*. Norwell, MA: Kluwer Academic Publishers.

Wheatley, G. H., (1991). Constructivist perspectives on science and mathematics learning. *Science Education*, *75*(1), 9–21.

Wittrock, M. C. (1990). Generative processes of comprehension. *Educational Psychologist*, *24*, 345–376.

Wong, B. Y. L. (1985). Self-questioning instructional research: A review. *Review of Educational Research*, *55*(2), 227–268.

Wood, E., Pressley, M., & Winne, P. H. (1990). Elaborative interrogation effects on children's learning of factual content. *Journal of Educational Psychology*, *82*(4), 741–748.

Varelas, M., Pappas, C. C., Kane, J. M., Arsenault, A. (2008). Urban primary-grade children think and talk science: Curricular and instructional practices that nurture participation and argumentation. *Science Education,* 92(1), 65–95.

Yore, L. D., Bisanz, G. L., & Hand, B. M. (2003). Examining the literacy component of science literacy: 25 years of language arts and science research. *International Journal of Science Education*, *25*(6), 689–725.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, *39*(1), 35 – 62.