Spring 2010

Characterizing the changes in student discussion after teacher questions with changing grade level

Brian Robert John Pinney
University of Iowa

CHARACTERIZING THE CHANGES IN STUDENT DISCUSSION AFTER TEACHER QUESTIONS WITH CHANGING GRADE LEVEL

by

Brian Robert John Pinney

A thesis submitted in partial fulfillment
of the requirements for the
Master of Science degree in Science Education
in the Graduate College of
The University of Iowa

May 2010

Thesis Supervisor: Professor Brian Hand

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Brian Robert John Pinney

has been approved by the Examining Committee for the thesis requirement for the Master of Science degree in Science Education at the May 2010 graduation.

Thesis Committee: ___________________________________
Brian Hand, Thesis Supervisor

____
Soonhye Park

____
Alice Fulton

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Constructivism is founded on the notion that learners have no access to objective reality. In other words, people cannot ever know things outside of an interpretable context and that all that is known and observed is shaped by all the other things that have been learned and observed. Therefore, learners construct knowledge and make sense of the world through perceptions and experiences that have also been dealt with through mediation of prior experiences. Learners, having no way of evaluating if something matches an objective reality, are most concerned with what makes sense to them based on their prior knowledge (Simon, 1995).

Teaching, then, must orient itself around how learning occurs and should encourage students to share their ideas. During exposure to the Science Writing Heuristic (SWH) approach, teachers are encouraged to allow students to negotiate ideas with each other. Here, the teacher's position in the classroom is to support student discourse and is not intended to remove content or teacher voice from the classroom or discussions. However, if students are not allowed the opportunity to engage the ideas, true student learning may not be realized. In addition, student negotiation allows students the opportunity to learn many other skills, such as argument and use of evidence in making claims, that may be absent from a more traditional style classroom.

Teacher questions are a frequent component of classroom talk and therefore play a significant role in determining the nature of the discourse of the classroom (Chin, 2007). Teachers can guide discussion through their questioning and are typically associated around evaluating what students know; not what students think (van Zee & Minstrell, 1997). Eliciting what students think provides the opportunity for student-

student negotiation of ideas. Teacher questions are a common feature of science talk (van Zee, Iwasyk, Kurose, Simpson & Wild, 2001). Teachers may encourage discussion by asking more open ended questions and reducing the sense of evaluation by providing neutral feedback to student answers (van Zee & Minstrell, 1997).

Some results from discourse analysis on teachers exposed to SWH implementation show that as teachers incorporate more student voice or ideas into their utterances, an increase in student talking is seen. Importantly, this is not a shift that happens over the course of a class period. These are changes that require the teacher to understand that students construct their own knowledge and to enact a change in teaching practice that requires time, practice and reflection.

The analytic frame that was developed as a pilot study for this master's study stemmed from prior research (Basir, Chen, Chanlen, Tseng, Hand & Norton-Meier, 2009). Both that research and the pilot study examined teacher changes as a result of SWH implementation. However, the pilot study characterized details of teacher questioning in order to capture teacher change. This study modifies the analytic frame from the pilot study in order to characterize student responses to teacher questions and to examine and control teacher variability.

Teacher questioning provides a scenario where teachers explicitly ask for a student to talk during class. The pilot study examined questions in terms of the voice of question, purpose of question and the discussion effect from the questions. The description of those levels of analysis remained almost unchanged from the pilot study through this study, with the exception of the addition of clarification type questions to purpose of questions. It is important to note that some of these levels of analysis contain further breakdowns that are also represented in this study.

While knowing the ideas represented as far as question and purpose are important, these questions are meant to encourage either answers or dialog. This dialectical interaction provides the essential interactions for negotiation of ideas. The discussion effect analysis is a crude measure of student involvement in the discussion. While this is not a direct measure of the quality of dialog, it does provide a measure for number of turns associated with the discussion, which can indicate higher student involvement. If the assumption is made that the average value of student input stays the same, then higher student turns in discussion would indicate an improvement in the discussion of the idea.

Results of Pilot Study:

The results of the pilot study indicated teachers in SWH implementation had an increase of nearly three times the number of student voice questions and a small decrease in the number of teacher voice questions. This indicated that the teacher asked many more questions involving student language and ideas. The purpose of question analysis demonstrated a shift toward more questions that develop student ideas. This teacher showed a shift toward more student centered instruction through her implementation of SWH.

The final level of analysis looked at the discussion effect in teacher and student idea oriented questions. Overall, there was an increase in student replies per question. In this environment, students were more likely to reply to questions that involved student ideas than those questions that involved teacher ideas. The results indicated that students in the classroom that was after SWH implementation had a higher discussion effect than the classroom from the start of the SWH project. This represents a shift toward a rich environment for students to have negotiation of ideas.

The overall picture of change for this classroom was a shift from stressing the teacher idea to stressing the student ideas. In addition, there is a change in the discussion that results from teacher questions to more student replies per question. Here, teacher questions could be followed up by a student answer, which may then be followed by another teacher question that may lead to more student replies. In the way in which transcripts were analyzed, each question was counted as having a separate discussion effect and separate discussion turns. While this may seem like a weakness, students may also get better at asking the follow up questions that were typically associated with a teacher question. This helps students ask important questions, as well as move towards further student led negotiations. Therefore, in some sense, the analysis helps capture this shift in student negotiation.

There also exists an increase in the amount of data and evidence being reported while these ideas are being discussed. This shift encourages students to develop argumentation skills that utilize data and evidence to support their claims. There is also an implication here that students may be negotiating between alternative explanations. Because discussion turns increase, we can expect that the teacher is not merely providing an answer but allowing students to make sense of data and evidence through negotiation.

Master's Study

This study looked at teacher questioning and the resulting effect on student discussion in grades two through six. The analytic frame used for these analyses was the same as in the pilot study (with the exception of adding "clarification" type questions to

Purpose of Questions). I was interested in determining if a change in the amount of discussion occurred as grade level changed. The levels of analysis provided showed what proportion of questions teachers were asking. This shed light on whether the changes in discussion were due to pedagogy or if they were perhaps linked to the change in grade level.

It is important to note that the analytic frame from the pilot study was initially developed to examine changes that occurred to teacher questioning to help see some pedagogical changes that might be occurring. While the focus of this study was to examine student discussion effects, this analytic frame was still useful. Changes in student discussion could be due to several factors. For instance, if a teacher were to ask more clarification questions (for instance), this could result in a change in the discussion effect. This analytic frame helped show differences in the types of questions teachers were asking as well as the proportion of those questions to each other. Therefore, if teachers express similar patterns of questioning, the differences in changes seen in student discussion have a higher chance of being due to student effects.

A potential implication that could result from this study is related to student effects seen in discussion. It is possible that as students mature, they are either more willing or able to participate in negotiation of ideas. This would tend to increase the discussion effects as students get older. However, there are other issues that may change this. Younger students may not be as concerned with the social pressures of "not knowing" an answer, and therefore they may be more willing to engage in discussion. If older students show a larger amount of discussion, this type of activity should be stressed in the classroom. Active negotiation of ideas by students is critical, but this does not mean the practice is not important in lower grades. If older students see decreased involvement in discussion, this hints at other pressures on students that may be related to social pressures that should be addressed in the classroom (perhaps related to a "non-threatening learning environment"). This was not expected because the skills of discussion and negotiation are progressive and should not decrease over these grade levels.

Teacher questions carry an implicit stress on the focus of the classroom. Analyzing these questions allowed for the characterization of discussion oriented around the ideas represented in the teacher question. From previous research, a trend was noted that suggested students with exposure to the SWH approach engaged more frequently in discussion. Through the pilot study, differences were noted in discussion oriented around student ideas and the teacher idea, which raised the research question below.

Due to previous research demonstrating a change of teacher role and teacher questioning in the classroom, another question developed. This question related to changes that were attributable to the students in these classrooms. This became important because teachers changed in response to implementation of an argument-based inquiry approach that should carry student changes as well.

Research Question

Is there a change in discussion as grade level increases (from 2nd – 6th grade) which could be indicative of an increased willingness or ability to negotiate ideas and is this dependent on the type or purpose of the question being asked?

Chapter Overviews

Chapter 2 (Literature Review) discusses the literature support for the theory underpinning this research. It discusses argument based inquiry, the Science Writing Heuristic approached used by the teachers in this study, the pedagogical work needed for this approach, the significance of teacher questioning and finally the impact on student discussion. This chapter provides the grounding for the work that follows.

Chapter 3 (Methods) details the methods used for this study. It discusses the origin of the research, the selection criteria for transcripts, the context associated with those selection criteria, a detailed explanation of the analytical frame, how certain variables are controlled as well as a report of inter-rater reliability. In addition, the Reformed Teacher Observation Protocol (RTOP), a measure used in selection, is explained.

Chapter 4 (Results) breaks the analysis down into global and local analysis (analysis that uses the analytic frame). The global analysis is used to describe general trends associated with the transcripts and some of the global qualities of the classroom (such as the proportion of questions being asked). The analytic frame is then applied to each teacher question in order to characterize them. The results are then reported in terms of proportions of questions represented by the analytic frame. Finally, the discussion effects from questions that develop ideas are examined and reported based on whose idea is being developed by the question.

Chapter 5 (Discussion) answers the research questions laid out in Chapter 1. It discusses possible avenues for future research to extend this project. It also highlights limitations of this study; which range from newness of researcher to limited sample size.

CHAPTER 2: LITERATURE REVIEW

This chapter addresses the theoretical underpinnings of this project. It will start by explaining what argument based inquiry is as well as why it is an important feature in the science classroom. The argument based inquiry approach used in the classrooms of this study, the Science Writing Heuristic approach, is then discussed to explain the expected classroom activities that occur. Next, argument based inquiry approaches require certain pedagogical shifts that are explained followed by the importance of teacher questioning and its possible effects on student discussion.

Argument Based Inquiry

Traditional science instruction approaches science from a positivist perspective that often inhibits scientific discourse. In these instructional approaches, the views of the larger scientific community and the views of members within the classroom community are not subject to being critiqued and evaluated. This in turn largely prevents students from engaging in student-student discussions (Kuhn, Kenyon & Reiser, 2006). Science instruction in classrooms typically represents science as a set of information that has been separated from the process used to create that knowledge (Osborne, 2005). This method of instruction leaves students with the impression of science as a collection of facts (Driver, Newton & Osborne, 2000). Current philosophy of science views emphasize that science is not merely the accumulation of facts of nature; science offers explanations of the way the world may be as a result of the construction of theories that are advanced through dispute, conflict and argumentation rather than general agreement (Erduran & Dagher, 2007). Osborne (2005) suggests the traditional approach to science instruction fails to offer students the opportunity to experience how science develops and/or how to develop scientific ways of thinking.

In contrast, argument based inquiry approaches science instruction from a view of science as argument instead of the positivist perspective. Argumentation, the use of evidence and theory to support or refute a claim, explanation, model or prediction, is a critically important epistemic task and discourse process in science (Erduran, Osborne & Simon, 2005). Argumentation is a tool in science and using argument in the science classroom enables learners the opportunity to engage in scientific discourse (Kelly & Chen, 1999). This carries a significant difference in the epistemology of science as taught in the classroom. A positivist view suggests science knowledge is fixed and something that can be "found." The view of science knowledge as a social construction derived from evidence driven argument suggests science knowledge as flexible and dependent on evidence derived from data collected in human designed experiments. Knowledge is something that is created in a social context oriented around justifying beliefs through reasoning, conjecture, evaluating evidence and considering counter-arguments (Osborne, 2005).

Therefore, a critical feature of science is the use of data in constructing evidence to support a claim. These explanations, while frequently left out of classroom practice, can change a student's view of science and enhance their learning of content (Lizotte, McNeill, & Krajcik, 2004). This stresses the importance of evidence based argument in science. In essence, it teaches thinking in a scientific way, instead of stressing learning scientific "facts." However, in the process of thinking scientifically, content is also taught and the classroom discourse is more in line with scientific discourse. Science requires that teachers offer their students the opportunity to engage in scientific argument (Osborne, 2005). Separating science knowledge from the way in which that knowledge is produced suggests science produces facts. Such an approach also fails to develop critical thinking skills that are crucial in science.

Science is a social activity that advances through processes that occur between people (Kuhn, 1993). Teaching science as inquiry must focus on epistemic goals that stress how we know what we know, how that knowledge is supported, what evidence may be anomalous to that knowledge and how that science knowledge fits into other knowledge (Duschl & Osborne, 2002). The ability to generate persuasive arguments through using evidence to support or refute a claim is a critical feature of inquiry (Sampson & Clark, 2008). However, many inquiry tasks given to students do not reflect core attributes of scientific reasoning (Chinn & Malhotra, 2002). Though these processes are, in some sense, meant to be an act of student discovery, they do not reflect authentic science or the reason or meaning making involved in it.

A key distinction here is evidence derived from data. Data, in and of itself, says nothing. Evidence is the interpretation of that data using reasoning. Therefore, it is possible for the same data to lead to different evidence. In traditional classrooms, data leads to irrefutable, predetermined evidence that is logically and straightforwardly designed to have students arrived at an expected answer (Driver et al., 2000). Many students are frequently unaware of what counts as evidence, often citing their data as evidence and are inconsistent in separating their claims or theories from the evidence that supports them (Kuhn et al., 2006). Critical evaluation of evidence and developing the ability to differentiate between claims and evidence as well as the ability to examine the fit between them can only occur in a context where there is evidence to evaluate and that this evidence forms the basis of scientific argument (Kuhn et al., 2006; Osborne, 2005). This suggests students need to understand the difference between data and evidence as well as how they interact.

Argument-based inquiry stresses the formation of evidence from data to be used to support a claim. Here, what counts as evidence is dependent on the students that formed that evidence. However, it must stand up to the critique of fellow students that have also developed evidence. The key feature of this type of classroom is that these students may have arrived at different conclusions and must enter into discussion or negotiation to reach consensus. In fact, a common feature of many argument based inquiry classrooms is the presentation of alternative conceptions requiring students to consider the evidence and evaluate the arguments presented in support of each (Osborne, 2005). This social negotiation provides the opportunity for students to develop critical thinking and argumentation skills.

Therefore, if a critical feature of science is the social negotiation of meaning from evidence using argument, then a critical feature of the science classroom should also be a social negotiation of meaning from evidence. While this may result in a replication of science knowledge, it also replicates the process of arriving at that knowledge. This teaches science not as a collection of facts, but rather a process of social construction for understanding. It highlights key features of the nature of science that traditional instruction fails to address, such as the tentative nature of science knowledge. This process also encourages the development of scientific reasoning and argument structures.

O'Neill and Polman (2004) suggest that schools would be more productive by stressing less science content and more on deepening the understanding of how science knowledge, claims and theories are constructed. Traditional style instruction fails to stress the epistemology and nature of science. This becomes especially important for students that will not pursue science oriented degrees. Engaging students in argument is a way in which a balanced set of learning goals can be restored in learning science (Osborne, 2005).

The Science Writing Heuristic Approach

The Science Writing Heuristic (SWH) approach (Keys, Hand, Prain & Collins, 1999) consists of a framework designed to guide science inquiry activities and provide metacognitive support to prompt student reasoning about data. When using the SWH approach, students set their own investigative agenda for laboratory work by framing questions, proposing methods to address those questions, and carrying out appropriate investigations. The SWH approach is designed to promote classroom discussions during which students' personal explanations and observations are tested against the perceptions and contributions of other students in the class. Students are encouraged to make explicit and defensible connections between questions, observations, data, claims, and evidence.

The SWH approach has several key phases. They include students beginning with student generated questions. Students then evaluate what they did to test those ideas. After that, students note what they observed during those tests and what they can claim based on those observations. Students form evidence to support their claim from the data they collected during observation. Then they examine reference material and compare how their ideas compare with the ideas of others. Finally, they reflect on what they have learned, how their ideas have changed and write the best possible explanation of what they have learned.

This approach has many differences to typical lab experiments. First, in traditional labs, students are given questions to investigate. Students are not expected to understand why the tests they did yield the results they did. Observations are typically assigned as part of a table that students fill out instead of allowing students to decide the observations that are necessary in order to approach the questions they asked. Little emphasis is placed on forming evidence from data. Students are expected to arrive at a predetermined answer and if they arrive at an answer that does not match they are told their answer is “wrong.”

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

Pedagogical Work Needed for Argument Based Inquiry

Teachers using argument-based inquiry have to approach education differently than traditional style teachers. Argument based inquiry carries the additional pedagogical task to develop argument skills in students because students in traditional classrooms typically have little need to understand alternative conceptions or consider whether those conceptions carry any merit (Kuhn et al., 2006). However, Riemeier et al. (2010) report that students argued without instruction on how to argue as well as without being prompted to argue. Therefore, teachers should encourage argument and focus on scaffolding the structure of that argument to be consistent with scientific discourse. Riemeier, Fleischhauer, Rogge, von Aufschnaiter & Liebig (2010) continue by suggesting students are more likely to express their arguments in terms of everyday experiences rather than addressing scientific ideas. This highlights the importance of stressing the inclusion and critical evaluation of data and evidence in argument.

Changing the view of science to one of social construction requires a change in pedagogy. It requires activities oriented around discourse, especially argument (Driver et al., 2000). This change in pedagogy encourages further student discussion and negotiation and shifts the focus to how evidence is used in constructing explanations, to how arguments link data and scientific theories and the development of evaluative criteria by which those constructions of explanations are judged (Erduran et al., 2005). Moving argument and negotiation into a main feature of the science classroom engages learners with conceptual and epistemic goals (Duschl & Osborne, 2002) and is more aligned with the constructivist perspective. It also provides the teacher an opportunity for evaluation in a student centered manner.

Teachers moving towards constructivist perspectives encourage student dialog, which helps make explicit students' conceptual frameworks as well as their prior knowledge (Henriques, 1997). Without this act, students may form weak conceptual connections to material which are fragile and only applicable for them inside a narrow context. However, allowing negotiation of ideas helps students form stronger conceptual connections that are integrated within existing conceptual frameworks and applicable in new contexts (Windschitl, 2002). An important focus of teachers becomes guiding students to use evidence when evaluating claims and while students tend to struggle with this they do tend to move towards using evidence when resolving alternative conceptions (Kuhn et al., 2006).

Students often have short, imprecise answers when discussing abstract ideas which makes communicating their ideas or representations more challenging (Hogan, Nastasi & Pressley, 1999). Teachers approaching abstract ideas in science then must scaffold student discussion and take care to encourage students to attempt to fully explain their thoughts. The act of argument, especially one that follows the norms of science, requires practice and scaffolding (Kuhn, 1991). Contexts that promote student-student interaction foster the development of argumentation (Osborne et al., 2004).

Important Aspects of Teacher Questioning

A primary source of information in the classroom comes from teacher and teacher-student interactions (Chin, 2006). These interactions between teachers and students can be rather varied. Teacher questions are a frequent component of classroom talk and therefore play a significant role in determining the nature of the discourse of the classroom (Chin, 2007). Teachers can guide discussion through their questioning, as well as provide insight to the type of environment in the classroom. Teacher questions are typically associated around evaluating what students know; not what students think (van Zee et al., 1997). The difference may seem subtle at first, but carries significant ramifications.

Eliciting what students think provides the opportunity for student-student negotiation of ideas. Through making these student ideas explicit, alternative conceptions are brought into the classroom and meaningful discourse can be used in resolution of these conceptions. It provides students the opportunities to not only recognize possible alternative conceptions arising from potentially similar data but the opportunity to develop argument skills while reaching consensus.

Teacher questions are a common feature of science talk (van Zee et al., 2001). Through use of questions, teachers can close down discussion through use of IRE (Initiate-Response-Evaluate) cycle questioning, which are typically information-seeking and require a predetermined short answer (Chin, 2006). However, teachers may also encourage discussion by asking more open ended questions and reducing the sense of evaluation by providing neutral or delayed feedback to student answers (van Zee et al., 1997). This can even occur when students are wrong by allowing the possibility for other student ideas to enter into discussion and a resulting negotiation of ideas. A common feature of approaches that led to more student discussion was a teacher following up on a preceding student contribution in a productive way. In the way it is being used here, a productive method encourages more student ideas to be expressed in the classroom. This served functionally to not only affirm student responses but to make the ideas more available to other students in the class. These classrooms also had socially constructed knowledge with a gradual meshing and blending of voice to produce a dialogic outcome (Chin, 2007).

Importantly, constructivism stresses the importance of student ideas and negotiation of meaning. If this is being stressed in the classroom then questions should not be seeking a predetermined short answer. This is not to suggest that all questions should be meant to spur discussion or to encourage sharing of student ideas. Teachers using authoritative discourse convey information more directly and sometimes provide factual knowledge (Chin, 2006). This act may provide necessary anomalies to student representations or allow teachers to more directly approach a content goal.

Learners construct knowledge through personal perceptions and mediation from prior experience (Simon, 1995). Therefore, it becomes important for teacher questions to elicit these perceptions and attempt to understand the conceptual frameworks students bring to the classroom, encourage students to elaborate on their previous answers and ideas and to help students construct conceptual knowledge (Chin, 2007). This cannot be done through authoritative discourse. However, it is also important for teachers to bring content into student negotiations and may chose to do this either before the negotiations (to encourage the content to be the subject of negotiation) or during negotiations as an opportunity to provide anomalies to student conceptions.

Teacher questioning in this student centered context is used to diagnose and extend student ideas and scaffold student thinking. This teacher forms their questions so that the authority for evaluating answers and ideas shifts from the teacher to the students of the classroom: a community of learners (Chin, 2007).

Summary

Science is typically taught as a positivist subject; where there are clear “right” or “wrong” answers and where data leads to uncontroversial conclusions (Driver et al., 2000). This view of science aligns more closely with the authoritative discourse view discussed by Chin (2006). Further to the point, this view of science functionally serves to deactivate student discussion by searching for factual reproduction from students of science knowledge. The role of the teacher in these types of classrooms is typically to persuade students of the validity of scientific claims. In these classrooms, discourse is dominated by the teacher and focuses on the "facts" of science which encourages simple recall of science knowledge not the development of logic or reasoning skills or learning about science (Duschl & Osborne, 2002).

In contrast with traditional science instruction, Fuller (1997) makes the claim that nonscientists need to know more about the philosophy and nature of science rather than the content of science. This highlights the importance of learning the epistemology underlying science rather than the pure content associated with it. It also becomes important for these nonscientists to be able to use the argument style associated with science. In this manner, students learn how to use evidence to support a claim, as well as what goes into scientific claims. O'Neill and Polman (2004) suggest that schools would be more productive by stressing less science content and more on deepening the understanding of how science knowledge, claims and theories are constructed.

Argumentation in the science classroom should be a core feature of the school science curriculum. Failing to provide students the opportunity to engage in scientific argument suggests to students that knowledge exists in the authority of the teacher and as a source of knowledge is no better than traditional transmission (Osborne, 2005). The SWH approach provides students and teachers an expectation for student discussion. It also provides this study with discussion opportunities that can be analyzed for discussion effects.

CHAPTER 3: METHODS

This chapter describes the qualitative nature of this study as well as the origins of the research approach used. It will then discuss the selection criteria for transcripts used in analysis as well as the analytic frame that was used. In addition to individual question analysis, a global analysis was performed on the transcripts. Some limitations of variable control are discussed followed lastly by the inter-rater reliability results from analysis.

This study is a qualitative research project that looks into a possible reason(s) student discussion patterns may change as students get older. This is an exploratory study with a relatively small sample size (one transcript per grade for five grade levels), quantitative results would have little power or be inconclusive. The qualitative nature of this study allows for a rich examination into the context involved in these classrooms as well as a frame of reference for possible research in the future that could have a larger sample size and thus be more applicable for quantitative analysis. Results drawn from this study produce information about the classrooms involved, and may provide grounding for further hypotheses onto other research, but no generalizable results should be taken from this study and applied to other classrooms.

This is study stems from a group research project that occurred in the fall of 2009 (Basir et al., 2009). The focus of that work was the role of the teacher in the classroom and how their role changes over time as a result of implementation of an argument based inquiry. This research extends the original research by examining a number of different issues.

First, both studies examined the “voice” of the teacher. In the original study, the analysis was focused on the ideas and language represented by the teacher utterance.

This study is different in that while ideas and language of the question do represent voice, the main focus here is the language being used and where the language used to make up the questions originates.

Secondly, while the original study focused on ownership of action in terms of student or teacher ownership, this study claims no look into ownership of action; indeed, this analysis does not take action into account at all. This study is focused on teacher questions, the ideas or skills being represented and developed as a result of those questions and the student discussion that follows questions intended to develop or clarify ideas.

Thirdly, the original study focused on the teacher role in the classroom and how it changes over time as a result of implementation of a student centered inquiry. This study examines teacher questioning as a way to control for effects that could result from differences in teachers that may affect the student discussion. This study also was focused on tracking patterns that may have developed as a result of types of questions asked and changes in student discussion as they relate to those types of questions.

The analytic frame that was developed for use in a pilot study that grew out of the original study on teacher roles examined how teacher questioning changed over time as a result of implementation of a student centered inquiry. The results of that study indicated that implementation of this argument based inquiry encouraged more student discussion per question asked by the teacher (Pinney & Hand, 2009). This analytic frame has had minor modifications to be more appropriate for this study.

This study builds off the pilot study by examining the student discussion following the teacher posing a question. The question for this study is whether increasing grade levels (increasing student maturity) was accompanied by an increase in student discussion. For this reason, a measure of teacher variable control had to be used. The pilot study analytic frame provided a framework for how this might be accomplished.

Teacher questions were chosen because they provide an explicit opportunity where students are expected to participate in discussion or at least have a reply. They also have the potential to encourage idea development by having students negotiate ideas. Questions can be used to help scaffold student thinking about ideas, experiments, and variables as well as considering alternative ideas. Teacher questioning is expected to change as a result of shifting to a more student centered approach as part of their implementation of an argument based inquiry.

Classes from 2^{nd}, 3^{rd}, 4^{th}, 5^{th} and 6^{th} grades were selected based on availability of transcripts from the SWH project (Hand, 2008). Transcripts chosen were from whole class discussion involving claims and evidence. In this manner, effects seen from either the teacher changes in question or student change in discussion were all centered around the same activity component and are therefore not attributable to change of activity.

A selection criterion for this study was a teacher score on the Reformed Teacher Observation Protocol (RTOP) scale. This scale is a measure of how aligned science and math teaching is to tenets of inquiry and student-centeredness as recommended by national organizations (i.e. NRC). The RTOP is a 25 question Likert test with scores ranging from zero to four. The total score possible on the RTOP is 100 points. The scores used in this study are from a modified RTOP that has a maximum possible score of 56 points (Martin & Hand, 2009). For the rating used in this study, a score of 0-20 represented low implementation, 21-39 represented medium implementation and 40-56 represented high implementation. Table 1 below represents the transcripts selected as well as the modified RTOP scores associated with the approximate time of instruction for the teachers. The utterances represented by the transcripts have also been listed. An utterance, as it is being used here, represents a full turn of talk. Therefore, these utterances represent the total turns of teacher and student talk represented in the transcript. The RTOP score is a measure of the implementation towards a student centered approach. For purposes of this study, importance was placed on isolating transcripts from teachers that had approximately the same RTOP score. This approach limits differences in levels of implementation which would confound data and interpretations of that data.

Table 1

Transcript Information: RTOP Scores and Utterance Count

Grade	Transcript	RTOP	Utterances
2	015-08-01-01-2008	31	302
3	005-10-01-01-2009	32	211
4	004-09-01-04-2008	36	180
5	002-02-10-04-2008	36	273
6	010-01-01-01-2007	28	485

Note. Average RTOP score was 32.6 and average utterances was 290

While ideally the transcripts would have the same number of utterances this was not possible to isolate. However, by comparing proportion of question types, many of the issues with differences in number of utterances were reduced. This stresses the importance of comparing trends of the proportion of question types to the distribution of discussion that is seen after the questions.

The analytic frame arose as a way to characterize specific question types. This was essential because, as reported in Chapter 2, different types of questions are likely to yield different discussion opportunities. Characterizing and differentiating questions based on idea development also allowed for looking at the discussion oriented around each type of question.

Table 2

Analytic Frame for Master's Study

Typology	Defining Characteristics
Voice of Question	
Teacher	Question contains teacher or science language or idea.
Student	Question contains student language or idea.
Purpose of Question	
Teacher Idea Oriented	Question develops a teacher or science idea.
Student Idea Oriented	Question develops a student idea.
Simple Task	Further breakdown below.
Clarification	Question asks students to elaborate or clarify.
Class Management	Question meant for classroom control.
Types of Simple Tasks	
Reporting Oriented	Asks students to report data, evidence or procedure.
Skill Oriented	Asks students to do something or about a skill.
Simple Task	Asks students to do a task that does not fit elsewhere.
Discussion Analysis	
Discussion Effect	Count of student replies to teacher question.

Explanation of Levels of Analysis

Table 3

Voice of Question from Analytic Frame

Voice of Question	Defining Characteristics
Teacher	Question contains teacher or science language or idea
Student	Question contains student language or idea

The *first level of analysis* of questioning involves looking at the voice of the teacher question. This level of analysis is important to see whose ideas the teachers are integrating into their questions. While a mixture of these is fully expected by all teachers, both initially and after years of SWH instruction, the proportion of student to teacher voice questions is likely to change. This is expected because teachers are attempting to teach content (which may result in a teacher voice question), but should also try to ensure that students understand the presented ideas (which would typically result in a student voice question). Being that SWH is a student centered inquiry approach, it is expected that teachers would shift to a higher proportion of student voice questions. This analysis is also important for other reasons. Simply asking more student voice questions could have an effect on the amount of student discussion. Because teachers may implement SWH differently, the proportion of teacher to student voice questions is likely to be different and a comparison across teachers of these proportions is required. Similar proportions of these questions across teachers will help reduce the chance that asking more student voice questions by a teacher caused the change student discussion effect.

Table 4

Purpose of Question from Analytic Frame

Purpose of Question	Defining Characteristics
Teacher Idea Oriented	Question develops a teacher or science idea.
Student Idea Oriented	Question develops a student idea.
Simple Task	Further breakdown in Table
Clarification	Question asks students to elaborate or clarify.
Class Management	Question meant for classroom control.

The *second level of analysis* looked at the purpose of the question. Ultimately, questions need a purpose. If there is no purpose, there is essentially no point in asking a question. The researcher would suggest that it is very likely that the purposes of teacher questions will change as a result of SWH implementation. Teacher idea oriented questions are questions that ask students about an idea that comes from the teacher or from content the teacher is trying to cover. Typically, these types of questions are encouraging students to incorporate these ideas actively into their knowledge bases. Student idea oriented questions are questions that ask students about either their own idea or another student's idea. These questions attempt to further develop students' ideas, which may or may not be "on track" with a content goal. The expectation is that teachers will have an increasing proportion of student idea oriented questions because they are using student centered inquiry.

The simple tasks will be further elaborated on later, but essentially these questions are not necessarily related to ideas or idea development. Clarification and elaboration questions encourage students to further discuss (or clarify) ideas they have shared. This may be because the initial statement was not clear or perhaps that the teacher felt that the idea was headed somewhere that would be useful for the classroom. With increasing stress on student centered instruction, clarification type questions should increase. The last category here is class management. Class management questions are not expected to occur in appreciable frequency simply because this is typically handled by teacher statements.

Table 5

Types of Simple Tasks from Analytic Frame

Simple Task	Defining Characteristics
Reporting Oriented	Asks students to report data, evidence or procedure.
Skill Oriented	Asks students to do something or about a skill.
Simple Task	Asks students to do a task that does not fit elsewhere.

An extension of the second level of analysis involved closer examination of simple tasks. These tasks are related to the idea, but are auxiliary to the idea development. This category presents opportunities for teachers to encourage students to use data or evidence when students make claims, or perhaps to ask students about how or why a measurement is done a certain way. Clearly, these ideas are important and related to the idea but they are not quite the key component of the idea. These are tasks that may help form or support ideas, but are not necessarily pursuing direct idea development or expression. They may be considered to be supporting a student view or idea.

Reporting oriented questions encourage students to report data from experiments, information that was found from searching sources or even evidence that a student or group developed from data. This is a key component of scientific negotiation; using evidence in the support of claims and helps promote argumentation skills for students.

Skill oriented questions are of a procedural nature. They may be related to asking a student how a variable (such as distance) should be measured or reported and may also be asking students how they might design an experiment or how to control variables. These ideas are integral to what measurements or observations really tell students and represent a very important part of understanding what an experiment really is. Through better understanding experiments, students become better able to isolate weaknesses in their experimental designs and for sources of error.

Simple tasks in this category relate to other things the teacher may ask a student to do, such as to get a book, or look up information. These may be in preparation for the students to do something along the lines of idea development or the other types of tasks represented in this category.

The *third and final level of analysis* examined the discussion effect on students of these questions. This was analyzed only for questions relating to development of an idea (be it teacher or student) and clarification questions. This is critical as it is where negotiation of ideas occurred. This measure is not necessarily suggesting a higher quality of negotiation is occurring as a result of increased amount of discussion. However, if comments are roughly equal, then an increasing amount of comments in discussion would suggest that more negotiation is occurring.

Controlling for Classroom Activity

The Science Writing Heuristic approach has several different types of associated activities. It makes sense that differing classroom activities could (and most likely would) have a direct influence on the discussion that may or may not be occurring. In addition to this, different teachers would approach these activities differently. The easiest way to control for this is to limit all analyzed discourse to the same activity.

With this being said, of key importance is the negotiation of ideas. Especially in science, and in the Science Writing Heuristic approach, key components are claims and the evidence to support those claims. However, even claims and evidence in the classroom is too broad for this analysis. Instead, classroom activity was limited at classroom discussion of claims and evidence. In this manner, all students have opportunity to engage in discussion. Further, use of evidence in claims can play a critical role in resolving anomalies in students' conceptual frameworks.

Controlling for Teacher Effects

Initially, the analytic frame was intended to look at changes in teacher questioning in order to look at how teaching practice changed through SWH implementation. However, the researcher believed it was very important to look at potential changes in student discussion in this analysis. If changes in student discussions were seen, the results could be attributable to teachers or students (or a combination of both). The analytic frame allowed for comparison of teacher questioning, which would help limit the effects of the teacher. Change in teaching practice as a result of implementation of the Science Writing Heuristic approach is expected. This change in teaching practice is also expected to change how students interact in the classroom, as they begin to engage in idea negotiation.

Therefore, by analyzing the change in teacher questioning by grade, we get an idea of how each teaching practice is different. Further, as the teachers are approximately equivalent to each other, changes or increased differences in student discussion are more likely to be attributable to student changes. That is, if all teachers show a similar pattern of questioning but older students have a greater increase in discussion of ideas, then those increased effects may be due in part to some characteristic of the students rather than the teachers.

In addition, by analyzing different purposes of teacher questioning, the researcher can see how changing the purpose of the question effects student discussion. The researcher believed that the teachers would not change their practice in the same manner, resulting in some teachers that ask questions with different purposes in differing proportions. These different purposes may have an influence on student discussion as well. Therefore, if a pattern attributable to student discussion is not seen as a result of this analysis, it is entirely possible that specific changes in the purpose of teacher questioning may be highlighted as a result of increased or suppressed student discussion.

Limitations of Variable Control

While there are certainly other variables, such as individual qualities of students in all classes, efforts have been made to control variables based on activity and changes in teaching practice. By controlling for such variables, this study attempts to attribute actual changes in student discussion that are due to students' interaction with the change in teaching practice on the students. This study does not control for factors such as socio-economic status, race, gender or scholastic aptitude. To overcome researcher bias in analyzing the transcripts, two colleagues have been selected for inter-rater reliability and results are reported below in Table 6. These results represent moderate agreement. If this project were to be extended further, rater training or more descriptive levels would help increase agreement.

Table 6

Inter-rater Reliability of Analytic Frame

Inter-rater Reliability of Section	Cohen's Kappa
Voice of Question	0.51
Purpose of Question	0.59

The inter-rater reliability was calculated from analysis of 100 utterances, which contained 37 teacher questions. The overall percent agreement of all levels of analysis was 77.7%. Individual levels of analysis are given below. For further studies, rater training would be used to help increase overall agreement. Further developing and clarifying each level of analysis would help as well.

Table 7

Percent Agreement of Levels of Analysis

Level of Analysis	Percent Agreement
Voice of Question	80.0%
Purpose of Question	72.1%
Type of Simple Task	85.0%

Note: Overall Agreement was 77.7%

CHAPTER 4: RESULTS

This chapter discusses the global analysis and the analytical frame results. First, global analysis was used to characterize the overall trends in the transcripts. Second, the analytic frame results are expressed in terms of each level of analysis. The discussion effect results are then compared across grade levels and across different purposes of questions in order to display changes that occurred.

The researcher would like to point out that this analysis does not include all discussions that occurred within the observed classrooms but rather the discussion occurring after teacher questioning was examined. The researcher recognizes it is likely that some aspects of real classrooms will not be represented well or perhaps at all by this analysis. The analysis started as a comparison at a global level.

Global Analysis

A global level analysis is important to allow a sense of comparability between teachers. Here, the important aspects are that teachers are asking similar proportions of questions to total teacher utterances as well as teachers having roughly similar RTOP ratings. As explained in Chapter 3, the RTOP test is a measure that was developed to detect the degree to which classrooms are reformed to the National Science and Mathematics Standards.

First Global Analysis – RTOP Score of Teachers

The teachers in this project had RTOP scores ranging from 28 to 36 as reported in Table 8 below. These scores were completed by independent raters prior to commencement of this project. They were used for selection of teachers and transcripts because they were all rated as medium level implementation and within the required grade levels. Importantly, in grades two and three, the RTOP scores are very similar, and in four and five they are equivalent. Also, across these grades overall, the difference is small. This means, at least on this level of analysis that the teachers are relatively equal.

Table 8

RTOP Scores of Teachers

Grade (Teacher Code)	RTOP
2 (015)	31
3 (005)	32
4 (004)	36
5 (002)	36
6 (010)	28

The RTOP scores of all of these teachers represent a medium level of implementation. Teachers scored as medium are typically student centered, where students in these classrooms are typically doing some of the activities and teachers demonstrate flexibility in allowing students to do these activities. Student discussion in small and large groups is expected but lack high quality as the teachers in this scoring range try to change student ideas directly.

In low level implementation, teachers help guide students to an already solved problem or to arrive at an already known answer. The medium level classroom shows teachers helping students solving an already known problem with limited help. Students in these settings sometimes come up with new ideas but they are lead to the already known answer. Higher scoring classrooms have students arriving at potentially unexpected answers. Teachers in this setting help students by leading them in classroom in discussion to reach consensus rather than trying to directly change students' ideas.

The RTOP scores of teachers were similar so a simple analysis of teacher to student utterances was done. This allows some sense of who dominates the classroom discourse. In this analysis, the three teachers of second, third and fifth grades showed very similar proportions of student to teacher utterances as reported in Table 9 below. Two of the teachers showed different proportions than the others. Grade four appeared to be more teacher dominated and grade six appeared to be more student dominated.

In this analysis, a classroom that shows more student utterances by proportion is expected to be more student dominated. However, the researcher would like to point out that this does not necessarily equate to the classroom being student centered. It may represent a class where students are more active in discussion or the teacher may simply choose to not speak as often as they could. The opposite condition would be a teacher dominated classroom. This situation was not realized as fully as the prior condition in the analysis but would result in many more teacher utterances to student utterances. This was not expected as the RTOP score for this teacher would not be similar to the other teachers in this study.

Table 9

Proportion of Teacher to Student Utterances by Grade

Grade	Teacher Utterances (Proportion)	Student Utterances (Proportion)
2	129 (0.427)	173 (0.573)
3	78 (0.370)	133 (0.630)
4	98 (0.544)	82 (0.456)
5	104 (0.381)	169 (0.619)
6	47 (0.097)	438 (0.903)

It is important to restate here that all of these teachers were engaged in a similar activity (classroom discussion of claims and evidence). Table 9 above highlights on a simple level a striking difference in classroom discourse across the different grade levels. The researcher did not expect that these classrooms should match in every analysis; however there was an expectation that they would be somewhat similar on many of the analyses based on RTOP score.

Second Level Global Analysis – Proportion of Teacher Questions to Teacher Utterances

Table 10

Proportion of Teacher Questions to Teacher Statements

Grade	Teacher Questions (Proportion)	Teacher Statements (Proportion)
2	63 (0.488)	66 (0.512)
3	71 (0.910)	7 (0.090)
4	68 (0.694)	30 (0.306)
5	55 (0.529)	49 (0.471)
6	33 (0.702)	14 (0.298)

To extend this first global analysis a follow up analysis on the proportion of teacher questions to teacher utterances was done. The reason for this particular analysis was to establish an expected proportion of questions for these teachers. This is important because the classroom dynamics of a teacher that asks a large amount of questions are different than a teacher that asks few questions. Asking more questions encourages more student talk, even if that talk is a simple answer to a knowledge seeking question. The results shown in Table 10 above indicate that all of the teachers in this study appear to have a similar proportion of questions to statements with the exception of the third grade.

These teachers were typically between 50% and 70% questions as compared to statements in their overall utterances.

Third Global Analysis – Proportion of Teacher Questions to Student Utterances

Another important global metric relates the proportion of teacher questions to student utterances. This analysis gives an idea of the possible discussion average per question that might be obtained in the local analysis. Importantly, this analysis makes no claim of the discussion following questions, only the number of teacher questions and student utterances (be they student statements or questions). Differences in this analysis may mean teachers are asking different types of questions or may be asking questions that are more or less effective at leading to discussion. While most teachers were between 20% and 40% teacher questions to student utterances, fourth grade was higher, and sixth grade was very low. This could be an early indicator of the level of response per question in these classrooms or it could simply be related to the amount of talk that is occurring. A key issue here is that the analyses are looking simply at utterances and not number of words being spoken. Student replies that are full and complete but only take up one utterance are equivalent (analytically speaking) to student replies that are incomplete and may require follow up but are contained inside one utterance. This highlights the critical notion that this analysis is looking quantitatively at replies and not the quality of replies.

Another important aspect of Table 11 below is the realization that the fourth grade teacher asked a very large portion of questions compared to the other teachers. This may lower the discussion effect seen in later analyses. Importantly, the fourth grade teacher and sixth grade teacher show a dramatic difference in the proportion of questions to utterances between them. During analysis, it was noted that the students in the sixth grade course asked questions that would be typical of teacher questions in the other grades. While this may influence the analysis, it also demonstrates a shift of the learning environment toward one of student ownership of learning and discussion.

Table 11

Proportion of Teacher Questions to Student Utterances

Grade	Teacher Questions (Proportion)	Student Utterances (Proportion)
2	63 (0.267)	173 (0.733)
3	71 (0.348)	133 (0.652)
4	68 (0.453)	82 (0.547)
5	55 (0.246)	169 (0.754)
6	33 (0.070)	438 (0.930)

The global analysis provided a sense of how similar the classrooms and teaching practices were in terms of questioning that may not be fully represented by the RTOP score. This analysis showed each teacher seemed to have a classroom that was similar to all the other teachers chosen. Teacher questioning pattern analysis showed some differences that were more closely examined later. The most variable aspect of the global analysis was the proportion of teacher statements to teacher questions. When taken with the proportion of teacher questions to student utterances, there may be a sense of different types of questions occurring.

Analysis of individual question types and purposes allows for further comparison between teacher's questioning. Because different types of questioning are expected to produce different discussion results, global analysis of questioning would not provide enough information for comparison of discussion between grades. The analytic frame was designed to highlight key components of individual questions that might determine an effect on student discussion related to question type and not student effects. As noted in Chapter 2, open-ended (student idea) questions tend to offer more potential for discussion. For reasons associated with this, analyzing the purpose of the question became critical.

Local Analysis (Analytic Frame)

The *first level of analysis* was the voice of question. The voice of question is related to whose language or ideas are being used to create the question. Interestingly, after 2nd grade, a large proportion of student voice questions were asked. The examples below are of Teacher Idea Oriented questions. Here, the teacher is using questions to get students to talk about a gray bell (the student answer) in terms of what it is made of (the teacher idea). This chimera represented in the question occurs frequently. Teachers use student replies in an attempt to guide students toward the teacher idea. This guidance appears to be intended to help students link the ideas of metal being a conductor, and is expected in a medium level RTOP classroom.

> Teacher 3: Okay, she used a grey bell. Now when we talk about this our question was what material, so what do we need to say? Did she use a grey bell, she used a…?

The next example is insulating glass; followed by insulating plastic. The teacher has a very clear goal in mind when she is discussing the different materials these objects are made of and is actively moving students through the discussion using her ideas and attempting to use student language to compose her questions. In these examples, the teacher has phrased her questions in a manner that lets the students know they have not provided her with the answer or information she is seeking. In addition, the teacher is also introducing science terminology; in this case, insulator. These questions occur at distinctly separate times of the transcript and have been grouped here for the sake of demonstration of teacher voice questioning.

Teacher 3: A marble. What was a marble made out of?

Teacher 3: Can everyone say: insulator? So read about that again.

Teacher 3: This about light switches, what's on? When you flick that on and off, do you flick a metal switch on?

This is different than a teacher asking a student voice question. Here, the language comes solely from the students and is used in the formation of the question. In these questions, teachers do not explicitly try to change the students' ideas and the questions do not give an impression that the teacher is seeking information that was not provided by a previous student answer. The following examples below are of student voice questions and show less introduction of science terminology while asking students questions made of language that came from other student's statements.

Teacher 2: Okay, would you say that's a fair description Garrett? That not every owl eats the same thing?

Teacher 2: And what makes the difference in what they eat?

The teachers in this study tended to encourage their students to bring up scientific terminology through questioning or to explicitly mention this terminology through statements. Importantly, if teachers did bring up science terminology through statements, they then sought to have students use this terminology in their replies when they asked teacher voice questions. The encouragement of students to use science terminology or to move their ideas toward the teacher idea constrains student responses.

Figure 1.

Voice of Teacher Question by Grade

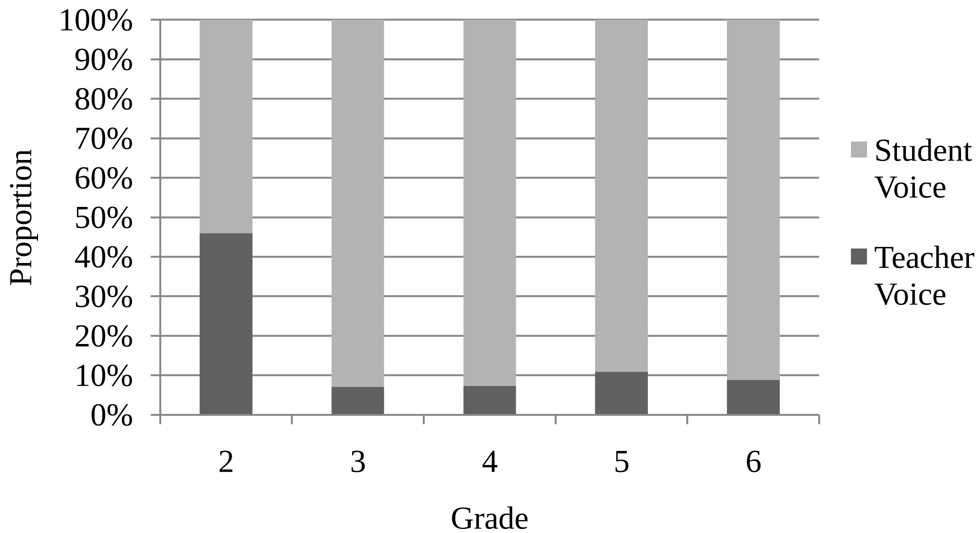


Table 12

Voice of Teacher Question

Grade	Teacher Voice (Proportion)	Student Voice (Proportion)
2	29 (0.460)	34 (0.540)
3	5 (0.071)	65 (0.929)
4	5 (0.074)	63 (0.926)
5	6 (0.109)	49 (0.891)
6	3 (0.088)	31 (0.912)

Second Level of Analytic Frame

The second level of the analytic frame looked at the purpose of the question. The purpose of the question is critical, as without purpose, questions would not be asked. The purpose also demonstrates whether the teacher is working to develop student ideas or encourage students to develop the teacher or science idea. Five categories of purpose were identified for analysis. Table 4 below from Chapter 3 describes the purposes that were analyzed.

Of the five purposes, only three are expected to offer the potential for discussion. While reporting evidence may lead to multiple student replies, it is not expected to typically lead to discussion, as this is the result of an individual student being asked to perform a simple task: to report *their* evidence. This is something only someone of that group would know. A follow up question that may spur discussion would be the teacher asking how that evidence may support a claim. This follow up question then changes from a reporting oriented task to a student idea oriented question, so long as the claim is student generated.

Of the categories possible, all but class management were expected to be represented in every transcript. Class management is typically associated with teachers controlling for student behavior in the classroom. This is typically handled through teacher statements, not questions. However, there are occasions where teachers may ask a student to behave. This may be more expected in classrooms that stress a nonthreatening learning environment, but was not observed frequently in this analysis.

The grade three and six teachers asked similar and a relatively large proportion of clarification questions. All of the teachers asked a relatively large amount of student idea oriented questions. The teacher idea oriented questions were always in a lower proportion than student idea oriented questions. Simple tasks were typically also lower than student idea oriented questions except for the third grade class.

The researcher reiterates that no judgment on the quality of questioning based on its purpose is made in this analysis. This analysis is merely to show the level of similarity in purpose of teacher questions to determine possible effects on discussion resulting after these questions are asked. The following examples are individual teacher questions that have been taken out of context and grouped together here as examples of different purpose types of questions.

Clarification questions are meant to have students elaborate or clarify statements or ideas. Simple tasks asked students to do something like report data or evidence. These tasks typically are oriented around the idea but are auxiliary to their development. Student idea oriented questions are meant to help develop student ideas, and they frequently ask what a student thinks about something or why something might occur. Teacher idea oriented questions seek to encourage students to think about a teacher idea. In these examples, the teacher is discussing forces and motion.

Table 13

Examples of Different Purposes in Teacher Questions

Purpose	Utterance
Clarification	Okay, did you read somewhere that they ate trees?
Clarification	They're not going to necessarily eat the same thing. Is that what you're saying?
Clarification	What, how do you mean they change it? Okay, so what would you think would be the reasons why some owls might eat…
Clarification	So what is it that you know?
Clarification	It ties in and that is important in finding the prey is that what you're saying?
Clarification	It doesn't have what?
Simple Task	Okay, did we have any evidence in what we did?
Student Idea Oriented	Why might they do that?
Student Idea Oriented	What do you think?
Teacher Idea Oriented	Okay, we know unequal forces cause what?
Teacher Idea Oriented	Motion, does it… does the balloon move?

Figure 2 below shows the variability in the purpose of questions used by the teachers in this study. However, even though variability existed, the general pattern of student idea oriented questions was between 25% and 45% across the teachers. This is expected based on similar RTOP scores. The rest of the purposes showed relatively large variability. Teachers ranged from almost no teacher idea oriented questions to almost

30% of their questioning as teacher idea oriented questions. Some teachers asked a large proportion of their questions as clarification or elaboration questions.

Figure 2.

Purpose of Teacher Question by Grade

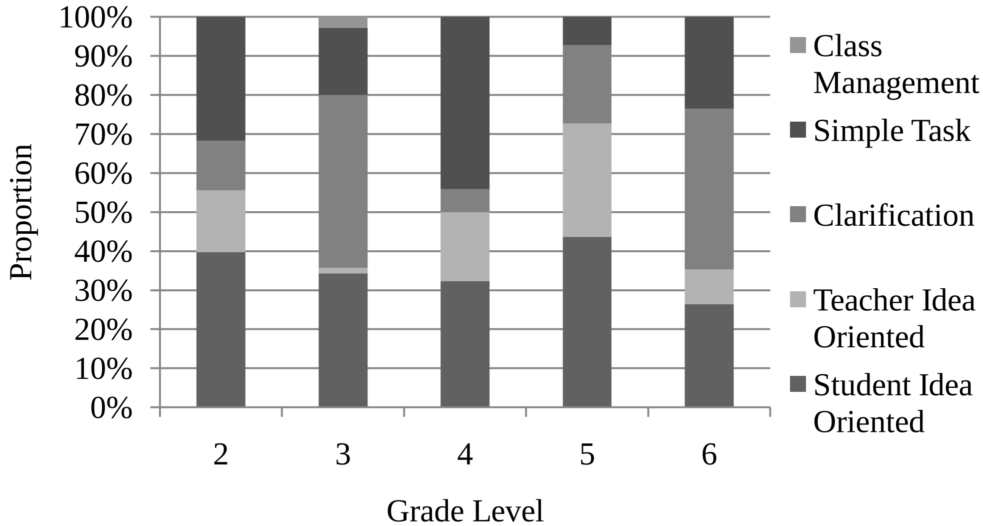


Table 14

Number of Occurrences of Purpose of Questions

Grade	Student Idea	Teacher Idea	Clarification	Simple Task	Class Management
2	25	10	8	20	0
3	22	3	31	12	2
4	22	12	4	30	0
5	24	16	11	4	0
6	9	3	14	8	0

Simple tasks were relatively varied as seen below in Figure 3. The fifth grade teacher only asked students to do tasks, instead of skill oriented or reporting oriented questions, though these may have been handled by teacher statements in this classroom. All the other teachers had a mixture of the three categories, typically favoring reporting oriented questions. This analysis gives a measure of the amount of data or evidence that may be brought into discussion. The researcher would like to restate that reporting oriented questions ask students to report data or evidence from experiments. When brought into discussion about claims and evidence, these can be used to enhance argumentation.

Figure 3.

Types of Simple Tasks in Teacher Questions by Grade

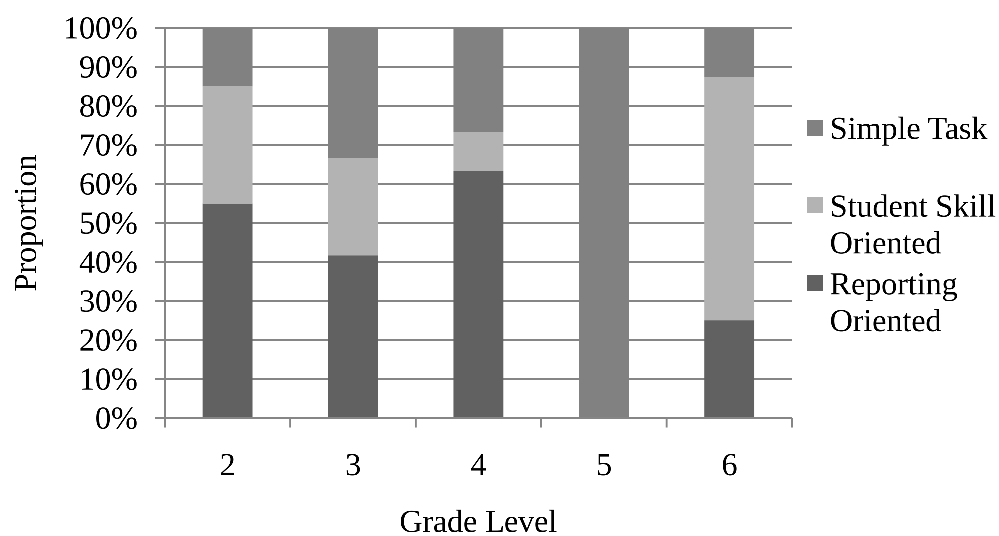


Table 15

Types of Simple Tasks in Teacher Questions by Grade

Grade	Reporting Oriented	Skill Oriented	Simple Task
2	11	6	3
3	5	3	4
4	19	3	8
5	0	0	4
6	2	5	1

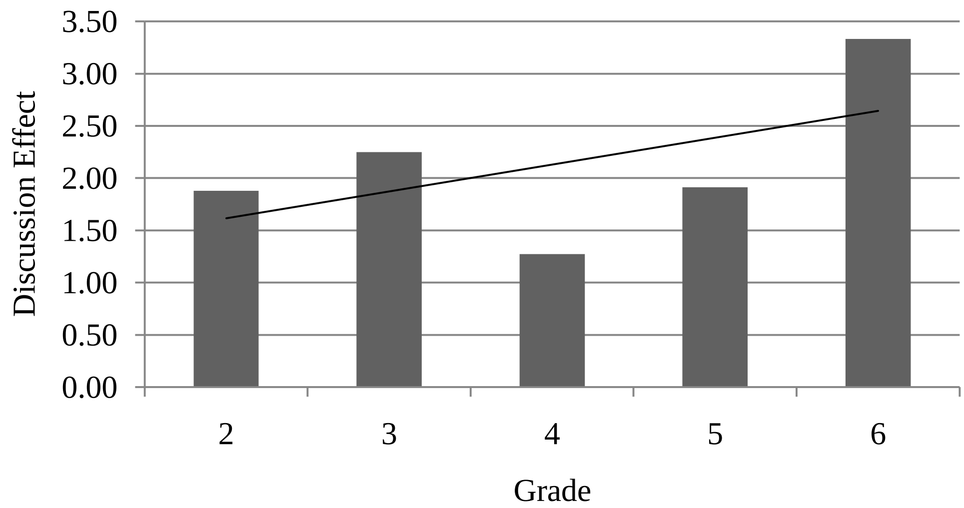
Third Level of Analytic Frame

The third level of analysis examined the discussion following certain question purpose types. As mentioned earlier, discussion is not expected after all purpose types of questions. Therefore, this analysis did not examine student replies after all purpose types, but rather focuses on discussions oriented around developing ideas. These purpose types included teacher and student idea oriented questions as well as clarification questions. The first two types are directly related to actively developing ideas. Clarification questions are oriented around extending ideas.

The overall trend of questions oriented around developing the student shows a general increase with grade level as displayed in Figure 4 below. This supports the idea that as students mature, they become more able or willing to participate in discussion. The fourth grade teacher shows a lower discussion than expected by the trend line. This trend shows students are engaging in discussion on other students' ideas more frequently as grade level increases.

Figure 4.

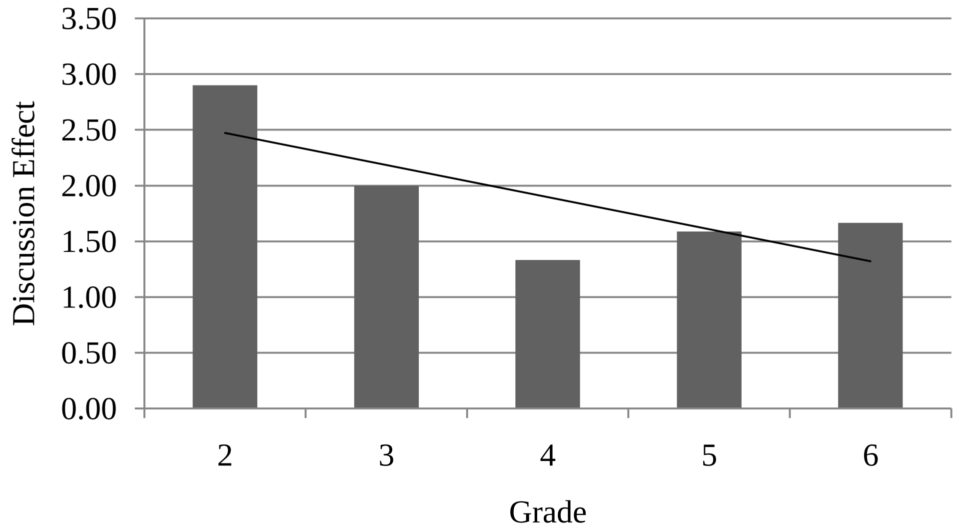
Discussion Following Student Idea Oriented Question by Grade



The general trend of questions around developing the teacher or scientific idea decreased with increasing grade level as shown in Figure 5 below. Here again, the fourth grade has reduced discussion. This trend may go along with the notion that as grade level increases, science is typically taught more as a body of facts. Therefore, when teachers ask about these types of knowledge, students may be expected to give answers instead of engaging in discussion. This pattern could indicate a failure to understand how science knowledge is produced. This epistemology of science may be an enculturation that has a cumulative effect on student discussion. That is, as students become more used to science being represented as not interpretable, they view it less open to discussion of alterative ideas. Perhaps science is not taught as somewhat interpretable, or model based. This epistemology represents science as memory recall.

Figure 5.

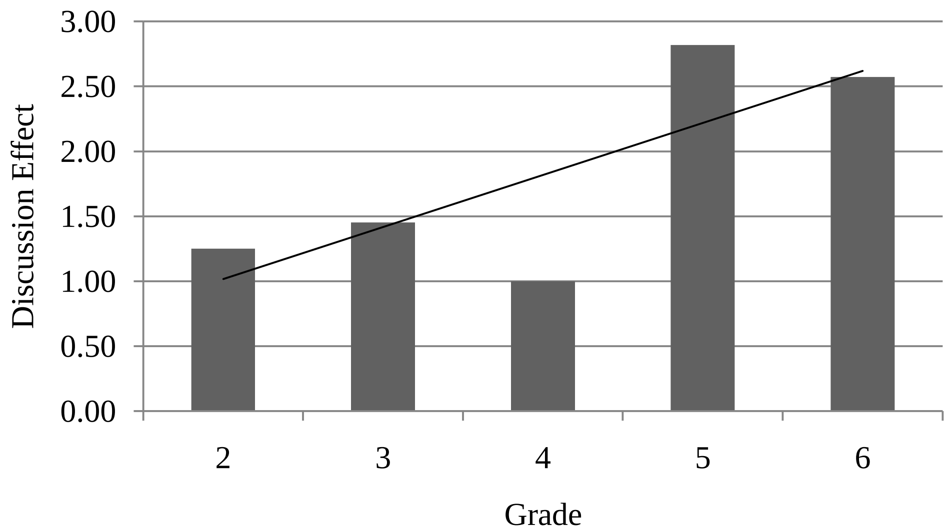
Discussion Following Teacher Idea Oriented Question by Grade



Clarification oriented questions are typically associated with student ideas and are thus expected to follow the same increasing pattern that was seen with those ideas. The analysis showed a general increase with grade level, as shown in Figure 6. The fourth grade discussion is reduced again here. This category is important because results greater than one reply per question show other students entering discussion on clarification of another student's idea. There is more of a shared sense of student ideas. This supports the idea of a community of learners, where students are taking responsibility for the knowledge that the community produces.

Figure 6.

Discussion Following Clarification Questions by Grade

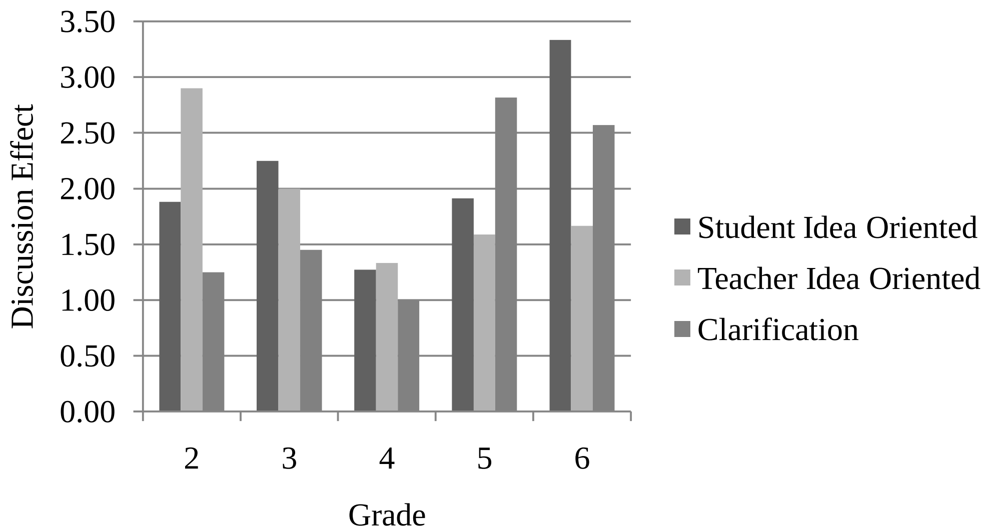


Summary

Composing all of the discussion effects together allows a more complete view of what types of question purposes led to the most discussion by grade. Figure 7 below shows in second grade, teacher idea oriented questions yielded a full reply per question more than the next largest purpose type. By fourth grade, the purpose types had leveled out, perhaps as a byproduct of this teacher asking such a large proportion of questions to student utterances. However, by fifth and sixth grade, the clarification and student idea oriented questions were the categories that led to the most discussion by students. In fact, students in sixth grade enhanced the trend that first appeared in fifth grade. This demonstrates the total discussion effect per class.

Figure 7.

Average Discussion Effect by Grade and Type of Teacher Question



Adjusting the data representation allows a more careful look at how each type of purpose is changed with grade level. Figure 8 below shows the relative discussion occurring in each purpose type by grade level. In this representation, all purpose types are able to be examined longitudinally. Student idea oriented questions and clarification questions both show growth while the teacher idea oriented questions show rapid decrease followed by relative stagnation of discussion turns.

Figure 8.

Average Discussion Effect by Type of Teacher Question and Grade

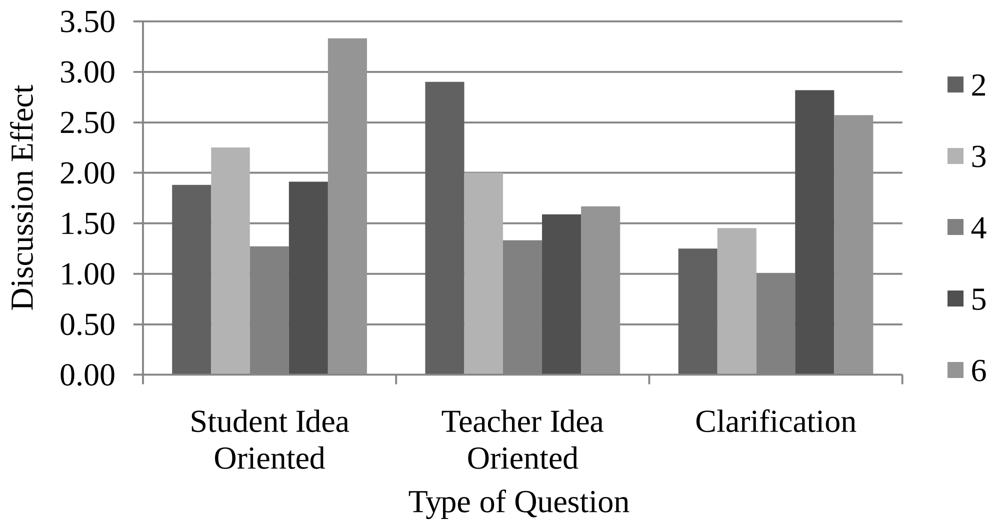


Table 16

Average Discussion Effect by Grade and Question Type

Grade	Student Idea Oriented	Teacher Idea Oriented	Clarification
2	1.88	2.90	1.25
3	2.25	2.00	1.45
4	1.27	1.33	1.00
5	1.91	1.59	2.82
6	3.33	1.67	2.57

Importantly from all of this is the realization that students at lower grade levels showed more fondness for discussion oriented around a teacher or science idea than around their own ideas. In addition, older students tended to discuss after questions oriented around their ideas. This may be related to the way science knowledge is represented. It may also be that the students become better able to engage in discussion or become more willing.

CHAPTER 5: DISCUSSION

This chapter starts by answering the research question posed in Chapter 1. It then discusses the implications of the results of the global and the analytical frame as well as the limitations of this study. While limitations were mentioned briefly in Chapter 3, they are given more attention here with consideration for how they might affect the results of this study. Importantly, calls for other research to more closely examine some of the questions that are raised by this study are listed.

Research Question Answered

> Is there a change in discussion as grade level increases (from 2nd – 6th grade) which could be indicative of an increased willingness or ability to negotiate ideas and is this dependent on the type or purpose of the question being asked?

The results showed a purpose dependent change in discussion across grade levels that showed students in this study saw an increase in discussion associated with questions that developed or extended student ideas. A decrease in discussion oriented around teacher idea development was seen. When considered with the controls of this study, this suggests an increased ability or willingness associated with an increase in student grade level.

This study started out asking the question of whether students had an increase in discussion following a teacher question with an increase in grade level. In order to address this question, an analysis of teacher questioning became critical. It is worth stressing again here that this analysis makes no claim at the overall student discussion occurring in these classrooms, merely the discussion occurring as whole class discussion following a teacher question in a claims and evidence activity.

Several global aspects of the teachers were analyzed in order to help selection of transcripts. The main aspect of this was the RTOP scale. This scale is a measure of cooperative learning, interactive engagement and measures of pedagogical content knowledge of classrooms and teachers. Teachers were selected based on similar RTOP scores as a way to select classrooms that were similar. This means that similar types of learning environments should be present in these classrooms. These medium level implementation classes should be student centered and expected to have student discussion in large and small groups. This analysis looked only at whole class discussion following certain types of teacher questions.

Another global analysis was done on the proportion of teacher to student utterances. This was a rough measure that helped indicate who had a primary role in the transcript. In all but the sixth grade classroom, the transcripts were approximately equal. Some of these tended to have slightly more student utterances or slightly more teacher utterances, however the sixth grade classroom was dominated by student utterances and will have possible reasons explained later.

The final non-specific global analysis looked into the proportion of teacher questions to student utterances. This provided a proxy for how many questions were asked per utterance. Three of the teachers were around 20% or less here, with the third and fourth grade teachers above that. Most notably, the fourth grade teacher was approaching 50% questions to student utterances. This was important because this teacher had a lowered discussion effect due to asking more questions per student utterance. In fact, on average it was anticipated that her students' discussion would approach around one reply per question. This is expected on average because her questions are roughly balanced with student utterances.

The local analysis looked into specifics of question types and composition. This is critical because different purpose types of questions are expected to have different possible outcomes. Here, the purpose of the question may be to encourage a discussion, or merely to have students do something. Therefore, a categorization of these questions was required. Further, different purposes intended to develop ideas are likely to have different discussion effects. In fact, this study sought to characterize the different discussion effects associated with these different purpose types of teacher questions.

The analysis of purposes of questions showed few patterns. All of the teachers in this analysis asked more student idea oriented questions than teacher idea oriented questions. As transcripts were selected in almost every case from later in the Science Writing Heuristic project, this was expected as the classrooms shifted toward being more student-centered as a result of SWH implementation. This was also expected as a result of the RTOP scores demonstrating a medium level of implementation for all teachers and transcripts in the study.

Teachers were compared in the patterns that emerge from discussion effects to either student or teacher effects. Overall, most of the teachers were rather similar in RTOP score as well as the proportion of utterances between teachers and students. Most teachers asked predominantly student voice questions. Teachers varied on the proportion of questions to student utterances with the highest proportion at fourth grade and the lowest proportion in second and sixth grade. No discernable pattern was seen in the purpose of question other than a fairly consistent amount of student idea oriented questions. The type of simple task asked of students also showed no pattern.

The discussion effects were broken into three categories because they represented a different sense of epistemology. Student idea oriented questions ask about a student's personal knowledge or interpretation of some idea and seek to develop that idea. This could be seen as not necessarily right or wrong, merely personal knowledge. Teacher idea oriented questions ask about the teacher's knowledge or idea or even about a scientific knowledge or view. These types of questions have a lower sense of interpretability. This is especially true if science is seemingly taught more as content or fact that is independent of the way that knowledge came to be. Clarification questions seek to extend a student reply or clarify a statement or idea. Because of this, they are expected to be more oriented around a student idea than content idea, though this is not always the case.

If a general improvement in discussion ability or willingness is expected, it is anticipated that this would show up in student idea oriented questions. Here, the subject of discussion is seen as interpretable and therefore open for negotiation of ideas. It is also expected to be easier for a student to challenge another student's idea than a teacher or science idea. In contrast, the more science knowledge is taught as factual the less likely is a discussion about a science idea is to be expected. It is also possible a sense of a student reply that resulted in personal interpretation may be followed up by a teacher question about the student's idea that would shift the focus of the question away from the science or teacher idea. Clarification questions, though expected to align with student idea oriented questions, could have a varied effect. In some sense, it could be expected that they might remain low because the question asks for clarification of a student idea or statement. It is also possible that students would still consider this clarification as interpretable and would result in a similar pattern as the student idea oriented questions. However, a teacher asking a particular student to clarify his/her statement may not always be interpreted by students as an invitation to discuss alternative ideas.

Student idea oriented questions saw an increase with grade level, almost doubling between second and sixth grade. A notable depression is seen by the fourth grade discussion, which could be the result from the global analysis indicating the teacher asking a rather large proportion of questions to student utterances. Interestingly, the two teachers with the highest RTOP scores had the lowest discussion effect from student idea oriented questions. This could mean that the teachers had follow up questions intended to challenge student ideas and statements that may have shortened the discussion after the initial question.

An important aspect of the way discussion effect was examined is that each individual utterance is counted as equal. This makes no claim about the quality of the utterance, merely the quantity of utterances. The underlying premise is that if more students are entering discussion about an idea, the likelihood of productive discussion increases. Therefore no claim about the quality of discussion is attempted, only a measure of the number of replies to the initiating question. Discussions and negotiations of ideas require an exchange of ideas, not mere answers to questions and therefore require multiple utterances.

In this analysis, clarification oriented questions aligned themselves with student idea oriented questions in the sense that they shared a similar pattern. The fourth grade results are again lower than the trend line. However, the fifth and sixth grade results show more than one extra utterance per question in these questions. This suggests these classrooms have moved more towards a shared ownership of the knowledge and ideas that are being negotiated between students. This community of learners takes responsibility for clarifying the ideas of others. An interesting note is that the fifth grade classroom was slightly under the trend line in student idea oriented questions, but on clarifying their ideas to those questions they were above the trend line. Perhaps this suggests the students had not adequately explained their ideas but were capable of doing so upon asking for clarification as a community of learners. This may also suggest that younger learners felt personal ownership of their ideas, and thus did not feel responsible for helping to clarify the ideas of others. This segregates the ideas of individuals and shows some sense of “my idea verses their idea” that could be used pedagogically for fruitful discussion of alternative ideas.

Teacher idea oriented questions showed the opposite trend as the other discussion effects. Here, less discussion was seen as grade level increased. As alluded to earlier, students may view the teacher idea as not as interpretable as their own ideas. This type of question also involves science or content oriented questions. All of these may come across as representations of “fixed” knowledge. Due to this, a restating of the idea suffices to replicate that knowledge in the classroom. Frequently, these types of questions are information seeking. This typically tends to result in close-ended questions that do not frequently result in discussions. A discussion of interpreting this knowledge may not occur if students view it as “fixed”.

In summary, for this study, a discussion effect was seen with changing grade level. The effect was dependent upon the ideas the questions were intended to develop. It is unlikely that students become less able to have discussion as they mature, which suggests the types of questions teachers ask certainly have an effect on the discussion that results. The results indicate students participated more in discussion oriented around student ideas and clarification of ideas, which were typically about the student idea.

Limitations

The researcher has identified four areas of limitations including newness of researcher, the analytic frame, small sample size and data availability. These will be explained individually and their potential implications on the results are given. It is expected that other limitations exist.

Newness of researcher

This project represents the first study done by the researcher. As such, there are expected to be subtleties of the research that need further development because of the researcher's lack of familiarity with the research process. As such this may have resulted in the researcher not controlling for enough classroom variables. This study highlights areas of possible future research as well as exposure to development and implementation of an analytic frame. This limitation is likely to limit the scope of the conclusions reached from this study as well as the claims that can be made from the results.

Analytic Frame

This research also involves an analytic frame that was developed by the researcher and has yet to be fully established or defined. Increasing inter-rater reliability would be possible with training of raters. The voice of the question of this analytic frame is an area that needs further defining. While the idea of the voice of question represents an important classroom aspect, it becomes rather difficult to identify whether the ideas or language being expressed in a question originate with students or teacher. This represents an area that additional projects might address.

Small Sample Size

The structure of the project limited the sample to five transcripts, one from each grade level. The limitations posed by available data meant quantitative analysis for this project was not possible. The small sample size stresses the qualitative nature of this research and thus limits any sense of generalizability that might result. Therefore, this research suggests areas for further research instead of results that can be applied to other classrooms or describe general trends in education.

Data Availability

Due to time constraints as well as readily available data, the researcher used data in a data-base instead of personally collecting the data that was most applicable to the study. The data base had sufficient samples to approach the research question. However, the available data made additional classrooms for this study not possible to isolate.

Implications

It is likely that the views of students pertaining to discussion are shaped cumulatively. Therefore, if students are frequently exposed to science as “fact”, it should be expected that discussion about science ideas should decrease with grade level. These students may grow to expect teacher questioning about a science idea as information seeking, as discussed by Chin (2006). This relates back to close-ended questions that are frequently not fruitful for discussion. Similarly, if an environment of active negotiation of ideas is harbored then increases in discussion should be seen with increase in grade level. Again, this is most likely the result of open-ended questions. In this analysis, most of the open-ended question types occurred around student ideas or clarification of ideas. Further research is needed to support these claims.

This analysis showed an increase in student discussion oriented around ideas that are seen as interpretable or formed by someone that is somewhat less of an expert than science or the teacher. It is worth noting these types of questions are less information seeking, and thus more open to discussion. It also shows a decrease in ideas that are seen as less interpretable (more "fixed") or from a more expert source. These ideas may be directly from the teacher or about a science idea. There are several implications from these results.

The results suggest further research should focus on discussion in lower grade levels being scaffolded so students are better able to engage in negotiations and to determine if modeling appropriate discourse patterns is important for students to successfully engage in argument. Argument is a key feature of science and thus should also be a key feature of science education.

Further, because students in this study appear to be more able or willing to participate in discussion of their ideas as they mature, this may be an activity that teachers should stress more in classrooms. Further research should be done to see if it is important to encourage small group as well as large group discussion with students. The students in the analyzed sixth grade classroom also started taking over asking some of the questions that would typically be expected to be asked by the teacher, which suggests this classroom moving towards being a community of learners.

Another interesting finding from this study is the purpose types and relative discussions that occurred by grade level. It suggests younger students are more willing to have discussions relating to teacher idea or science oriented questions in this study. This raises questions that further research could approach more appropriately. First, it suggests these students have either not been enculturated into the view of science as factual or that their own representations or conceptions of knowledge about the topic of discussion were limited to the point that students did not feel comfortable entering into discussion about them. Second, it suggests these students may have conceptual representations that view the teacher or science idea as anomalous and therefore they are attempting to talk through their internal conflict to resolve the anomaly.

Older students in this study appeared to be more willing or able to discuss their own ideas than a teacher or science idea. Intuitively, it makes sense that students would feel less pressure discussing ideas seen as more interpretable. Also, if science is taught as a collection of facts as discussed in Chapter 2, there is expected to be a lower chance for discussion unless a student misreports the factual knowledge that was asked for by the teacher question. However, large gains were seen in student idea oriented and clarification questions with grade level. This suggests discussion could be used as a method to encourage students to share their ideas and to enter into argument in defense of their ideas or others' ideas. Further, even if these students view science as factual, they can still use science knowledge in their argument structure.

However, these students may not be likely to critically evaluate or challenge knowledge that appears to come from a "more knowledgeable" source. This could include the teacher, text or science. Critical thinking is also an important feature of science. Knowing what knowledge supports or refutes claims is an important part of successful argument. Therefore, students must view science knowledge as somewhat interpretable. This is a striking difference to the way science is typically represented. This suggests a change in how science is taught. Encouraging students to examine what science knowledge applies to claims they make and what knowledge would refute a scientific representation may help students view the epistemology of science as one of social construction.

REFERENCES

Basir, A.M., Chen, Y., Chanlen, N., Tseng, C.M., Hand, B., & Norton-Meier, L. (2009, December). *The long-term transformation of teachers in inquiry-oriented classroom dynamics*. Poster presented at the Iowa Educational Research and Evaluation Association Conference, Iowa State University, Ames, Iowa.

Chin, C. (2006). Classroom interaction in science: Teacher questioning and feedback to students' responses. *International Journal of Science Education*, *28*(11), 1315-1346.

Chin, C. (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching*, *44*(6), 815-843.

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, *86*(2), 175-218.

Clark, D. B., Sampson, V., Weinberger, A., & Erkens, G. (2007). Analytic frameworks for assessing dialogic argumentation in online learning environments. *Educational Psychology Review*, *19*(3), 343-374.

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

Duschl, R. A., & Osborne, J. (2002). Supporting and promoting argumentation discourse in science education. *Studies in Science Education*, *38*, 39-72.

Erduran, S., & Dagher, Z. R. (2007). Exemplary teaching of argumentation : A case study of two science teachers. In R. Pintó & D. Couso (Eds.), *Contributions from Science Education Research* (pp. 403-415). The Netherlands: Springer.

Erduran, S., Osborne, J., & Simon, S. (2005). The role of argumentation in developing scientific literacy. In K. Boersma, M. Goedhart, O. DeJong, & H. Eijkelhof (Eds.), *Research and the quality of science education* (pp. 381-394). The Netherlands: Springer.

Fuller, S. (1997). *Science*. Buckingham, UK: Open University Press.

Hand, B. (2008). Introducing the science writing heuristic approach. In B. Hand, (Ed.), Science inquiry, argument and language (pp.1-11). Rotterdam, The Netherlands: Sense Publishers.

Henriques, L. (1997). *Constructivist teaching and learning. A study to define and verify a model of interactive constructive elementary school science teaching*. (Unpublished doctoral dissertation). University of Iowa, Iowa City, IA, USA.

Hogan, K., Nastasi, B. K., & Pressley, M. (1999). Discourse patterns and collaborative scientific reasoning in peer and teacher-guided discussions. *Cognition and Instruction*, *17*(4), 379-432.

Johnson-Laird, P. N. (1999). Deductive reasoning. *Annual Review of Psychology*. *50*, 109-135.

Kelly, G.J., & Chen, C. (1999). The sound of music: Constructing science as sociocultural practices through oral and written discourse. *Journal of Research in Science Teaching*, *36*(8), 883-915.

Keys, C. W. (1999). Revitalizing instruction in scientific genres: Connecting knowledge production with writing to learn in science. *Science Education*, *83*(2), 115-130.

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

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

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

Kuhn, D., & Udell, W. (2003). The development of argument skills. *Child Development*, *74*(5), 1245-1260.

Kuhn, L., Kenyon, L. O., & Reiser, B. J. (2006, June). Fostering scientific argumentation by creating a need for students to attend to each other's claims and evidence. Paper presented at the 7th International Conference on Learning, Bloomington, IN.

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

Lizotte, D. J., McNeill, K. L., & Krajcik, J. (2004, June). Teacher practices that support students' construction of scientific explanations in middle school classrooms. Paper presented at the 6th International Conference on Learning Sciences, Los Angeles, CA.

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

Mortimer, E. F., & Machado, A. H. (2000). Anomalies and conflicts in classroom discourse. *Science Education*, *84*, 429–444.

National Research Council (1996). National Science Education Standards. Washington, DC: National Academy Press.

National Research Council. (2000). Inquiry and the national science education standards: A guide for teaching and learning. Washington, DC: National Academy 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.

O'Neill, D. K., & Polman, J. L. (2004). Why educate "little scientists?" examining the potential of practice-based scientific literacy. *Journal of Research in Science Teaching*, *41*(3), 234-266.

Osborne, J. (2005). The role of argument in science education. In K. Boersma, M. Goedhart, O. DeJong, & H. Eijkelhof (Eds.), *Research and the quality of science education* (pp. 367-380). The Netherlands: Springer. DOI: 10.1007/1-4020-3673-6_29.

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.

Pinney, B., & Hand, B. (2009, December). *Characterizing the changes in teacher questioning in the Science Writing Heuristic (SWH) approach*. Poster presented at the Iowa Educational Research and Evaluation Association Conference, Iowa State University, Ames, Iowa.

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.

Riemeier, T., Fleischhauer, J., Rogge, C., von Aufschnaiter, C., & Liebig, J. (2010, March). *How do students' argumentations depend on their conceptual understanding and vice versa?* Paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

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

Sawada, D., Piburn, M.D., Judson, E., Turley, J., Falconer, K., Benford, R., et al. (2000). *The reform teaching observation protocol (RTOP) (Technical Report No. IN00-1)*. Tempe, AZ: Arizona State University.

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

Simon, M.A. (1995). Reconstructing mathematics pedagogy from a constructivist perspective. *Journal for Research in Mathematics Education*. *26*(2), 114-145

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), 235-260.

Tippett, C. D. (2009). Argumentation: The language of science. *Journal of Elementary Science Education*, *21*(1), 17-25.

van Zee, E. H., & Minstrell, J. (1997). Using questioning to guide student thinking. *The Journal of the Learning Sciences*, *6*, 229–271.

van Zee, E. H., Iwasyk, M., Kurose, A., Simpson, D., & Wild, J. (2001). Student and teacher questioning during conversations about science. *Journal of Research in Science Teaching*, *38*(2), 159-190.

Wallace, C.S., Hand, B., & Prain, V. (2004). *Writing and learning in science classroom*. Dordrecht, The Netherlands: Kluwer Academic Press.

Wellington, J., & Osborne, J. (2001). Talk of the classroom: Language interactions between teachers and pupils. In J. Wellington & J. Osborne (Eds.), *Language and literacy in science education* (pp. 24–40). Buckingham, UK: Open University Press.

Westgate, D., & Hughes, M. (1997). Identifying "quality" in classroom talk: An enduring research task. *Language and Education*, *11*(2), 125–139.

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research*, *72*(2), 131-175.